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Nutrient profiling as a tool to respond to public health needs

From the SAIN,LIM system to the SENS algorithm: a review of a French approach of nutrient profiling

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Nutrient profiling aims to classify or rank foods according to their nutritional composition to assist policies aimed at improving the nutritional quality of foods and diets. The present paper reviews a French approach of nutrient profiling by describing the SAIN,LIM system and its evolution from its early draft to the simplified nutrition labelling system (SENS) algorithm. Considered in 2010 by WHO as the 'French model' of nutrient profiling, SAIN,LIM classifies foods into four classes based on two scores: a nutrient density score (NDS) called SAIN and a score of nutrients to limit called LIM, and one threshold on each score. The system was first developed by the French Food Standard Agency in 2008 in response to the European regulation on nutrition and health claims (European Commission (EC) 1924/2006) to determine foods that may be eligible for bearing claims. Recently, the European regulation (EC 1169/2011) on the provision of food information to consumers allowed simplified nutrition labelling to facilitate consumer information and help them make fully informed choices. In that context, the SAIN,LIM was adapted to obtain the SENS algorithm, a system able to rank foods for simplified nutrition labelling. The implementation of the algorithm followed a step-by-step, systematic, transparent and logical process where shortcomings of the SAIN,LIM were addressed by integrating specificities of food categories in the SENS, reducing the number of nutrients, ordering the four classes and introducing European reference intakes. Through the French example, this review shows how an existing nutrient profiling system can be specifically adapted to support public health nutrition policies.

Food: Nutrient: France: Labelling: Nutrition information

This review illustrates how an existing nutrient profiling system can be specifically adapted to support public health nutrition policies, with the example of a French approach of nutrient profiling. The present paper is divided into four sections. The first section introduces the preliminary indicators to estimate the nutritional quality of foods, which laid the foundations for the French SAIN,LIM (score of nutritional adequacy of individual foods (SAIN); score of nutrients to be limited (LIM)) system. The second is devoted to the presentation of the SAIN,LIM system, including the context in which it was generated, the calculation principle and its improvements. The third explains how a nutrient profile originally designed to help regulating health and

Abbreviations: AFSSA, French Food Standard Agency; DRV, daily recommended value; EC, European Commission; ED, energy density; F&V, fruits and vegetables; LIM, the score of nutrients to be limited; MRV, maximal recommended values; NDS, nutrient density score; SAIN, score of nutritional adequacy of individual foods; SENS, simplified nutrition labelling system.
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nutrition claims was transformed to an operational system for simplified nutrition labelling, in the context of both European and French legislation on the provision of food information to consumers. The fourth section situates the simplified nutrition labelling system (SENS) in the international context of food labelling by emphasising its specificities in relation to other nutrient profiling systems underlying simplified nutrition labels launched worldwide.

Emergence of indicators to estimate the nutritional quality of foods: the nutrient density score and the score of nutrients to be limited

In 2005, the Dietary Guidelines for Americans recommended that consumers give priority to nutrient-dense foods, defined as those with a high nutrients-to-energy ratio, and then consume discretionary energy depending on their energy needs[1]. Although the concept of nutrient-dense foods was well understood as this time, no uniform standard of nutrient density existed. In this context, a joint France–US research team developed a scoring system to estimate the nutritional adequacy of foods. Precursor of the SAIN, the nutrient adequacy score was defined as the mean of percent daily values for sixteen nutrients, expressed per 100 g of food but also per 418·4 kJ (100 kcal) as a nutrient density score (NDS), or per unit cost (nutrient-to-price ratio)[2]. The idea that food prices and diet costs may be one factor limiting the adoption of healthier diets, especially by the low-income consumer and may contribute to the observed socioeconomic disparities in health[3] was reinforced by this innovative approach that put forward the relationship between nutrient content, energy density (ED) and food costs. The new concept of nutrient profiling appeared therefore as a relevant tool to rank foodstuffs according to their contribution to a balanced diet and better consider the issue of food costs and nutrient-to-price ratios[4]. A scoring system built on two indicators was developed: (1) the NDS, based on twenty-three qualifying nutrients (i.e. positive nutrients); (2) the LIM, based on disqualifying nutrients.

To identify the optimal base of calculation, indicators were expressed by 100 g or 418·4 kJ of food or per standard serving sizes. Results showed that indicators based on serving sizes and on 418·4 kJ were preferable for positive scores[5]. Since negative scores incorporated energy-providing nutrients (i.e. macronutrients), it was preferable to express them per 100 g of food, in order to not penalise foods with a low ED (such as fruit and vegetables (F&V))[5]. In the absence of standardised European serving sizes, the team therefore decided to express the NDS per 418·4 kJ, while the LIM was expressed per 100 g of food.

