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Nutrient profiling: comparison and critical analysis of existing systems

V Azaïs-Braesco[1,*], C Goffi[2] and E Labouze[2]
[1]CRNH-Auvergne, BP 321, F-63000 Clermont-Ferrand, France: [2]Bio Intelligence Service, 1 rue Berthelot, F-94200 Ivry/Seine, France

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Abstract

Background: Nutrient profiling systems aim at positioning foodstuffs relative to each other according to their contribution to a balanced diet. The accuracy and performance of methodologies are still debated. We present here a critical analysis of the structure and efficiency of the current schemes.
Methods: The literature survey detected only four systems addressing the issue on an 'across the board' approach and with enough detail to enable analysis. The building principles of these systems were compared and their performance was estimated via their classification of a series of 125 foodstuffs on the basis of nutritional composition. These classifications were compared with one another and with an empirical classification by expert nutritionists.
Results: All systems gave a similar overview, with fruits and vegetables ranked as the most favourable foods and fatty and sugary foods as the least favourable ones, but numerous discrepancies existed in every system, mainly related to their choice of nutrients and thresholds. The FSA scoring system seemed the most consistent approach, although it still generated some questionable rankings. Expert classification did not clearly validate any scheme, and cannot be considered as a true reference.
Conclusion: Nutrient profiling systems are confirmed to be powerful tools to translate nutritional information related to the whole diet into the level of individual foods. However, the performance of the existing schemes remains moderate. Alternative approaches, such as considering food categories or introducing more stringent validation steps by a panel of expert nutritionists, could be ways to reach more efficient and consensual tools.

Keywords
Nutrient profiles
Nutritional quality
Food Categorisation
Nutritional balance

During the past 25 to 30 years, epidemiological and experimental research has gathered a consistent and convincing body of scientific evidence linking nutrition and food behaviour to health. Exampled by the pioneer vision of Doll and Peto[1], numerous studies have connected, for instance, a high consumption of fruits and vegetables to a weaker incidence of cardiovascular diseases and cancer, or the intake of saturated fats to an enhanced risk of vascular pathologies. Indeed, up to 90% of coronary heart diseases, 90% of type 2 diabetes and 30% of cancers could be avoided by an adequate lifestyle, of which nutrition is recognised as a critical issue[2]. In the same period, obesity has increased dramatically in most countries, including among child populations, and this has been concomitant with a striking growth of type 2 diabetes and metabolic syndrome. The prospective figures are highly worrying and indicate a likely worsening of the situation, a trend that could reduce the mean life expectancy of humans for the first time in centuries[3].

Both these scientific and public health contexts are now urging authorities of most Western-type countries to tackle this critical question. Concerning nutrition, the issue is now to be able to improve the quality of the diet. The main lever is of course to modify food behaviour towards more balanced food choices, yet improvement of the nutritional quality of individual foodstuffs should not be neglected. So far, most initiatives have consisted of nutritional education or communication, based on consensual dietary advice, which promotes the consumption of fruits and vegetables, wholegrain cereals and calcium-rich foods and warns against excessive intake of saturated fats and sodium. Although apparently simple, these recommendations have been poorly effective so far in improving overall diet quality and in reducing the incidence of nutrition-linked pathologies. Changing behaviour is indeed an extremely difficult challenge, and numerous reasons for this failure can be raised. Among others, one certainly lies in the lack or inadequacy of translating a nutritional message referring to the whole diet into clear

*Corresponding author: Email braesco@clermont.inra.fr
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and practical recommendations for everyday individual food choices. This probably comes, at least partly, from the intrinsic complexity of any food item that comprises several nutrients whose consumption is more or less favourable to health, which in turn makes any food item able to find room in a balanced diet provided the amount and the frequency of consumption are adapted. This last point is the basis of the now classic adage: 'no bad foods, only bad diets'. However, although this adage remains true theoretically, recent experience confirms that it does not help to improve food behaviours: in spite of a growing – although still far from optimal – awareness of major dietary recommendations by consumers, there is still a significant gap between their nutritional knowledge and their eating behaviours. Understanding food behaviour is of course a very tricky issue, yet it is likely that precise information on individual food items and their practical involvement in the whole diet can participate in clarifying consumers' perceptions on nutritional matters.

This would be even more useful when considering the ever-increasing number of foodstuffs offered to consumers by the food industry, often with confusing messages regarding their link to health. In that respect, individual countries, as well as the European community, are currently working on a concept of 'nutritional profiles' that could help to frame nutritional communication and to guide consumers by positioning individual foodstuffs regarding their contribution to a healthful diet. The adequate methodologies to establish these profiles are still a matter of research: the objective is to build a quantitative score, aggregating nutritional criteria into a composite index that will accurately characterise each food according to its contribution to the overall balance of the diet and allow comparisons between food items concerning this contribution.

Although there is no current consensus about the overall usefulness of such nutrient profiling systems among nutritionists, the concept is certainly valuable enough to deserve close attention and adequate contributions. The purpose of the present work was thus to undertake a critical analysis of the existing methods which classify food items according to their nutritional composition. This analysis was based in particular on a comparison of their mutual performance in classifying a group of 125 foods.

