REVIEW

Development of a new front-of-pack nutrition label in France: the five-colour Nutri-Score

Chantal Julia[1,2], Serge Hercberg[1,2]

[1] Paris 13 University, Nutritional Epidemiology Research Team, Centre for Epidemiology and Biostatistics Sorbonne-Paris-Cité (CRESS), Bobigny, France

[2] Public Health Department, Avicenne Hospital (AP-HP), Bobigny, France

Corresponding author: Chantal Julia (email: c.julia@eren.smbh.univ-paris13.fr)

ABSTRACT

Background: The French Government recently announced the implementation of a novel front-of-pack nutrition label at the national level. The selected system, the Nutri-Score, is a five-coloured label developed by the Nutritional Epidemiology Research Team, an academic public research unit, and has been the object of scientific research for validation purposes.

Methods: The objective of this narrative review is to examine the existing literature on the development, validation and testing of the Nutri-Score. Elements of the validity of the nutrient profiling system underlying the label and the format of the label were investigated.

Results: Scientific evidence suggests that the British Food Standards Agency nutrient profiling system underlying the Nutri-Score front-of-pack label can adequately characterize the nutritional quality of foods, and that an individual score based on the weighted mean of the score of the foods consumed (the Food Standards Agency nutrient profiling system dietary index) can adequately summarize the nutritional quality of the diet. Moreover, a high dietary index (reflecting unhealthier diets) is associated with the onset of chronic diseases. Finally, the format of the Nutri-Score (and its former version, the five-colour nutrition label) appears to be well perceived and understood. The Nutri-Score was associated with a higher nutritional quality of purchases in experimental and large-scale trials.

Conclusion: Altogether, these elements provide evidence-based support for the implementation of the Nutri-Score in France. The research steps undertaken to examine the effects of the Nutri-Score could be used in other settings to help policy-makers considering the implementation of front-of-pack labels as a public health nutrition measure.

Keywords: FRONT-OF-PACK LABELLING, VALIDATION STUDIES, REVIEW, PUBLIC HEALTH POLICY

BACKGROUND

Industrialized countries face a major public health challenge in the form of the increasing burden of chronic diseases, influenced by the ageing of the population. Nutritional risk factors have been recognized as some of the main drivers of chronic diseases in the WHO European Region *(1–5)*. Low- and middle-income countries are also facing a rapid modification of dietary behaviours associated with increased risks of nutrition-related diseases, contributing to the rising burden of nutritional diseases worldwide *(6, 7)*. It is clear that nutrition represents a key lever to public health policies as it corresponds to a modifiable determinant of health that could be addressed through primary prevention interventions.

Given this challenge, worldwide government-led strategies and policies have introduced multifaceted interventions aiming to improve diets in the population *(8–12)*. Among the variety of possible interventions, front-of-pack nutrition labels have received growing attention from public authorities and learned societies *(11, 13)*. While back-of-pack nutritional labelling is now mandatory in most countries, only a fraction of consumers use it for food selection *(14)*. Conversely, front-of-pack nutrition labels are considered helpful guidance for consumers towards healthier food choices at the point of purchase, as they deliver at-a-glance nutritional information *(15–17)*. Such information can easily be incorporated into food choices in shopping environments, where consumers make food selections within an average of 35 seconds *(14)*. Moreover, it is thought to be an incentive for manufacturers to reformulate their products towards healthier composition, evidence of which would materialize on the front-of-pack label *(18, 19)*.

In Europe, front-of-pack labelling was initially introduced in the 1980s by Sweden and Denmark (Green Keyhole *(20)*) and in the 2000s in the Netherlands (Choices *(21)*) and the United Kingdom (Multiple Traffic Lights *(22)*). In 2014, New Zealand and Australia introduced the Health Star Rating System *(23)*. Finally, in 2016 Chile adopted warning symbols for each nutrient whose content is considered too high in foods. Parallel to these government-endorsed schemes, FoodDrinkEurope (representing private firms) developed the Guideline Daily Amounts (GDA) scheme, recently modified as the Reference Intakes scheme, which was introduced in 2006 as a voluntary initiative from manufacturers worldwide and appears as a front-of-pack nutrition label in numerous countries *(24)*. In the European Union (EU), regulations on food information to consumers *(25)* and on nutrition and health claims *(26)* determine the contours of front-of-pack nutrition labelling. In this legal framework, only voluntary schemes are currently possible.