The NDS summarises the positive aspects of the food by assessing the percentage of adequacy with the recommendations for essential nutrients. It was defined as an unweighted arithmetic mean of the percent adequacy for the qualifying twenty-three nutrients present in the food composition tables and for which a daily recommended value (DRV) existed[6]. The generic equation is:

$$\mathrm{NDS} = \frac{\sum_{p=1}^{23} \mathrm{Nut}_p/\mathrm{DRV}_p}{23} \times 100,$$

where Nut_p, is the quantity (in g, mg or µg) of nutrient p provided by 418·4 kJ (100 kcal) of the food and DRV_p the French corresponding DRV (mean for men and women), expressed in the same unit as Nut_p[7].

The LIM score summarises the unfavourable aspects of the food. It was defined as the mean percentage of the maximal recommended values (MRV) for three disqualifying nutrients that should be limited in a healthy diet: sodium, simple added sugars and SFA[6]. The generic equation is:

$$\mathrm{LIM} = \frac{\sum_{p=1}^{3} \mathrm{Li}_p/\mathrm{MRV}_p}{3} \times 100\,,$$

where Li_p is the content of limiting nutrient p in 100 g of the food and MRV_p is the maximum recommended value for nutrient p expressed in the same unit as Li_p. The MRV for SFA and added sugars correspond to 10 % of the recommended energy intake of 8368 kJ (2000 kcal). The MRV for sodium is 3153 mg, corresponding to a daily intake of 8 g NaCl.

NDS and LIM were found to accurately characterise the nutritional quality of individual foods[6]. Thus, median NDS:LIM values of foods selected in diets modelled by linear programming increased with increasingly stringent nutritional constraints included in the models, i.e. with increasing nutritional quality level of the modelled diets[6].

Additional consideration of energy cost (i.e. the cost of energy) disclosed that foods[6] and food groups[4] differ widely in terms of nutritional quality and cost. Combined together, NDS, LIM and energy cost were used to identify foods with good nutritional quality for their price, revealing that those foods must be preferentially selected to obtain healthy diets at a low cost[6]. These results put forward strong evidence that effective dietary guidance must take into account both the nutrient profile of foods and their nutrient and energy costs to allow consumers to identify and select optimal foods at an affordable cost.

Two-score nutrient profiling system: the SAIN,LIM system

The notion of nutrient profiling appeared in the early 2000s, fostered by a widespread consumer interest for nutrition information. More aware of the link between diet and health, they strongly expressed the desire to get informed about the nutritional properties of the food they eat. Improvements in nutrition labelling and consumer communications policies on health claims appeared as a solution to make the existing point-of-purchase environment more conducive for healthy choices. To avoid misleading consumers about the overall nutritional quality of foods, the European