Materials and methods

Literature survey and selection of systems

The first step consisted of identifying, via a Medline and Google-assisted search, the existing methods that can be considered as an attempt to classify food items according to their nutritional quality. In order to be compared objectively, the selected systems had simultaneously to fulfil three criteria: (1) consider the diet as a whole and thus develop a unique method, independent of the food category or the possible use of the system; (2) provide a score allowing for unambiguous classification; and (3) be published in a peer-reviewed journal or be validated by adequate expert processes.

Many different schemes have been developed to distinguish between 'healthy and unhealthy foods'. Some come from private retailers, especially in the UK, and we chose not to consider them here because they have no real scientific endorsement and it is difficult to trace the steps of their elaboration. Others have been designed by associations such as dental, diabetic or heart health associations and focus on specific needs, and were thus not included in our survey. Similarly, a large number of proposals are issued from regulatory bodies which determine, sometimes quite precisely, the nutritional characteristics of a food that wishes to bear a nutrition or a functional claim[4,5]. Some European national agencies have generated tools allowing for a broad classification of foods. The Swedish 'keyhole' system* is designed for labelling food products that may or may not bear a nutrition logo; the 'VoVo' system† is intended for nutrition information and leads to advice such as 'preferable', 'middle course' or 'exceptional' as a function of the nutritional characteristics of the product. All of these schemes provide a 'yes–no' answer, and were not universal enough to meet our goal of a generic system.

Numerous papers concern the process needed to go 'from nutrients to foods'[6–8] and refer to the concept of food-based dietary guidelines, itself often based on the grouping of foods into several groups (cereals and starchy foods, fruits and vegetables, fat and oils, meat, eggs and fish, milk and dairy products being the five groups most often encountered). These guidelines give quantitative advice by recommending a number of servings within each category[9], yet they are not sufficient to position products within a food group and thus were not considered in the present study. Closer to the approach we wished to address here, several North American authors of the late 1970s looked for an evaluation of food quality[10,11]. They worked around the concept of nutritional density, which has recently gained renewed interest in the USA[12], and proposed to illustrate the contribution of a given food by the amount of nutrients that are brought by 100 kcal or 100 g. A slightly more sophisticated tool was developed by Lachance and Fischer[13], who managed to classify foods according to their content in some nutrients relative to their energy

*The Swedish keyhole. National Food Administration administrative provisions on the use of a particular symbol, 2004 (www.slv.se).
†Netherlands Nutrition Center. Criteria for the nutritional evaluation of foods. The Netherlands tripartite classification model for foods, 2005 (www.voedingscentrum.nl).

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content. The resulting CFN (Calorie For Nutrient) index does not consider any 'negative nutrient' and its elaboration calls for several scientific and technical questions, yet it is – to our knowledge – the first real attempt for a method able to classify individual food items. Two papers, one from Australia[14] and the other from the USA[15], were found with interesting approaches describing and pre-testing systems of nutritional profiles. A fourth system has been extensively described; it comes from the UK Food Standards Agency (FSA) and was built with the purpose of redressing the imbalance in the way foods are currently promoted to children[16]. These four systems were analysed in the present work.

Additional systems, likely to be eligible for our work, have been mentioned in reviews or reports, especially variations on the concept of 'nutrient for calorie'[12], but they have not been published and the description available is not sufficient for considering them in this analysis.

The systems selected

Calorie For Nutrient (CFN)

This index was first created with nine nutrients[13] and has been updated to adapt the nutrients chosen, as reported by Zelman and Kennedy[12]. The primary objective of this tool is educational: it was designed in 1986 to help the consumer in obtaining a balanced array of nutrients and reach the recommended daily allowance while avoiding an excessive energy intake. It thus focuses on the concept of nutrient density and can be defined as the cost in calories required to reach, with the considered food item, 1% of the daily requirement of an average of key nutrients (protein, thiamin, riboflavin, niacin, vitamin C, vitamin A, calcium, magnesium, iron, zinc and folic acid). For calculation, per cent daily values for the 11 nutrients are established for 100 g, then summed and divided by the number of the nutrients involved. The final score results from the ratio of calories to the mean per cent daily value.

Nutritious Food Index (NFI)

The NFI[14] was also designed for educational purposes and to assist the 'user to rank foods into different levels of overall nutritional desirability consistent with dietary guidelines'. It considers 13 'desirable food components' (DFC) and four 'non-desirable food components' (NDFC), which are weighted by different coefficients according to their importance for Australian nutritionists. The DFC and their weights are: calcium, iron, zinc, fibre, folate (weight 0.114 each); magnesium, potassium, niacin, riboflavin, thiamin, vitamin C, vitamin A (weight 0.057 each); and phosphorus (weight 0.029). The NDFC and their weights are: total fat (0.31), saturated fat (0.5), sodium (0.13) and cholesterol (0.063). The index of a given food is then calculated according to the following formula:

$$NFI = \sum_{i=1}^{i=13} \frac{DFC_i w_i}{REC_i} - \sum_{j=1}^{j=4} \frac{NDFC_j w_j}{REC_j},$$

where DFC_i and $NDFC_j$ refer to the amount of the corresponding nutrient in a serving size of the food, $w_{i,j}$ are the weights and $REC_{i,j}$ refer to the daily recommendations of intake coming from Australian public health authorities.