France launched a public health nutrition policy in 2001: the *Programme National Nutrition Santé* [National Nutrition and Health Programme] (PNNS), which includes a combination of laws, regulations and incentives in the field of nutrition (diet and physical activity) aimed at improving the health status of the French population *(27, 28)*. A report commissioned by the Minister of Health from the president of the PNNS in 2014 relayed 15 new proposals to intensify the Programme's actions *(13)*, including the introduction of a front-of-pack nutrition label – the five-colour nutrition label (5-CNL).

Following the report, the principle of a simplified front-of-pack nutrition label was included in the health law discussed in 2015 *(29)*, which was voted on in Parliament in December 2016 and enacted in January 2017. The Nutri-Score (the definitive graphical version chosen after a test comparing different formats of the 5-CNL) was finally selected after comparison tests against several labels proposed by industry or retailers. Finally, in March 2017, the Nutri-Score was announced by the Minister of Health as the official front-of-pack nutrition label for France, and a notification was sent to the EU the following month. Between the proposal in 2013 and the actual selection of the Nutri-Score in 2017, the Nutritional Epidemiology Research Team at the University of Paris 13 (authors of this paper and developers of the scheme) conducted multiple studies on the Nutri-Score/5-CNL. Moreover, as part of a large consultation plan including scientists, retailers and industry representatives, under the umbrella of the Ministry of Health, a large-scale in-store trial and an experimental study were conducted. The in-store trial was conducted in partnership with economic actors.

The Nutri-Score/5-CNL relies on the computation of a nutrient profiling system, derived from the United Kingdom's Food Standards Agency nutrient profiling system (FSA-NPS), which was developed by OfCom to regulate television advertising to children *(30–32)*. The FSA-NPS is computed by using the nutrient content per 100 g for food and beverages. It allocates positive points (0–10) for energy (kJ), total sugar (g), saturated fatty acids (g) and sodium (mg) content. Negative points (0–5) are allocated for fruit, vegetables and nuts, fibre and protein content. The score is therefore based on a discrete continuous scale from −15 (most healthy) to +40 (least healthy) (Fig. 1). For the Nutri-Score, five categories of nutritional quality are derived from green to red (Fig. 2). The number of categories was selected to ensure a high discriminating power within food groups, while maintaining a central category in order to avoid dichotomous thinking – ascribing foods as bad or good. Letters were added to colours in order to improve the readability of the label.

This paper presents the various studies conducted in France prior to the selection of the Nutri-Score as its front-of-pack nutrition label to provide policy-makers with a framework for informed decisions. In particular, the methodology used to validate the various elements of the Nutri-Score could be replicated in other settings considering the implementation of a front-of-pack nutrition label.

METHODS

SELECTION OF STUDIES

Articles selected for this review included studies conducted in France pertaining to both the nutrient profiling system underlying the Nutri-Score/5-CNL and its derived dietary index (the FSA-NPS dietary index) and the graphical format of the label. Results of studies conducted under the umbrella of the Ministry of Health in 2016 as part of the consultation process were also included, although they were published in the form of reports.

Considering that data were not collected using strict systematic research terms, this paper is presented as a narrative review. However, *a posteriori* verifications in PubMed and ISI Web of Knowledge showed that all indexed published articles referring to the Nutri-Score/5-CNL were included. These were performed using the broad search terms, "nutrient profiling system", "front-of-pack labelling", "Nutri-Score", "5-colour nutrition label", "Food Standards Agency nutrient profiling system" and, "FSA-NPS dietary index", and were restricted to France. Some reports

FIG. 1. DETAILED COMPUTATION OF THE NUTRI-SCORE/5-CNL LABEL

1. ATTRIBUTION OF POINTS, BASED ON THE CONTENT OF NUTRIENTS AND OTHER ELEMENTS PER 100 G OF A FOOD/ BEVERAGE

Points A			Specific cut-offs: **beverages**			Specific cut-offs: **fats**	
Points	Energy (kJ)	Sugars (g)	Energy (kJ)	Sugars (g)	Saturated fat (g)	Saturated fat/lipids (%)	Sodium (mg)
0	≤ 335	≤ 4.5	≤ 0	≤ 0	≤ 1	< 10	≤ 90
1	> 335	> 4.5	≤ 30	≤ 1.5	> 1	< 16	> 90
2	> 670	9	≤ 60	≤ 3	> 2	< 22	> 180
3	> 1005	> 13.5	≤ 90	≤ 4.5	> 3	< 28	> 270
4	> 1340	> 18	≤1 20	≤ 6	> 4	< 34	> 360
5	> 1675	> 22.5	≤ 150	≤ 7.5	> 5	< 40	> 450
6	> 2010	> 27	≤ 180	≤ 9	> 6	< 46	> 540
7	> 2345	> 31	≤ 210	≤ 10.5	> 7	< 52	> 630
8	> 2680	> 36	≤ 240	≤ 12	> 8	< 58	> 720
9	> 3015	> 40	≤ 270	≤ 13.5	> 9	< 64	> 810
10	> 3350	> 45	> 270	> 13.5	> 10	≥ 64	> 900
	0–10 (a)	**0–10 (b)**	**0–10 (a)**	**0–10 (b)**	**0–10 (c)**	**0–10 (c)**	**0–10 (d)**
Total	**Points A = (a) + (b) + (c) + (d) [0–40]**						