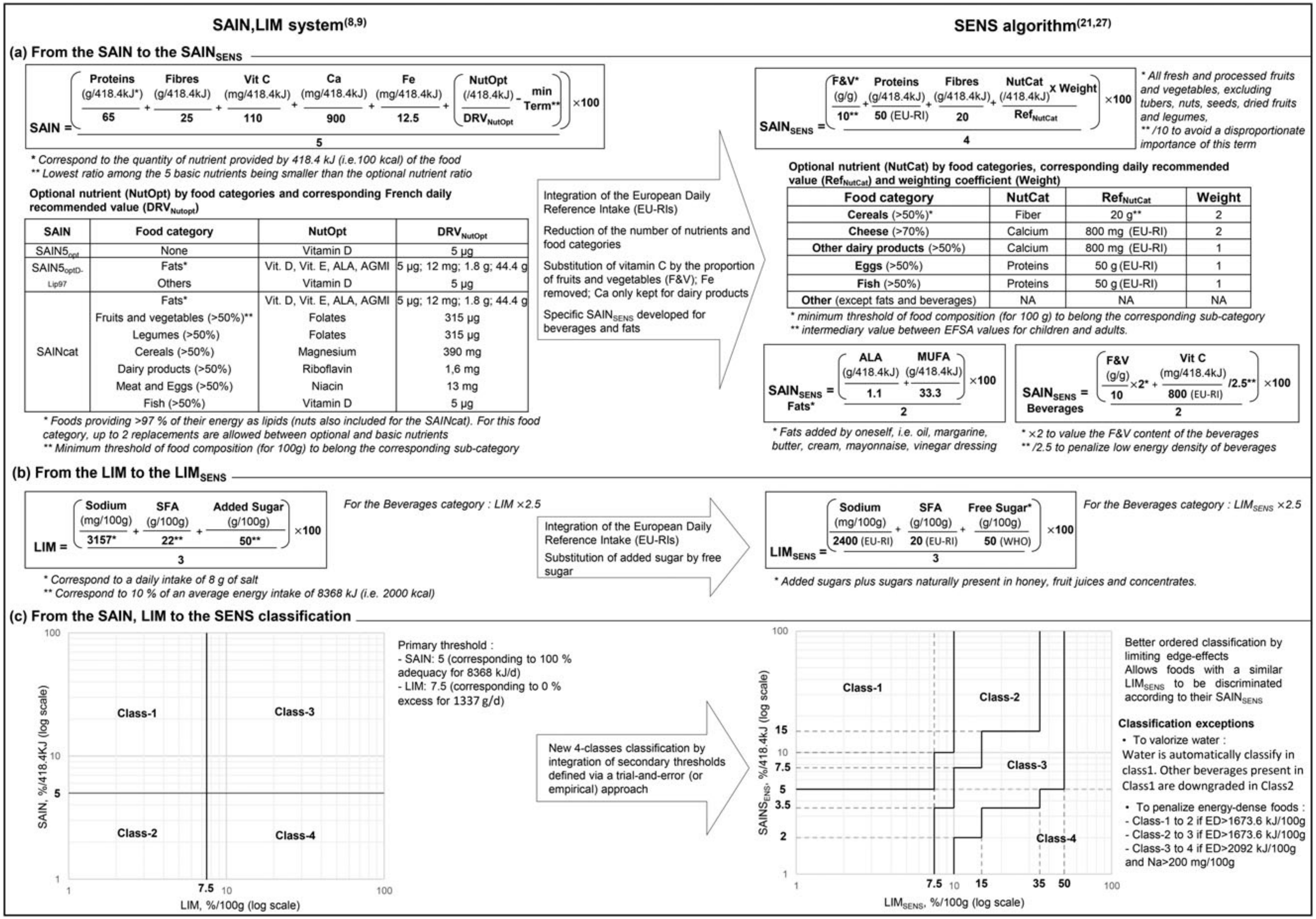

Fig. 1. From the SAIN,LIM (score of nutritional adequacy of individual foods (SAIN); score of nutrients to be limited (LIM)) system to the simplified nutrition labelling system (SENS) algorithm.

Commission (EC) decided to define the eligibility to nutrition or health claims according to the nutrient profile of each food[10]. Considering the overall nutritional status of a food, the main issue was to identify the limiting nutrients for which dietary intake should be reduced, and positive nutrients for which increased dietary intake is desired in terms of nutritional goals of public health policies. In this context, the French Food Standard Agency (AFSSA), initiated a working group, which ended proposing an original nutrient profiling scheme: the SAIN,LIM system (Fig. 1)[8,9]. This French system was derived from the two afore-mentioned indicators, the NDS and the LIM, considering that positive and negative nutrients are both needed to define food healthiness. Primary threshold value was allocated to each indicator, hence defining four nutrient profile classes. Threshold for good nutrient density was set at 5, given that a SAIN > 5 is equivalent to 5 % of nutritional adequacy for 418·4 kJ corresponding to 100 % of nutritional adequacy for 8368 kJ/d (reference daily energy intake). For the LIM, a high content of limited nutrients was defined by a LIM > 7·5, i.e. 7·5 % for 100 g corresponding to 0 % excess in disqualifying nutrients for 1337 g/d (mean daily food intake observed in the French population).