Ratio of Recommended to Restricted Foods (RRR)

Recently developed in the USA, the RRR[15] aims at providing 'consumers with a summary of food label information to guide healthful, single–item food selections'. It is based on a similar principle of desirable (recommended) and non–desirable (restricted) food components, which are chosen according either to the requirement for labelling a food as 'healthy' or the Dietary Guidelines for Americans. These 11 food components all have an equal weight and are aggregated into an index via the following ratio:

$$\frac{(\%\text{DV protein} + \%\text{DV dietary fibre} + \%\text{DV calcium} + \%\text{DV iron} + \%\text{DV vit. A} + \%\text{DV vit. C})/6}{(\%\text{DV calories} + \%\text{DV sugars} + \%\text{DV cholesterol} + \%\text{DV saturated fats} + \%\text{DV sodium})/5},$$

where %DV per cent daily value.

The Nutrient Profile

The Nutrient Profile from the FSA is available only on the Internet and has not yet been peer-reviewed, although it has been validated by an expert group*. Two successive versions have been delivered, in October 2004[16] and in September 2005[17], and then a final version in December 2005[18], which is the one considered here. Its main objective is relatively restricted, since it should serve as a scientific support to establish 'rules on broadcast advertising of foods that are high in fat, saturated fats, salt or sugars to children'. However, the report also states that the model is equally applicable for other age groups (excluding the salt threshold). It comes from a highly systematic study of possible methods that could allow for food classification. The scheme as finally proposed takes into account seven criteria, chosen as the critical factors for determining what is a 'healthy food' or a 'food rich in fat, sodium or sugar'. Per 100 g of a food, the value of each of these criteria

*A scientific workshop was held in London in February 2005, whose report and participant list can be viewed at http://www.food.gov.uk/healthiereating.

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provides a certain number of points, according to the following rules.

Energy:

$$\leq 335\,\text{kJ} = 0; 335\text{–}670\,\text{kJ} = 1; 670\text{–}1005\,\text{kJ} = 2;$$

$$\text{and so on up to} > 3350\,\text{kJ} = 10$$

Saturated fat:

$$\leq 1\,\text{g} = 0; 1\text{–}2\,\text{g} = 1; 2\text{–}3\,\text{g} = 2;$$

$$\text{and so on up to} > 10\,\text{g} = 10$$

Sugars:

$$\leq 4.5\,\text{g} = 0; 4.5\text{–}9.0\,\text{g} = 1; 9.0\text{–}13.5\,\text{g} = 2;$$

$$\text{and so on up to} > 45\,\text{g} = 10$$

Sodium: $\leq 90\,\text{mg} = 0; 90\text{–}180\,\text{mg} = 1; 180\text{–}270\,\text{mg} = 2;$

$$\text{and so on up to} > 900\,\text{mg} = 10$$

Non-starch polysaccharide (NSP) fibre:

$$\leq 0.7\,\text{g} = 0; 0.7\text{–}1.4\,\text{g} = 1; 1.4\text{–}2.1\,\text{g} = 2;$$

$$\text{and so on up to} > 3.5\,\text{g} = 5$$

Protein:

$$\leq 1.6\,\text{g} = 0; 1.6\text{–}3.2\,\text{g} = 1; 3.2\text{–}4.8\,\text{g} = 2;$$

$$\text{and so on up to} > 8.0\,\text{g} = 5$$

Fruit, vegetables and nuts:

$$\leq 40\% = 0; 40\text{–}60\% = 1; 60\text{–}80\% = 2; > 80\% = 5$$

Then, by subtracting the 'desirable' food components (protein, NSP fibre, and fruit, vegetables and nuts content) from the 'non-desirable' ones (energy, saturated fats, sugars and sodium), a score is obtained which qualifies the food as 'high in saturated fat, salt or sugar' when it scores 4 points or more. Drinks are similarly classified when they score 1 point or more.

Comparison between tools

Choice of food items

We compared the performance of each of the four tools by submitting a series of 125 food items to their criteria. These food items were chosen in various food groups and the list is likely to represent most of the foods regularly consumed in European countries[19]. Availability of food composition data has also been considered before inclusion in the list. These data come mostly from the McCance and Widdowson food composition table[20]. Traces have been considered as 'zero'; missing data (especially the values for polyunsaturated fatty acids) have been replaced by data from either the Souci–Fachmann–Kraut table[21] or alternatively the French food composition table[22].

Concerning the fortification or supplementation of foods with vitamins and minerals, most tools stipulate that the food composition data should be taken prior to any fortification; however, because of the poor availability of these data, the calculations are made, including in our comparison, with the nutrient content of the final product.

Because the NFI scheme uses serving size as the quantitative basis for calculations, the usual serving sizes of the 125 food items have been estimated using data from a recent French dietary survey[23].

Reference values

Each method refers to recommended values for consumption of the nutrients it considers. These recommended values usually come from national agencies and they are not always identical. In order to compare the four methods on the same basis we used a common set of reference values, based as often as possible on international standards (Table 1).