		Specific cut-offs: **beverages**	Points C	
Points	Fruit, vegetables (%)	Fruit, vegetables (%)	Fibre (g)	Protein (g)
0	≤ 40	≤ 40	≤ 0.7	≤ 1.6
1	> 40	–	> 0.7	> 1.6
2	> 60	> 40	> 1.4	> 3.2
3	–	–	> 2.1	> 4.8
4	–	> 60	> 2.8	> 6.4
5	> 80	–	> 3.5	> 8.0
6	–	–	–	–
7	–	–	–	–
8	–	–	–	–
9	–	–	–	–
10	–	>80	–	–
	0–5 (a)	**0–10 (a)**	**0–5 (b)**	**0–5 (c)**
Total	**Points C = (a) + (b) + (c) [0–15]**			

2. FINAL SCORE:
–15 TO 40 POINTS

Points A ≥11
- **Fruit and vegetables points = 5** → **Final score = Points A – Points C**
- **Fruit and vegetables points < 5** → **Final score = Points A – (fibre points + fruit and vegetables points)**

Points A < 11 or for cheese → **Final score = Points A – Points C**

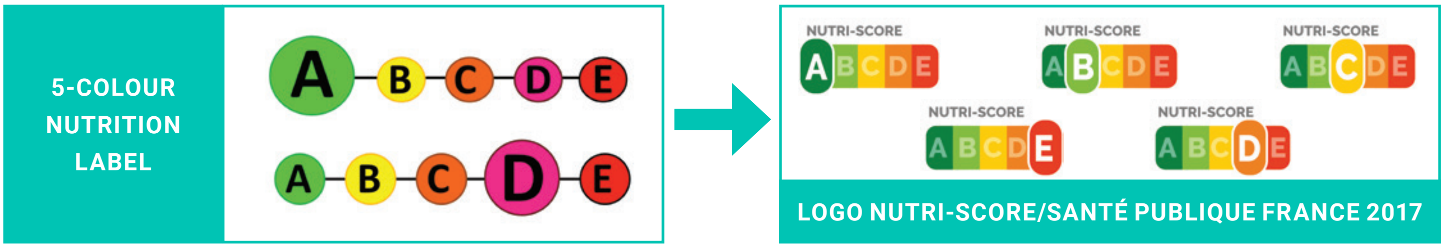
3. ATTRIBUTION OF COLOURS

Foods (points)	Beverages (points)	Colour
Min to −1	Water	Dark green
0 to 2	Min to 1	Light green
3 to 10	2 to 5	Yellow
11 to 18	6 to 9	Light orange
19 to max	10 to max	Dark orange

NUTRI-SCORE A B C D E

Dark green: highest quality **Dark orange: lowest quality**

FIG. 2. NUTRI-SCORE AND ITS FORMER GRAPHICAL FORMAT, THE 5-CNL



or publications in French in non-indexed journals or in journals in other fields of research than medicine (such as marketing research) may have been omitted.

OUTCOMES OF RELEVANCE

The selection of outcomes of relevance was performed using theoretical frameworks published in the literature and pertaining to either the validation of a nutrient profiling system or the selection of a front-of-pack nutrition label (referred to as the validation of the graphical format).

The theoretical framework laid by Townsend *(33)* suggests that the validation of a nutrient profiling system undergoes three phases: analysis of the classification of foods against a benchmark that can be either expert agreement or national dietary recommendations; assessment of the capacity of the nutrient profile to measure diet quality adequately in the individual; and the prospective association of the individual dietary index with health outcomes.

A theoretical framework to describe the various stages involved in the use of front-of-pack nutrition labels in purchasing situations was proposed by Grunert & Wills in 2007 *(34)*. This states that to be efficient a front-of-pack nutrition label needs to attract the consumer's attention, to be favourably perceived and to be understood before it can be used in a purchasing situation.

Following selection of the theoretical frameworks, the outcomes of relevance considered in this review for the nutrient profiling system were classification of foods, characterization of the individual diet and associations with health outcomes. Outcomes of relevance for the graphical format included consumer perception and understanding of the label, as well as use in purchasing situations.