The SAIN,LIM system calculation principle

The twenty-three nutrients considered in the previous NDS were included in the first version of the SAIN developed by the AFSSA: SAIN23. Nevertheless, from a practical perspective, it would have been challenging to require this level of information for both administrators and economic operators. Several expressions were tested for the SAIN score and the final one was limited to five basic nutrients: proteins, fibre, vitamin C, calcium and iron, and one optional nutrient, vitamin D ($SAIN5_{opt}$). Namely, when the vitamin D ratio ($VitD_{(\mu g/418{\cdot}4\ kJ)}/DRV_{vitD}$) was higher than the lowest ratio among the five basic nutrients, this lowest ratio was replaced by the vitamin D ratio in the equation. To ensure the relevance of this selection, different SAIN were generated from 613 foods of a French database (INCA1) by randomly selecting five, seven, nine, eleven or thirteen of the twenty-three initial nutrients. Spearman correlations were calculated between the simulated scores and the contents of each of the twenty-three nutrients in the table. Results showed that there was no benefit to include more than five nutrients in the SAIN, considering that the number of strong correlations was little affected by the number of selected nutrients[8]. The choice of nutrients reflects a balance between the need to include nutrients of importance to public health (inadequate intakes of iron, calcium and vitamin C exist in the French population), nutrients markers of key food categories that are subject to nutritional recommendations (iron for meats, calcium for dairy products, fibre and vitamin C for F&V) and nutrients markers of other essential nutrients (proteins in foods are usually correlated with that of other essential nutrients, such as vitamins B_2, B_3, B_5, B_{12}, iodine, selenium or zinc)[8].

As well as NDS, SAIN is a marker of the nutrient density and is expressed per 418·4 kJ of food. The LIM is the same as the one previously developed. The score is calculated per 100 g of cooked or rehydrated food. Because a negative score based on 100 g is more lenient towards drinks due to their low ED[5], the LIM score was multiplied by 2·5 for soft drinks. The weighting factor of 2·5 was chosen considering that a portion of 250 ml is relevant for liquids.

Based on the SAIN and LIM values and on the threshold defined for each score, each food was allocated to one of four possible SAIN,LIM classes. Foods with the most favourable nutrient profiles are in Class-1, and foods with the least favourable nutrient profiles are in Class-4. In response to the European regulation on nutrition and health claims (EC 1924/2006), AFSSA proposed that only foods present in Class-1 would be eligible to health claims, and foods in Class-1 or Class-2 to nutrition claims[8].

Four years after the AFSSA report, an American research team proposed a novel method to selecting and weighting nutrients for nutrient profiling of foods and diets[11]. Their statistical approach was based on correlations between nutrients intakes and an overall index of dietary quality: the Healthy Eating Index score. Applied to the National Health and Nutrition Examination Survey survey population, the novel method led to a model containing five qualifying nutrients (protein, fibre, calcium, unsaturated fat and vitamin C) and three disqualifying nutrients (SFA, sodium and added sugar). Except for iron (not selected with the Healthy Eating Index-correlation study), these nutrients turned out to be the same as the nutrients included in the SAIN, LIM system, despite using different approaches and populations. These results further strengthened the choice of the nutrients in the SAIN,LIM system, and raised the possibility of extending it beyond France and Europe.

Improvement of the SAIN,LIM system

Vitamin D was first chosen by AFSSA as the optional nutrient of the $SAIN5_{opt}$ score to correct misclassifications for oily fish. Subsequently, changes were introduced to improve the nutritional relevance of the system. As described by the AFSSA report, analyses were conducted on the French food database (INCA1) to identify which essential nutrients were, or were not, correlated with the nutrients included in the $SAIN5_{opt}$ score. The underlying assumption was that only nutrients strongly correlated ($R^2 > 0{\cdot}5$) with one or several of the six nutrients included in the score would be represented (though indirectly) by the score. It turned out that all water-soluble nutrients not included in the $SAIN5_{opt}$ score were in fact strongly correlated with at least one nutrient of the score (Table 1)[8]. In contrast none of the fat-soluble nutrients were strongly correlated with nutrients of the $SAIN5_{opt}$, except DHA which was strongly correlated with vitamin D. Thus, a more refined version was developed depending on the lipid contents of the food: $SAIN5_{optD-Lip97}$. For foods providing more than 97 % of their energy as lipids, four fat-soluble nutrients, namely vitamin E,

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Table 1. French Food Standard Agency assessment of the nutritional relevance of the SAIN using Spearman correlations between the six nutrients composing the $SAIN5_{opt}$ and eighteen other nutrients[8]