Expert classification

The list of foods was submitted separately to 12 nutrition experts who were asked to place each food item in a group (from 1 – 'healthier' to 5 – 'less healthy') so that each group contained 25 food items. As in the similar consultation that the FSA[17] has recently undertaken to challenge its system, no precise definition of 'healthier' or 'less healthy' was provided and the experts were asked to rate foods according to their own knowledge and experience of its contribution to a balanced diet. Among these experts were 10 experienced scientists in nutrition, sitting on official expert committees, and two operational dietitians. No nutritional information was given, except for the fat and/or sugar content of fresh dairy products and margarine, mayonnaise and fat spreads, to help discriminate between closely related foods. The final attribution of a foodstuff in a quintile is the median of the quintile values attributed by the experts.

Calculations and statistics

For each system, calculations were made via an Excel spreadsheet that was designed according to the system's equations and the composition data. These Excel spreadsheets were also used to make simulations. The 125 foods were classified by each tool, which attributed a score to individual foods. However, because the objective was the relative positioning of one food versus another, we chose to examine how each tool was ranking the foods and thus we considered the rank of each individual food in each system, from the most to the least desirable food. When several foodstuffs had the same score, the median rank, rounded to the above value, was attributed to all of

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Table 1 Reference values of criteria used in the nutrient profiling systems

	CFN*	NFI	RRR	FSA†	Reference basis used for comparison
Energy (kJ/kcal)	×	9450/2260	8360/2000	8903/2130	9196/2200‡
Total fat (g)	×	75	×	×	73‡
Saturated fats (g)	×	25	20	26	25‡
Sugars (g)	×	×	50	63	55.3
Sodium (mg)	×	2300	2400	2350	2400‡
Cholesterol (mg)	×	300	300	×	300‡
Protein (g)	60	×	60	43	60
Fibre (g)	×	30	25	18	25‡
F&V (g)	×	×	×	380	380
Vitamin C (mg)	60	75	60	×	60§
Vitamin A (IU)	5000	4000	5000	×	2664§
Niacin (mg)	20	19	×	×	18§
Riboflavin (mg)	1.7	1.7	×	×	1.6§
Thiamin (mg)	1.5	1.2	×	×	1.4§
Folate (μg)	400	400	×	×	200§
Calcium (mg)	1000	1200	1000	×	800§
Iron (mg)	18	12	18	×	14§
Magnesium (mg)	400	340	×	×	300§
Phosphorus (mg)	1000	1200	×	×	800§
Potassium (mg)	×	1950	×	×	3000‡

CFN – Calorie For Nutrient Index; NFI – Nutritious Food Index; RRR – Ratio of Recommended to Restricted Foods; FSA – Food Standards Agency's Nutrient Profile; F&V – fruit and vegetables; × – criterion not considered in this scheme.
* US Recommended Dietary Intakes and Dietary Reference Values, US Food and Drug Administration, Center for Food Safety and Applied Nutrition, 1998.
† The FSA system was initially developed for children aged 11–16 years; the reference values are those of this age range.
‡ Eurodiet core report, 2000 (http://eurodiet.med.uoc.gr/). Values are for an energy intake of 9196 kJ (2200 kcal).
§ Nutritional labelling of foods, Directive 90/496/CEE, 1990.

these foods. This kept most of the information retained in the score values, although it no longer allowed a measure of the proximity of foods within a given system. In order to compare the rankings of a food in the four systems with that in the expert classification, the foods were then partitioned in five groups according to their rank, using StatView software (SAS Institute, Cary, NC, USA). For comparisons of ranks and quintiles, Spearman correlation coefficients for non-parametric values were calculated both on the ranks and the quintiles; a 'disagree value', defined as the difference between the lowest and the highest rank obtained by a given food product across the four systems, helps to identify anomalies and major discrepancies between methods.

Results and discussion

Performance of each tool

Table 2 shows the classification of the 125 foodstuffs according to each tool.

The CFN system provides a classification in which most breakfast cereals, vegetables, pulses and lean meat are in the first quintile; most other meats, fish and low-fat dairy products are in the second one; most bread, cheese and fatty meats are in the third one; and most fats, biscuits and sugary foods are in the fifth quintile. It is interesting to note that the absence of any 'negative' nutrient does not abusively favour fatty products, probably because of their great influence on the energy content. This apparent consistency is, however, tempered by some questionable positions, such as raw apple having a worse ranking (97) than apple juice (45) or the large difference between whole-milk yoghurt plain (rank 75) and whole-milk yoghurt with fruits (rank 41), whereas fat-free plain and fruit yoghurts are very close (respectively ranks 28 and 29).

The NFI model classifies most breakfast cereals, pulses, vegetables and low-fat dairy products in the first quintile and most fruits and breads in the second quintile, whereas oils, fats and biscuits are in the fourth quintile and the fifth one contains most fatty meat products, cheese, pastries and processed foods. Sugary foods such as cola, fruit gums, honey or sponge cakes are classified as intermediate foods, in the third category, probably because the system does not consider the sugar criterion.