VALIDATION OF THE FSA-NPS IN THE FRENCH CONTEXT

The studies on the nutrient profiling system underlying the French front-of-pack label included all three stages of validation set out in Townsend's theoretical framework: classification of foods, characterization of the individual diet and prospective association with health outcomes *(33)*.

CLASSIFICATION OF FOODS

The ability of the FSA-NPS to classify foods adequately in the French environment and to serve as a basis for a five-category label was evaluated through the application of the FSA-NPS to several food composition databases, including both "generic" foods usually consumed in France and branded products as sold *(35–37)*. Application of the FSA-NPS to the French NutriNet-Santé food composition database *(37)*, which includes generic foods usually consumed in the French diet, aimed to investigate the overall classification of foods in comparison with French food-based dietary recommendations. It also evaluated the ability to derive five categories of nutritional quality of foods from this classification, which would be used to define the cut-offs for the five colours of the 5-CNL (using quintiles of distribution).

Overall, classification of foods was consistent with nutritional recommendations: fruit and vegetables were consistently classified with higher nutritional quality than sugary and salty snacks: 82.41% of fruit and vegetables were in the first quintile of distribution, whereas 32.57% and 21.97% of "sugary snacks" were in the fourth and fifth quintile of distribution, respectively. Moreover, wide variability was observed within food groups; this allowed for discrimination of nutritional quality both across groups of foods and within a food group. However, for some food groups (cheese, beverages and added fats) the application of five categories of nutritional quality was not consistent. For cheese, the protein component – a proxy for calcium – was not taken into account, although cheese is a major source of calcium in the population *(38)*; for beverages, the narrow distribution of the score did not allow identification of five consistent categories; for added fats, the distribution in the original score did not allow discrimination between animal and vegetable added fats.

The FSA-NPS was next applied to a food composition database reflecting foods as sold in France: the Open Food Facts database *(35)*. This allowed the feasibility of application of the 5-CNL to be tested using directly available data on the composition of branded foods. The discriminatory capacity of the 5-CNL at different levels of detail (across food groups, within food groups and across brands for equivalent foods) was assessed. Moreover, adaptations to the initial algorithm were proposed in order to ensure maximal consistency between the classification of foods using the FSA-NPS and French dietary recommendations.

The discriminatory capacity of the 5-CNL was similar to that observed with the NutriNet-Santé food composition table across food groups, within food groups and to a lower extent for equivalent foods from different brands. Limitations to the original algorithm were identified for the same groups: cheese, beverages and added fats. The modifications proposed in those cases to the original FSA-NPS algorithm were shown to improve the discriminatory capacity of the 5-CNL and optimize its consistency with French recommendations. Modifications consisted of adaptations to the grids for saturated fatty acids for fats and for energy and sugars for beverages and modification of the final algorithm (taking protein into account) for cheese.

Finally, use of the 5-CNL was also investigated in a large specific group of foods (breakfast cereals), using data collected from the Internet and supermarkets (N=380) *(36)*. The discriminatory capacity of the 5-CNL was considered high in breakfast cereals, as all types of cereal were classified in at least three categories. It was also high for similar cereals from different brands, as these were also distributed in at least three categories.

Overall, these results tend to substantiate the possible use of the FSA-NPS as a basis for a five-category labelling system. However, as the FSA-NPS was initially developed to be used as a binary indicator, even if it was well adapted for most food groups, some limitations to the score became apparent during the transposition process to a labelling system that employs a five-point spectrum. These limitations were confirmed in a report by the French Agency for Food, Environmental and Occupational Health and Safety *(39)*. The French High Council of Public Health, an independent agency providing collective expertise in the field of public health for policy-makers, was commissioned to improve the precision of the algorithm thresholds defining