	$SAIN5_{opt}$ components					
	Water-soluble nutrients					Fat-soluble nutrients
	Protein	Fibres	Vitamin C	Ca	Fe	Vitamin D
Water-soluble nutrients						
Vitamin B_1	0·45	0·49	0·54*	0·24	0·54*	−0·13
Vitamin B_2	0·64*	0·10	0·34	0·50*	0·49	0·09
Vitamin B_3	0·63*	0·25	0·34	−0·08	0·58*	0·03
Vitamin B_5	0·53*	0·29	0·49	0·33	0·51*	0·08
Vitamin B_6	0·46	0·44	0·59*	0·25	0·60*	−0·05
Vitamin B_9	0·19	0·69*	0·72*	0·47	0·58*	−0·09
Vitamin B_{12}	0·58*	−0·45	−0·20	−0·07	0·21	0·42
K	0·40	0·61*	0·71*	0·44	0·68*	−0·19
Mg	0·46	0·59*	0·57*	0·54	0·70*	−0·20
I	0·53	−0·29	−0·12	0·42	0·02	0·38
Cu	0·27	0·57*	0·50*	0·18	0·73	−0·13
Se	0·70*	−0·23	−0·10	0·04	0·31	0·34
Zn	0·73*	0·10	0·16	0·40	0·54*	0·02
Fat-soluble nutrients						
DHA	0·46	−0·39	−0·24	−0·22	0·06	0·61*
ALA	0·09	0·13	0·16	0·15	0·14	0·09
Vitamin E	0·02	0·30	0·33	0·04	0·20	0·06
Vitamin A	0·05	0·27	0·40	0·41	0·23	0·23
MUFA	0·03	−0·50	−0·50	−0·27	−0·31	0·30

Nutrients are expressed in percent of their daily recommended value (per 418·4 kJ) after log transformation of the variables.
* Correlation above 0·5.

vitamin A, α-linolenic acid and MUFA, were used as optional nutrients and up to two replacements were allowed between optional and basic nutrients. For other foods, vitamin D was kept as the only optional nutrient[12]. The next version of the SAIN, named SAINcat, was proposed as the part of the Optimed programme[9], designed to help small food companies in the Mediterranean areas for the promotion and nutritional optimisation of their products. The aim was to derive from the SAIN,LIM system, a more nutrient-sensitive system that could be used as a tool to predict the evolution of the nutritional quality of a given food product under the impact of a reformulation or a food process. As a special feature, the SAINcat algorithm integrated nutritional specificities of food categories with the introduction of the new notion that the optional nutrient should be a category-specific nutrient[9]. Based on an epidemiological analysis of the contribution of the different food categories to the intake of nutrients in the diets of French adults, the following category-specific nutrients were identified: folates (for fruits, vegetables and legumes), magnesium (for cereals), riboflavin (for dairy products), niacin (for meat and eggs products) and vitamin D (for fish).

Practical use of the SAIN,LIM system in intervention and research studies

By classifying individual foods based on their overall nutritional quality, the SAIN,LIM system is able to identify foods that should be encouraged to promote healthy eating[12,13]. This is especially relevant when translating the nutrient profiles of individual foods into concrete and quantified advice to promote overall nutritional balance. Therefore, the scope of the SAIN,LIM system was largely extended leading to multiple public health implications. It provided new insights into how diet cost affects consumer choice and diet quality and should be counted among the key socioeconomic determinants of health[14]. Among other things, it was used to identify foods with a good nutritional quality for price[6], to explore the impact of food price policies (subsidies and/or taxes) on the expenditures and nutritional quality of the diet[15], or to evaluate the impact of food transformations on final nutritional quality of food products[16]. The SAIN,LIM system was also used as a tool to support the Opticourses intervention, that aimed to reduce social inequalities in nutrition and health, by improving the nutritional quality of food purchases in populations with budgetary constraints. Through participatory workshops in socioeconomically deprived neighbourhoods of Marseille (France) an educational tool, named the Good Price Booklet, was constructed. Based on the SAIN/LIM ratio, to define nutritional quality, and national food prices, this booklet lists over 100 good nutritional quality foods and their good price, defined as the price below which a food of good nutritional quality can be considered as relatively inexpensive (http://www.opticourses.fr/). In addition, a 6-month intervention in retail shops was performed to increase the visibility and attractiveness of those inexpensive foods with good nutrition through shelf labelling and marketing strategies[17]. This social marketing intervention was found to improve food purchasing behaviours in disadvantaged neighbourhoods. In the context of food labels, an experimental study on consumers' beliefs about the tastiness and healthiness of food items (estimated from the SAIN,LIM system) revealed that simple nutrient information influences consumers' grocery choices[18]. More recently, the SAIN,LIM system has contributed to a better understanding of the relationship among the three dimensions of sustainability in foods: environmental impact, nutritional quality and price[19,20].