In the RRR system, it is more difficult to describe the classification by food groups or subgroups, which are often distributed over several quintiles, although there is a general trend for pulses and fruits and vegetables to be in the first quintile and for fats, pastries, sugary foods and fatty meats to be in the last ones. However, it remains puzzling to see some fruits (currants, grapes, bananas) in the last two quintiles whereas fruit cocktail is in the first one. In addition, probably because of its ratio structure, this system reacts very quickly to relatively minor changes in food composition and is thus not very robust. As an example, when ignoring the criterion cholesterol, boiled egg moves from 98th to 21st position.

The FSA model results in a consistent distribution of food groups relative to each other. Pulses, vegetables and most fruits are in the first quintile; low-fat dairy, fish and lean

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Table 2 Classification of 125 foodstuffs

	Rank*					Quintile†				
Food product	FSA	RRR	NFI	CFN	Disagree value	FSA	RRR	NFI	CFN	Expert
All-Bran	85	18	6	16	79	4	1	1	1	2
Apple juice, unsweetened	28	44	29	45	17	1	2	2	2	2
Apples, eating, average, raw, peeled	17	79	47	97	80	2	3	2	4	2
Avocado, average	23	46	113	101	90	1	2	5	4	2
Bacon rashers, streaky, fried	116	113	116	67	49	5	5	5	3	4
Baked beans, canned in tomato sauce	10	52	17	53	43	1	2	1	2	2
Bananas	39	81	32	71	49	3	4	2	3	2
Beef stew	47	29	58	51	29	2	2	3	2	4
Beef, rump steak, barbecued, lean	39	31	35	35	58	2	2	2	2	2
Big Mac	79	87	133	96	54	4	4	5	4	5
Broccoli, green, boiled	23	1	4	3	3	1	1	1	1	1
Butter	121	112	127	122	15	5	5	5	5	4
Camembert	106	68	111	58	53	4	3	5	3	4
Carrots, raw	74	10	12	12	58	1	1	1	1	1
Carrots, young, boiled	75	4	15	11	11	1	1	1	1	1
Celery, boiled in salted water	17	22	37	8	29	1	1	2	1	1
Cheddar cheese	116	54	122	68	68	5	3	5	3	4
Chicken nuggets, takeaway	76	85	112	84	36	3	4	5	4	5
Chicken, breast, casseroled, meat only	28	50	70	44	42	1	2	3	2	3
Chicken, breast, grilled without skin	23	39	25	24	16	1	2	1	1	2
Chicken, light meat, roasted	23	40	41	31	18	1	2	2	2	3
Chilli con carne	47	53	123	65	76	3	3	5	3	3
Chips, French fries	79	89	130	106	51	4	4	5	4	5
Chocolate chip cookies	116	114	109	113	7	5	5	5	5	5
Coco Pops	101	58	11	25	90	5	3	1	1	4
Cod, baked	39	61	65	49	26	2	3	3	2	1
Cola	62	127	60	118	67	3	5	3	5	5
Cola, diet	47	19	61	4	57	2	1	3	1	4
Corn Flakes	93	60	9	22	84	4	3	1	1	3
Cottage/Shepherd's pie	68	86	97	72	29	3	4	4	3	5
Cream crackers	90	75	80	104	29	4	3	3	4	4
Crème fraîche	93	106	126	119	33	4	4	5	5	5
Crème fraîche, half-fat	83	72	86	92	20	4	3	4	4	4
Croissants	97	88	118	102	30	4	4	5	4	5
Currants	68	118	51	110	67	3	5	2	5	1
Digestive biscuits, plain	106	96	101	111	15	5	4	4	5	4
Dressing, French	101	134	82	135	53	5	5	4	5	4
Drinking yoghurt	57	83	33	52	50	3	4	2	2	3
Eggs, chicken, boiled	47	98	89	54	51	2	4	4	3	2
Eggs, chicken, fried in vegetable oil	57	101	103	62.5	46	2	4	4	3	4
Fat spread (20–25% fat), polyunsaturated	83	135	75	61	74	4	5	3	3	4
Fat spread (60% fat), polyunsaturated	116	63	87	88	53	5	3	4	4	4
Fromage frais, plain	65	67	119	66	54	3	3	5	3	3
Fromage frais, virtually fat-free, natural	23	23	23	23	70	2	1	1	1	2
Fruit cocktail, canned in juice	17	24	36	34	19	1	1	2	2	3
Fruit gums/jellies	93	126	67	126	59	4	5	3	5	5
Fruit pie, one crust	72	82	95	112	40	4	4	4	5	4
Grapes, average	33	103	42	99	70	2	4	2	4	2
Green beans/French beans, boiled	22	8	5	13	11	1	1	1	1	1
Ham	87	94	66	18	76	4	4	3	1	2
Honey	90	131	62	127	69	4	5	3	5	3
Ice cream, dairy, vanilla	87	100	121	90	34	4	4	5	4	5
Ice cream, non-dairy, vanilla	79	115	115	91	36	4	5	5	4	5
Jam, fruit with edible seeds	87	121	63	115	58	4	5	3	5	4
Kiwi fruit	10	14	21	14	11	1	1	1	1	1
Lamb, loin chops, lean and fat, grilled	90	80	131	69	62	4	4	5	3	4
Lasagne	65	57	132	82	75	3	3	5	4	4
Lentils, dried, boiled	11	9	3	38	37	1	1	1	2	1
Lettuce, average, raw	10	7	44	6	38	1	1	2	1	1
Liver, ox, stewed	57	26	2	2	55	2	1	1	1	2
Margarine, soft, not polyunsaturated	125	105	114	121	20	5	4	5	5	5
Margarine, soft, polyunsaturated	123	76	104	124	48	5	3	4	5	4
Mars bar	123	120	120	116	67	5	5	5	5	5
Mayonnaise, made with rapeseed oil	103	124	93	131.5	38.5	5	5	4	5	4
Mayonnaise, reduced-calorie with rapeseed oil	103	129	77	128.5	52	5	5	3	5	4
Mayonnaise, reduced-calorie, without PUFA	113	128	76	128.5	52.5	5	5	3	5	4
Mayonnaise, retail without PUFA	113	123	92	131.5	39.5	5	5	4	5	5
Melon, canteloupe-type	10	6	10	7	54	1	1	1	1	1