TABLE 1. ASSOCIATION BETWEEN FSA-NPS DIETARY INDEX AND DIETARY INTAKES IN VARIOUS POPULATIONS

	NutriNet-Santé study, N=4225			SU.VI.MAX study, N=5882			ENNS study, men N=1014			ENNS study, women N=1740		
	FSA-NPS dietary index			FSA-NPS dietary index			FSA-NPS dietary index			FSA-NPS dietary index		
	Healthier (Quartile 1)	Poorer (Quartile 4)	p-trend across quartiles	Healthier (Quartile 1)	Poorer (Quartile 4)	p-trend across quartiles	Healthier (Quartile 1)	Poorer (Quartile 4)	p-trend across quartiles	Healthier (Quartile 1)	Poorer (Quartile 4)	p-trend across quartiles
Energy intake (kcal/day)	1783	2103	< 0.001	1842	2137	< 0.001	2135	2650	< 0.001	1538	1844	< 0.001
Lipids (%)	33.4	44.4	< 0.001	36.3	44.2	< 0.001	34.7	42.4	< 0.001	34.7	42.7	< 0.001
Carbohydrates (%)	46	39.5	< 0.001	44.4	38.8	< 0.001	46.2	41.6	< 0.001	44.7	41.5	< 0.001
Protein (%)	20.1	15.9	< 0.001	19.3	17	< 0.001	19.1	16	< 0.001	20.5	15.8	< 0.001
Simple sugars (g/day)	102	90.2	< 0.001	102.6	86.5	< 0.001	105.7	116.8	0.02	86.5	90.8	NS
Calcium (mg/day)	996	904	< 0.001	1019	921	< 0.001	1056.3	1079	0.01	972	817.3	0.001
Sodium (mg/day)	3425	3535	0.007	3448	3517	< 0.001	3446	3359	NS	2430	2267	0.001
Iron (mg/day)	15.5	12.4	< 0.001	13.3	12.5	< 0.001	16	13.5	< 0.001	12.7	10.5	< 0.001
β-carotene (µg/day)	4181	2628	< 0.001	4616	3354	< 0.001	3211	2117	< 0.001	3543.6	2034.7	< 0.001
Folate (µg/day)	395	280	< 0.001	337	294	< 0.001	371.1	258.8	< 0.001	337.6	230.1	< 0.001
Vitamin C (mg/day)	144	90.4	< 0.001	112	79.01	< 0.001	123.5	71.3	< 0.001	117.4	77.3	< 0.001
Vitamin D (µg/day)	3.17	2.53	< 0.001	2.87	2.72	0.04	2.88	2.24	0.02	2.22	2.02	NS
Fibre (g/day)	24.9	15.6	< 0.001	22.36	16.39	< 0.001	24.3	14.3	0.001	20.2	12	< 0.001

Notes: NutriNet-Santé study models adjusted for sex, age and energy intake. SU.VI.MAX models adjusted for sex, age and energy intake. ENNS models adjusted for energy intake.

Sources: adapted from Julia et al. ***(42)***; Deschamps et al. ***(44)***; Julia et al. ***(45).***

the five colours and to make necessary adaptations of the FSA algorithm for cheese, added fats and beverages *(40)*.

These elements suggest that the FSA-NPS is a useful basis for labelling purposes, with a computation using an across-the-board approach, but some limited adaptations to the local food supply can be necessary to ensure its consistency. Moreover, these results show that the FSA-NPS applied to a five-category labelling system reveals wide variability in nutritional quality of foods in the same category. This characteristic could help consumers make healthier choices through substitutions of foods, without modification of the structure of the diet.

All studies pertaining to the classification of foods using the FSA-NPS used nutritional recommendations as a benchmark to assess the consistency of the classification. No specific gold standard has been established to evaluate the consistency of nutrient profiling systems. Approaches considered in the literature include the use of expert grading or nutrition recommendations. Expert panels have been criticized for being prone to some biases, depending on the selection or the experts, while nutritional recommendations vary across countries, hindering potential comparisons across countries *(33)*. Some recommendations classify foods as core or discretionary, thereby providing a benchmark for the discrimination that should be achieved using a nutrient profiling system *(41)*. Nevertheless, though such a benchmark is highly suitable for use as a dichotomous assessment, it appears less operative in the case of a graded assessment. Overall, the use of nutritional recommendations as a comparison for FSA nutrient profiling appears to be a validated approach, although the use of multiple outcome measures, such as expert grading, would strengthen the results.

CHARACTERIZATION OF THE INDIVIDUAL DIET

The FSA-NPS, which characterizes the nutritional quality of foods, was transposed into an individual indicator reflecting the overall nutritional quality of the diet. The FSA-NPS dietary index was developed as the energy-weighted mean of the FSA-NPS of the foods consumed *(42)*. As with the FSA-NPS of foods, a higher FSA-NPS dietary index reflects lower nutritional quality of the foods consumed in the overall diet. The FSA-NPS dietary index was validated against food consumption, nutrient intake and biomarkers of nutritional status in three French studies: in a representative sample of the French population randomly selected from the NutriNet-Santé study (N=4225) *(42)*, in the French *Supplémentation en Vitamines et Minéraux AntioXydants* (SU.VI.MAX) cohort study (N=5882) *(43)* and in the representative population-based *Etude Nationale Nutrition Santé* (ENNS) cross-sectional study (N=2754) *(44)*.