A new nutrient profiling system operational for food labelling in Europe: the SENS system

In Europe, the European regulation (EC 1169/2011) on the provision of food information to consumers conveys EU rules on general food labelling and nutrition labelling[21]. Individuals are influenced by various contextual factors that influence their food purchasing behaviour, which include nutrition labelling on food products[22]. Interpretive labels have been proposed as a potentially effective approach to assist consumers in choosing healthier products[23]. This approach requires an effective and suitable nutrient profiling system able to rank foods according to their nutritional composition[24]. Because the European regulation has not stipulated which nutrient profiling system should be used to implement labelling, several nutrient profiling systems have been proposed. Among them, a group of experts and members of French food retailers and industries initiated the development of the simplified nutrition labelling system (SENS; Fig. 1), in line with the European regulation (EC 1169/2011) fostering multi-stakeholders and collaborative interventions[21]. The SENS algorithm is described (N Darmon, J Sondey, V Braesco *et al.*, unpublished results) and in a report of the French Agency for Food, Environmental and Occupational Health & Safety[25]. Adaptations from the SAIN,LIM to the SENS were introduced progressively, following an iterative process described in detail in a dedicated report[26]. The implementation of the algorithm followed a step-by-step, systematic, transparent and logical process, as encouraged by WHO in the guiding principles manual and methodological framework for developing nutrient profiling[24]. The main steps were as follows:

(1) *Define the purpose of the nutrient profiling model.* The SENS aims to classify food according to their overall nutritional quality, both between and within food groups as well as between similar food products.

(2) *Decide whether to use an existing model or to develop a new model.* It was decided to derive the SENS from across the broad SAIN,LIM system, in view of its many advantages. Hence, the SAIN,LIM was developed by independent experts under the aegis of the AFSSA. It was formerly recognised by the French authorities as a relevant system in the context of the European regulation on nutrition and health claims (EC 1924/2006). In addition, the SAIN,LIM system was initially developed to be adaptable and improvable as described in the AFSSA report[8].

(3) *Decide on the scope of and exemptions to the model.* In accordance with the European regulation (EC 1169/2011), the SENS algorithm mainly concerns packaged foods, but it can be calculated on all foods, including non-packaged ones (fruits, fish, meat, etc.). Alcoholic beverages are not in the scope of the system.

(4) *Decide the number of food categories that will be used in the model (if any).* Category-specific nutrient profiling systems including the specificities of food categories were previously found to be more effective in promoting an achievable healthy diet, provided that the number of categories is moderate and an across-the-board-approach is maintained[27]. Accordingly, a limited number of relevant food categories are taken into account in the SENS system. The algorithm distinguishes three main groups: added fats, beverages and solid foods. The latter is subdivided in six categories: cereals, cheese, other dairy products, eggs, fish and other solid foods. This categorisation differs slightly from the SAINcat to be closer to that considered in nutrient profiling systems proposed by the EC[28] and the WHO Regional Office for Europe[29].

(5) *Decide which nutrients and other food components should be involved.* As the SAIN,LIM system, the SENS is derived from two indicators: a NDS for qualifying nutrients ($SAIN_{SENS}$) and a limited nutrient score for disqualifying nutrients (LIM_{SENS}). In the $SAIN_{SENS}$ for solids foods, proteins and fibre were kept as basic nutrients, vitamin C was replaced by the percentage of F&V, and iron was removed. Food category-specific nutriments were introduced: fibre (for cereal-based products), calcium (for dairy products) and proteins (for eggs and fish) with dependent weighting factors to give greater prominence to these nutrients in the calculation, where needed. Other specific nutrients were selected in the $SAIN_{SENS}$ for beverages and added fats, respectively, vitamin C and F&V for beverages and α-linolenic acid and MUFA for added fats. In the LIM_{SENS}, added sugars were replaced by free sugars (added sugars plus sugars naturally present in honey, fruit juices and concentrates) in accordance with recent WHO recommendations on the need to reduce free sugar consumption[30]. Besides, including free sugars in the calculation will provide an incentive for the manufacturers to develop strategies to reformulate products high in sugar by fostering nutrient-dense ingredients containing naturally present sugar rather than ingredients with lower nutritional value. The SENS algorithm could encourage food companies to reformulate their products by improving the nutrient density while avoiding replacement of nutrient-dense ingredients by empty ingredients.

(6) *Decide the reference amount for the model.* As in the SAIN,LIM system, the $SAIN_{SENS}$ represents a nutrient density and is expressed per 418·4 kJ, while the LIM_{SENS} is expressed per 100 g.