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Table 2. *Continued*

Food product	Rank*					Quintile†				
	FSA	RRR	NFI	CFN	Disagree value	FSA	RRR	NFI	CFN	Expert
Muesli, Swiss style	81	48	20	43	61	4	2	1	2	2
Oat-based biscuits	109	109	96	109	13	5	5	4	5	3
Old potatoes, boiled	33	15	14	59	45	2	1	1	3	2
Old potatoes, mashed with butter	57	55	90	77	33	2	3	4	3	3
Olive oil	109	130	108	130	22	5	5	4	5	2
Onions, fried in corn oil	10	56	69	93	83	1	3	3	4	3
Orange juice, unsweetened	23	17	8	15	15	2	1	1	1	2
Oranges	10	13	13	10	133	1	1	1	1	1
Oven chips, frozen, baked	39	25	43	74	49	2	1	2	3	1
Parmesan, fresh	116	37	85	57	79	5	2	4	3	3
Peaches, raw	10	16	18	17	28	1	1	1	1	1
Peanuts, roasted and salted	72	66	102	76	36	4	3	4	3	5
Pears, average, raw, peeled	17	62	50	73	56	2	3	2	3	2
Pears, canned in juice	17	74	54	79	62	1	3	2	3	4
Pears, canned in syrup	23	104	57	108	85	2	4	3	5	2
Pizza, cheese and tomato	47	27	78	80	53	2	2	3	3	4
Pork sausages, fried	112	91	134	95	43	5	4	5	4	4
Pork, loin chops, grilled, lean and fat	65	70	98	42	56	3	3	4	2	4
Potato crisps	106	65	117	103	52	5	3	5	4	5
Potato crisps, low-fat	101	71	88	98	30	4	3	4	4	4
Prawns, boiled	76	108	84	27.5	80.5	3	5	4	2	2
Raisins	68	110	48	107	62	3	5	2	4	3
Rapeseed oil	97	132	91	133.5	42.5	5	5	4	5	2
Salami	121	116	128	83	45	5	5	5	4	5
Salmon, smoked	76	93	79	36	57	3	4	3	2	2
Semi-skimmed milk, UHT	47	47	56	40	16	3	2	3	2	2
Skimmed milk, UHT	33	32	19	19	14	2	2	1	1	1
Sorbet, fruit	72	90	53	87	37	4	4	2	4	3
Soya, alternative to milk, unsweetened	57	21	40	26	36	3	1	2	1	2
Soya, alternative to yoghurt, fruit	39	95	59	81	56	2	4	3	4	2
Spaghetti, white, boiled	33	20	39	100	80	2	1	2	4	2
Spinach, boiled	45	2	1	1	34	1	1	1	1	1
Sponge cake, jam-filled	97	117	74	114	43	4	5	3	5	5
Spreadable cheese, low-fat	72	64	73	39	34	3	3	3	2	4
Spreadable cheese, full-fat	97	99	110	105	13	4	4	5	4	4
Strawberries, raw	17	11	16	5	12	1	1	1	1	1
Sunflower oil	109	133	100	133.5	33.5	5	5	4	5	4
Tofu, soya bean, steamed	17	3	24	20	21	1	1	1	1	1
Tofu, soya bean, steamed, fried	28	5	7	32	27	1	1	1	2	3
Tomato ketchup	95	119	68	46	73	5	5	3	2	4
Tomatoes, raw	10	12	26	9	19	1	1	1	1	1
Tuna, canned in oil, drained	57	38	64	37	27	2	2	3	2	3
Vegetable soup, canned	47	97	49	48	51	3	4	2	2	2
Vegetarian sausages, baked/grilled	81	41	38	21	60	3	2	2	1	3
Wafer biscuits, filled	116	122	129	120	13	5	5	5	5	5
Walnuts	39	45	99	89	55	2	2	4	4	2
White bread, farmhouse or split tin	57	43	55	78	35	3	2	3	3	3
White bread, French stick	57	51	52	86	35	3	2	2	4	3
White bread, sliced	57	36	45	70	34	3	2	2	3	4
Whole-milk yoghurt, fruit	72	84	71	75	13	4	4	3	3	3
Whole-milk yoghurt, plain	47	42	46	41	6	3	2	2	2	3
Whole milk, UHT	62	59	107	60	48	3	3	4	3	3
Wholemeal bread	28	30	30	55	27	2	2	2	3	1
Yoghurt, low-fat, fruit	47	69	34	50	35	3	3	2	2	2
Yoghurt, low-fat, plain	47	35	27	33	20	3	2	1	2	2
Yoghurt, virtually fat-free, plain	39	33	22	30	17	2	2	1	2	2
Yoghurt, virtually fat-free, fruit	33	34	28	29	5	2	2	2	2	1