In all three studies, higher FSA-NPS dietary index (reflecting a lower nutritional quality of the diet) was associated with higher consumption of sweet, fatty and salty foods and lower consumption of fruit, vegetables, fish and whole grains *(42)*. It was also associated with higher energy intake, higher intake of saturated fats and added sugar, and lower intake of polyunsaturated fatty acids, fibre, vitamins and minerals (Table 1). Subjects with higher FSA-NPS dietary index were more likely to be men, younger and smokers, and to have lower incomes. In the SU.VI.MAX study, FSA-NPS dietary index was associated with lower levels of low-density lipoprotein cholesterol and antioxidant biomarkers (selenium, beta-carotene and vitamin C) *(43)*.

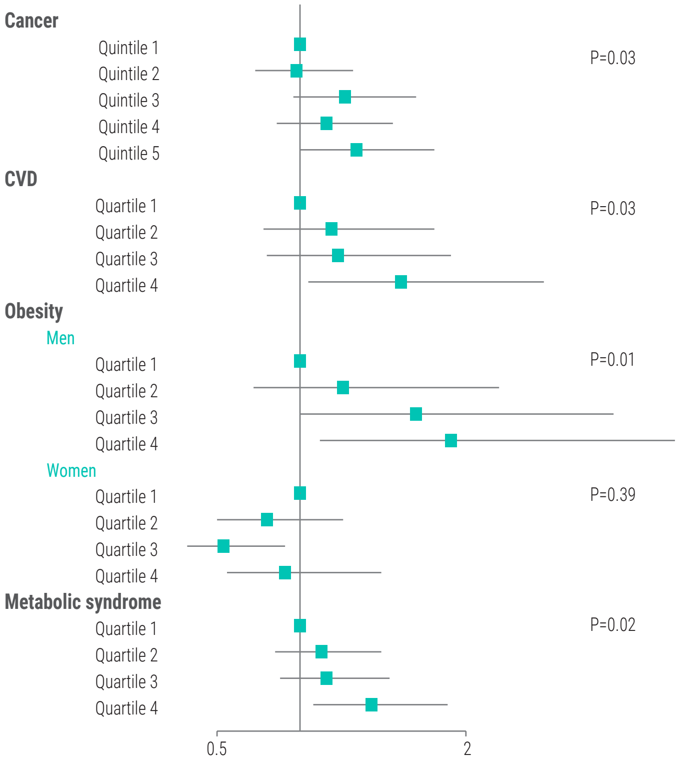
Similar results were found in a study using data from the British National Diet and Nutrition Survey *(46)*. Using a dietary indicator equivalent to the FSA-NPS dietary index, the authors showed that subjects with diets of poorer quality were more likely to be male and younger and to have higher body mass indexes. Moreover, they also consumed lower amounts of fruit, vegetables and fish, and higher amounts of meat or meat-based products and fats.

PROSPECTIVE ASSOCIATIONS WITH HEALTH OUTCOMES

The prospective associations between FSA-NPS dietary index and health outcomes were investigated in two large French cohorts: the SU.VI.MAX and the NutriNet-Santé cohort study. The outcomes investigated were cancer (specifically breast cancer in the NutriNet-Santé study), cardiovascular disease (CVD), metabolic syndrome and weight gain *(47–52)*. A synthesis of the observed associations in the SU.VI.MAX cohort is shown in Fig. 3.

Overall, poorer diets as expressed by the FSA-NPS dietary index were associated with a higher risk of developing a chronic disease in both cohorts. For example, the odds ratio of quartile four of the FSA-NPS dietary index (less healthy) versus quartile one (healthier) was 1.43 (95% confidence interval (CI): 1.08–1.89) for the onset of metabolic syndrome and 1.61 (95% CI: 1.06–2.43) for overweight and obesity in men in the SU.VI.MAX cohort. In particular, consistent associations were found in both studies for CVD and cancer: for CVD, a hazard ratio of 1.14 (95% CI: 1.03–1.27) was observed for a one point increment in the FSA-NPS dietary index in the SU.VI.MAX study, while the hazard ratio was 1.08 (95% CI: 1.03–1.13) in the NutriNet-Santé study; for cancers, the hazard ratio for a one point increment was 1.08 (95% CI: 1.01–1.15) in the SU.VI.MAX study and 1.06 (95% CI: 1.02–1.11) for breast cancer in the NutriNet-Santé study. Similar results were found in the Whitehall cohort study using another indicator of the nutritional quality of the diet, based on the FSA-NPS of foods *(53)*.