(7) *Decide whether to use scoring or thresholds (or both).* The previous SAIN,LIM classification was sensitive to small changes in the nutrient composition of a food due to a strong edge effect. This could lead to a leap over classes, even directly from Class-1 to Class-4. To overcome this issue, secondary thresholds were added to the primary ones (5 for the SAIN and 7·5 for the LIM). These threshold values of 10, 15, 35, 40 for LIM_{SENS} and 2, 3·5, 7·5, 10, 15 for the $SAIN_{SENS}$ were selected pragmatically to reach a better ordered classification and to allow food with a similar LIM_{SENS} to be discriminated against their $SAIN_{SENS}$ and vice versa.

(8) *Decide which numbers should be used to determine the thresholds or score.* The European regulation (EC 1169/2011) states that labelling should be based either on the harmonised reference intakes in Europe set out in Annex XIII, or in their absence, on generally accepted scientific advice on intakes for energy or nutrients[21]. In the SENS algorithm, existing reference intakes in Europe replaced French DRV for SFA, sodium, calcium and proteins. The 2015 WHO recommendation was used for free sugars[30]; FAO and EFSA (European Food Safety Authority) recommendations were used for MUFA and α-linolenic acid[31]. In the absence of reference intakes in Europe for fibres in Annex XIII of EC 1169/2011[21], a reference intake of 20 g was chosen, as an intermediate between the EFSA reference values[32] for children (14 g/d) and for adults (25 g/d). It was lower than in the original SAIN (i.e. 25 g), to better value foods rich in fibres (as a lower reference value increases the ratio $Fibres_{(g/418 \cdot 4\,kJ)}/DRV_{fibres}$, thereby increasing the $SAIN_{SENS}$)[32]. F&V were divided per 10 to avoid a disproportionate importance of this ratio relative to other ratio of the equation.

Implementation of the algorithm requires three main steps. The first is to collect information on ingredients to categorise a selected food in one of the eight food categories described earlier. Due to its specific composition, milk is considered as a dairy product rather than as a beverage. In accordance with the French nutrition and health programme, added fat is defined as fats added by oneself such as oil, butter, cream, mayonnaise or vinaigrette[33]. As suggested by the EC to avoid a food being classified in more than one category, the selected food must have more than 50 % of the sub-category ingredient for 100 g to belong to that sub-category (except for cheese requiring an amount >70 % in accordance with the French decree no 2013-1010). Once the sub-category is identified, the second step requires the collection of specific nutritional information to calculate the adequate $SAIN_{SENS}$ and LIM_{SENS}. Among nutrients required for the calculation of the SENS algorithm, only energy, proteins, SFA and sodium are subject to the mandatory nutrition declaration. However, manufacturers should be able to provide information about other nutrients or components. In the calculation, F&V include all fresh and processed fruits (tubers, nuts, seeds, dried fruits and legumes excluded). In the third step, the selected food will be positioned on a map with the $SAIN_{SENS}$ and LIM_{SENS} as axes to display their allocation in one of the four SENS classes. Water is automatically classified in Class-1 ($LIM_{SENS} = 0$ and $SAIN_{SENS}$ is infinite given that water is energy-free). Other beverages that may be present in Class-1 when the algorithm is applied are systematically downgraded to Class-2, to deliberately having water as the only beverage represented in Class-1. Other exceptions concern energy-dense foods: those foods with ED > 1673·6 kJ (400 kcal)/100 g that may be allocated to Class-1 or Class-2 by the algorithm are systematically downgraded to Class-2 and Class-3, respectively. Finally, foods with ED > 2092 kJ (500 kcal)/100 g and Na > 200 mg/100 g that may be allocated to Class-3 are systematically downgraded to Class-4.

As reported by WHO, validation is a key step in the development of a nutrient profiling system. Although no gold standard exists for defining a healthy food, various validation methods have been proposed to ensure the model classifies foods properly. These include assessment of construct validity, that is, testing the nutrient profile model ability to complement and support food-based dietary guidelines in the regions in which it is applied. The construct validity of the SAIN,LIM system was performed using diet modelling with linear programming for designing healthy and unhealthy diets. Although based only on few key nutrients, the system was able to predict the ability of a given food to facilitate, or to impair, the fulfillment of a large number of nutrient recommendations[12,34]. The SENS algorithm was validated by different approaches. Its implementation on the CIQUAL French database showed that SENS classification was consistent with nutrition principles and with food-based dietary guidelines (N Darmon, J Sondey, V Braesco *et al.*, unpublished results). Results also showed the SENS classification was positively associated with ED (N Darmon, J Sondey, V Braesco *et al.*, unpublished results), which is considered as one validation element of the nutrient profiling model[35]. Nevertheless, this classification was not ascribed solely to the ED and its strength lies in its capacity to also differentiate foods according to their nutrient density. Other analyses showed that the SENS algorithm leads to a hierarchical classification of foods considering their contribution to nutritionally adequate diets, suggesting that healthy choices can be advocated based on the relative contribution of foods from each SENS class[26].