FSA – Food Standards Agency's Nutrient Profile; RRR – Ratio of Recommended to Restricted Foods; NFI – Nutritious Food Index; CFN – Calorie For Nutrient Index; PUFA – polyunsaturated fatty acids; UHT – ultra heat-treated.
*Ranking by the four nutrient profiling systems.
†Partitioning into quintiles (nutrient profiling systems and expert judgement).

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meats as well as starchy foods are in the second and third quintiles; and sugary foods, fats and fatty meat in the fifth quintile. Breakfast cereals belong to both last quintiles. Some minor inconsistencies remain, however, such as fruit cocktail or fried onions being in the first quintile whereas currants are in the third one.

Comparative analysis of the systems: building principles

A common feature of all nutrient profiling systems is of course their dependency upon accurate food composition tables. Identical nutritional values have been used here, which limits their impact on the comparison, yet does not rule out the critical importance of the data quality for correct classifications.

As thoroughly developed in the reports of the FSA[16–18], several questions are to be addressed while elaborating a nutrient profile system: the model type, the choice and the thresholds of nutrients taken into account, and the basis of the calculation. Each of the four studied systems has its own specificities: their only common point, strictly speaking, is their use of an 'across the board' approach in which every food item is examined with the same algorithm, whatever the food category. By comparison, the VoVo scheme and the Swedish keyhole system have different criteria and different thresholds, leading to different rules of classification according to food categories.

Next, the mathematical structures of the systems are different. The FSA model is a simple scoring system, which attributes a given number of points for each criterion according to its position relative to pre-set thresholds. These points are then added or subtracted to produce a final score which is always a round number. The system is thus a discontinuous function, whereas the three others are continuous functions which are arithmetic combinations of weighted variables.

Furthermore, the different systems do not make the same choice of nutritional criteria, as shown in Table 1; they use between seven and 17 criteria. In addition, the reference values for the selected criteria vary when they appear in two or several systems. These differences are usually small, although in some instances they can reach 20 or 25% (as for saturated fats or vitamin A between NFI and RRR). However, in the comparison made on 125 food items, a common set of reference values has been used, thus avoiding possible discrepancies due to this variation source.

Finally, the amount of food from which the quantities of nutrient to include in the scheme are calculated is also a matter of choice, between weight (100 g), energy (100 kJ) and serving size or a combination of these three possible bases. The systems consider the nutrients or food components present in 100 g of the food, except for the NFI that takes into account the serving size. In the FSA reports[16–18], simulations with various bases are reported not to affect significantly the percentage of foods classified as high in fat, sugar and salt. Note that the RRR system, being a ratio and using per cent values, is not influenced by this question of basis.

The overall purpose of the system is likely to influence the choice of criteria, weights and thresholds. Among the four tested schemes, three state very clearly their educational, consumer-oriented aim. The first one (CFN) is designed to enhance the intake of foods with high nutritional density and does not directly consider nutrients to be avoided. However, because foods high in energy are also high in fat and sugars, these criteria are partially taken into account; on the other hand, the salt issue is not considered. The RRR and NFI have broadly the same purpose, but their choice of nutrients is somewhat different. These systems were designed 6 years apart, in different countries. The perception of nutritional emergencies evolves with time (the concern for sugar is higher today) and location (the context and the culture are highly country-dependent), and this, together with the author's own convictions, can explain the difference between nutrient choices. The recent FSA system is somewhat different in this respect since it focuses on a specific age group (children aged 6–11 years) and a specific purpose (support for regulators in avoiding advertisement broadcast of foods high in saturated fat, sugars and salt); this may explain the focus put on these nutrients. Nevertheless, the system also considers proteins, fibre, fruits and vegetables and thus aims at giving a definition of 'healthier' and 'less healthy' foods.

Comparative analysis of the systems: classification of 125 food items

In a first very broad approach, the four systems give a similar overview: globally, most fruits and vegetables are ranked in the first and second quintiles in the four systems, whereas foods high in fat and sugars fall in the fourth and fifth ones. The ranking given by a system is correlated with the other ones, yet with correlation coefficients between 0.64 and 0.78 (Table 3) which already denote some discrepancies. The mean of disagree values is 38 with a standard deviation of 21, indicating that numerous food items are classified in different groups by the four systems. Indeed, 46 products (37% of total) fall into three or four different categories according to these systems.

A closer examination of some food items whose ranking differs largely between systems gives interesting clues about the possible discrepancies brought by specific choices when developing the system, as illustrated by the following example.