FIG. 3. PROSPECTIVE ASSOCIATIONS (ODDS RATIO AND 95% CONFIDENCE INTERVAL) BETWEEN FSA-NPS DIETARY INDEX AND HEALTH OUTCOMES IN THE SU.VI. MAX COHORT STUDY



Notes: The cancer model was adjusted for age, sex, intervention group of the initial SU.VI.MAX trial, number of 24-hour dietary records, smoking status, educational level, physical activity, body mass index, family history of overall cancer and alcohol intake.
The CVD model was adjusted for age, sex, intervention group of the initial SU.VI. MAX trial, number of 24-hour dietary records, smoking status, educational level, physical activity, body mass index, family history of CVD, energy intake without alcohol and alcohol intake.
The obesity model was adjusted for age, sex, energy intake, number of 24-hour dietary records, alcohol intake, education, supplementation group, physical activity and smoking status.
The metabolic syndrome model was adjusted for age, sex, education, physical activity, smoking status, supplementation group, energy intake, number of 24-hour dietary records, alcohol intake and the delay between baseline and last follow-up examination.
The P values reported correspond to P for linear trend across quartiles or quintiles of FSA-NPS dietary index, depending on the type of analysis.

The literature suggests that validation of a nutrient profiling system needs to provide evidence not only on the classification of foods but also, and more importantly, on the capacity of the system to characterize diets adequately, and to be associated with health outcomes in the long term *(33)*. This step of transposing a nutrient profiling system of foods to individual diets is highly recommended, as it allows one of the major criticisms of nutrient profiling systems to be overcome: that they focus on individual foods and not the overall quality of diets. Furthermore, investigation of prospective associations between an individual dietary index based on a nutrient profiling system and health outcomes provides insights as to the predictive performance of the system, which is of high importance to policy-makers. Indeed, these consistent results support the contention that the nutritional quality of the diet, expressed through the nutritional quality of the foods consumed using the FSA-NPS, is associated with health outcomes in the long term. These results tend to support the use of the FSA-NPS as a basis for public health initiatives, showing that improvements in the nutritional quality of foods consumed would help prevent chronic diseases.

To the authors' knowledge, other than the Nutri-Score/5-CNL, only the NuVal system (associated with the individual dietary index Overall Nutritional Quality Index) has been shown to be associated with health outcomes in observational prospective cohort studies (namely total chronic diseases, overall mortality, CVD and diabetes, but not cancer) *(54)*. However, the NuVal system relies on a proprietary nutrient profiling system algorithm, which hinders the capacity of researchers to replicate the results *(55)*. Moreover, the NuVal computation requires extensive information on the nutritional composition of foods (including vitamin, mineral and even polyphenol contents); this renders it less operational for labelling purposes, given the cost of the required measurements at the food level *(56)*.

The development of an individual index based on a nutrient profiling system is a complex undertaking. First, the individual index derived from the nutrient profiling system would need to account for risks associated with intakes below nutritional requirements as well as above. This may be complex in the case of nutrient profiles based on a percentage of average requirements, for which transposition to individual indexes may cap contributions at 100% and therefore omit accounting for risks associated with intakes above this threshold *(57)*. Second, the weightings used to transpose data from foods to diets may include weight of the foods or energy provided by the foods, or may use a threshold of healthy/unhealthy foods, thereby deriving a proportion of healthy foods in the diet. Use of the weight of the foods tends to give a higher importance to foods consumed in high amounts, such as water, starchy foods or fruit and vegetables. Conversely, use of the energy provided by the foods tends to give a higher importance to energy-dense foods. Finally, the use of a threshold may somewhat reduce the variability of the nutritional quality of the foods consumed. In the case of the FSA-NPS dietary index, the development procedure with the selection of the weighing was described in detail, facilitating replication in other settings *(42)*. The prospective associations with health outcomes were explored in two different cohort studies, with consistent results, which tend to demonstrate the predictive performance of the system. However, no study directly explored associations with mortality, which would have strengthened the results. Moreover, studies were conducted in French cohorts. Validation studies exploring associations in other countries in the WHO European Region – such as in the European Prospective Investigation into Cancer and Nutrition cohort – would have allowed a wider perspective on the validity of the nutrient profiling system.