The SENS in the international context of food labelling

Initially driven by the regulation EC 1924/2006 to control access to nutrition and health claims in Europe, the scope of nutrient profiling systems has been extended to various applications, including marketing of foods to children, regulation of fortification, fiscal food implementation, the use of economic tools to orient food consumption, or product labelling logos or symbols. Regarding the latter, the rise of overweight and obesity has focused policymakers' attention on the improvement of nutrition information to consumers. Nutrition declaration tables may be difficult to understand for the average consumer, and simplified nutrition labelling, such as front-of-pack logos or symbols, might help consumers to spot a synthesised nutrition information when purchasing foods[36]. In that connection, different formats of front-of-pack labels have been launched worldwide. Summary indicators were first introduced by non-profit organisations and government agencies, such as the Green Keyhole in the late 1980s[37]. Used in Sweden, Norway and Denmark, this voluntary positive category-specific label is only placed on products that meet specific requirements relating to fibres, salt, sugar, fat and saturated fat set for a given food category. Following the European regulation (EC 1169/2011), the UK has opted for a nutrient-specific Traffic Light system developed by the UK Food Standards Agency combining colour and percentage of DRV for energy, fat, saturated fat, sugars and sodium[38]. In the USA, Facts Up Front was launched in 2011 as a joint initiative of the Grocery Manufacturers Association and Food Marketing Institute in the absence of government-endorsed scheme[39]. This label shows energy per serving and information on three nutrients to limit in the diet: saturated fat, sodium and sugar, and possibly up to two positive nutrients if providing more than 10 % of the DRV per serving. In 2014, Australian and New Zealand governments have developed in collaboration with industry, public health and consumer groups the Health Star Rating system, ranking foods from half to five stars[40]. The algorithm driving the calculation accounts for energy, saturated fats, total sugars, sodium and cases-specific points allocated to positive nutrients: protein, fibres and the amount of fruit, nuts, vegetables and legumes. In France, in addition to the simplified nutrition labelling based on the SENS system, other nutrient-specific labels have been proposed and are presently tested in real-life conditions: the Traffic Light system as applied in the UK[38], an improved Guideline Daily Amounts (percentage of Guideline Daily Amounts) label[41] and a five-colour system derived from the UK Ofcom nutrient profiling model[42].

Derived from the SAIN,LIM system, the SENS presents the unique advantage of not combining the two indicators that account for qualifying and disqualifying nutrients, respectively. This allows a separate evaluation of the positive and negative aspects of each food considered individually. Modifications were made from the SAIN,LIM system to make it more operational for simplified labelling in Europe. Missing data in the algorithm computation could however hinder its implementation. Not all components used in the SENS are subject to the mandatory nutrition declaration, such as fibres, free sugars and the proportion of F&V. Information about content of vitamin C, calcium, MUFA and α-linolenic acid may also be required according to the food category which the product belongs to. However, it seems legitimate to ask for this information as adding these nutrients better reflects the nutrient density of specific foods. Besides, manufacturers are expected to have a good command of their recipes and should be able to provide information about nutritional specificity of their products.

Conclusion

The SENS system is an adapted version of the SAIN, LIM system, while addressing its shortcomings by integrating specificities of food categories, reducing the number of nutrients, ordering the four classes and introducing European reference intakes. Through the evolution from the French SAIN,LIM system to the SENS algorithm, this review shows how a nutrient profiling system can be adapted according to scientific knowledge, public health orientation and legislation. Food labelling schemes designed to help steer consumers' choice towards healthier products are derived from various nutrient profiling systems differing in terms of nutrients selection, grouping of food products, type of reference amounts and cut-off values. Despite WHO guiding principles manual for developing nutrient profiling, designing a relevant tool remains challenging and no system is perfect, making comparisons and decision difficult. Nevertheless, present nutrient profiling systems align with basic nutrition principles making them a valuable tool to support public health nutrition policies.

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Conflicts of Interest

None.

Authorship

N. D, V. A.-B. and M. M. developed the concepts presented in the manuscript. M. T. wrote the first draft of the manuscript. N. D. and M. M. contributed to writing of the manuscript and proposed critical comments. All authors approved the manuscript for publication. N. D. has primary responsibility for final content.

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