The breakfast cereal 'All-Bran' is ranked in the first quintile by all except for FSA, which ranks it in the fourth one. This product is characterised by a high content of sugars, a criterion considered in the FSA and RRR systems; ignoring sugars improves the ranking in both these systems and brings the disagree value from 79 to 45. This importance of the criterion 'sugar' in the

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Table 3 Correlations between classifications with different nutrient profiling systems (all coefficients are statistically significant)

	Spearman correlation coefficients on ranks				
	CFN	NFI	RRR	FSA	
CFN	1	0.680	0.791	0.637	
NFI		1	0.658	0.698	
RRR			1	0.722	
FSA				1	
	Spearman correlation coefficients on quintiles				
	CFN	NFI	RRR	FSA	Expert
CFN	1	0.680	0.757	0.587	0.613
NFI		1	0.653	0.677	0.687
RRR			1	0.690	0.621
FSA				1	0.724
Expert					1

CFN – Calorie For Nutrient Index; NFI – Nutritious Food Index; RRR – Ratio of Recommended to Restricted Foods; FSA – Food Standards Agency's Nutrient Profile.

FSA system is confirmed when looking at its impact on the ranking of other breakfast cereals ('Coco Pops' cereal goes from 101st to 50th rank, and 'muesli, Swiss style' from 81st to 50th rank, when ignoring the sugar criterion) or in the ranking of some fruits (grapes' ranking goes from 33rd position up to 20th, currants' ranking from 68th to 25th). Sugar is even more critical in the RRR system, when its omission may deeply affect the ranking: the ranking of grapes improves by 83 positions (from 103rd to 19th).

Analysis of the systems: comparison with an expert empirical classification

The partition of the 125 food items by experts is intrinsically empirical and is likely to reflect the expertise and knowledge of each expert, as well as his/her personal or cultural point of view. This is confirmed by the one-to-one correlation coefficients between each expert's rankings, which vary widely (0.49 to 0.96). It is not within the scope of this paper to discuss in detail or evaluate these expert classifications, which are thus not shown; yet the median classification (Table 2) retained for comparison with the systems' classification might be considered an acceptable compromise. The FSA scheme is the nutrient profile system closest to the expert partitioning (Table 3), although the fit is far from absolute.

Comparisons between classifications or partitioning should be interpreted with caution: none of it, including the expert partitioning, can be considered as an absolute reference. Thus, correlation coefficients represent additional information, useful for examining the nutrient profiling systems relative to one another, but not relevant for stating that one system is more accurate than another. However, it is interesting to note that these correlation coefficients are in the same range (around 0.65) whether they are calculated on the rankings (1 to 125) or on the partitions in quintiles of the same list of 125 food items.

Conclusion

The four systems analysed in this work provide classifications of individual food products in an objective and reproducible way and are, in that respect, valuable and interesting tools. However, although the classifications, broadly speaking, rate better the foods that contribute positively to the balance of the diet, the overall consistency of these classifications is never perfectly accurate; this includes the FSA system, which nevertheless might be considered as the best performing tool among the ones tested. Although highly preliminary, the empirical classification proposed by experts in nutrition is not clearly more accurate. All this confirms, at least partly, the worries of some nutritionists who are sceptical about the possibility of establishing a nutrient profile based on the nutritional composition of foodstuffs and across the large variety of available foods.

An alternative to this global system aiming at positioning every foodstuff with the same criteria could be to question the relevance of the 'across the board' approach and to reconsider a system adapted to different food categories. From a technical point of view, such approaches, likely to be more consistent, have not been worked out as precisely as the ones presented here, although interesting attempts have been made. There is probably room for a system that would take the systematic approach of the nutrient profiling methods analysed here, while attributing different weights to nutrients according to the group the considered food belongs to. Another improvement could come from a better connection between human expertise and mathematical tools, with a systematic validation of the nutritional criteria, weightings and thresholds by a panel of experts, which would clearly be more efficient than individual advice.

The issue regarding the objective(s) of the profiling systems is of primary importance. In the schemes analysed here, it has a great influence on the choice and ranking of nutritional criteria. Additional work is required to explore whether different public health objectives justify different tools, which might be confusing, or if a generic system can be elaborated, with some reasonable flexibility in nutritional criteria and/or weights and thresholds to modulate food rankings according to specific needs. In our mind, the critical point is to reach the soundest system that is backed up scientifically; then the amendments to address specific questions should be possible with minimal and justified changes. In that respect, the FSA system is interesting because, starting from a well-defined and focused brief, it ended with a global positioning of foods which is consistent with wider objectives.

Whatever the approach, it must be kept in mind that such tools should be used with caution and by

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experienced nutritionists. It should also be remembered that the nutritional composition of a food is only one aspect of its nutritional quality; the other one being its use, determined by individual food behaviours. In that respect, an inadequate use of these profiles, especially for consumer-related purposes, may lead to deleterious and counter-productive effects; but on the other hand, they could provide helpful information for healthier choices. Nevertheless, well-designed and cleverly utilised nutrient profiles can be part of the toolbox needed to speed up the present-day compulsory achievement of efficient nutrition education and regulation.

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