PERCEPTION, UNDERSTANDING AND USE OF FRONT-OF-PACK NUTRITION LABELS

THEORETICAL FRAMEWORK

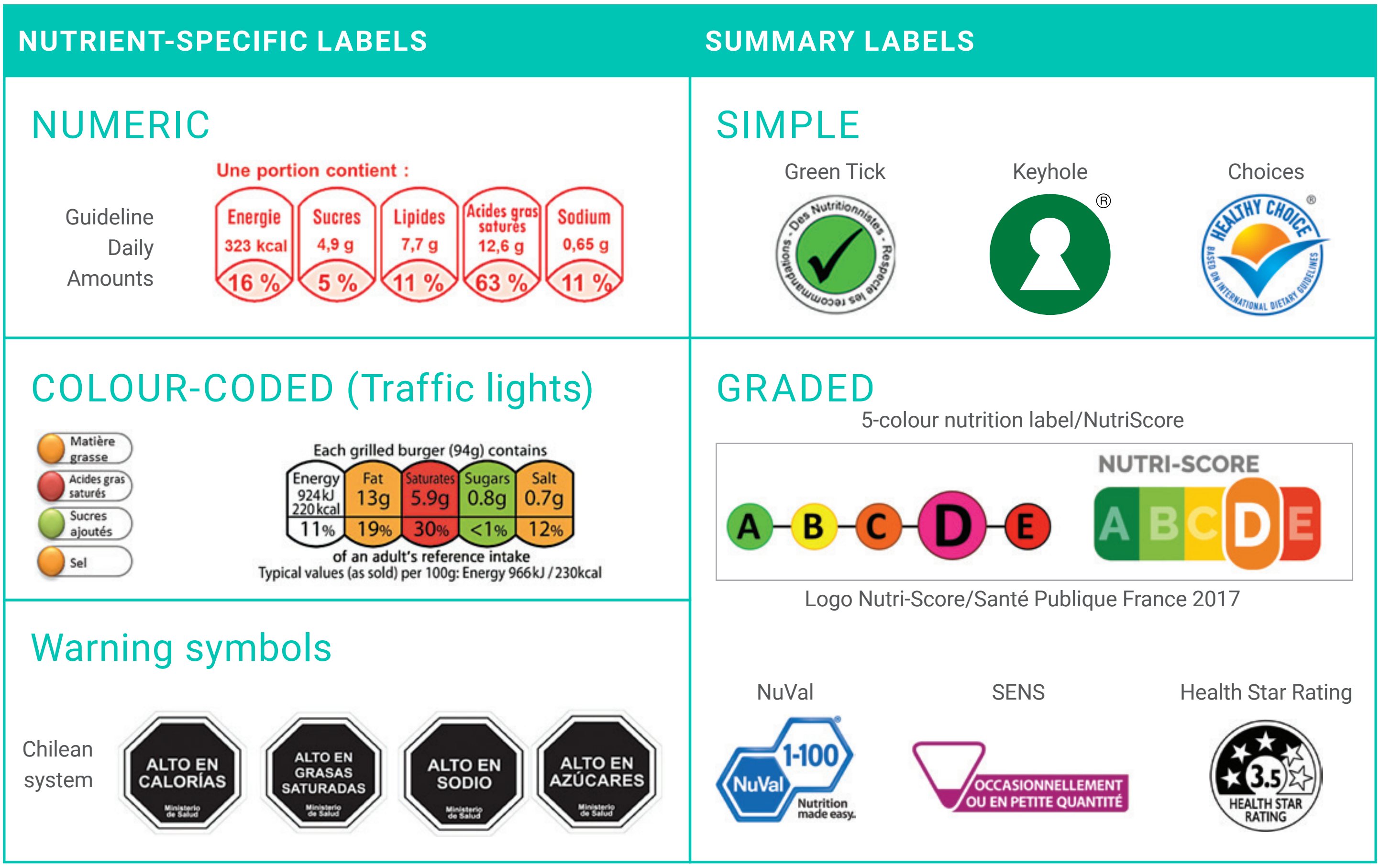
The various formats of the front-of-pack nutrition label currently in use throughout the world can be organized into two main categories: nutrient-specific and summary indicators. In the nutrient-specific category, two main formats appear: numerical (such as the Reference Intakes format) and colour-coded (such as the Multiple Traffic Lights format). A novel format developed in South America corresponds to warning symbols, which are affixed on foods depending on their levels of certain nutrients (as with the Chilean system). Summary labels can also be subdivided into two main categories: endorsement schemes (such as the Choices or Green Keyhole schemes), which are applied only to products with higher nutritional quality in a given food category, and graded indicators, which appear on all products and provide a global and graded information on the nutritional quality of the product (such as the Nutri-Score or the Australian Health Star Rating System). Examples of formats of front-of-pack nutrition labels based on these categories are presented in Fig. 4.

The Nutri-Score/5-CNL was assessed directly using the theoretical framework created by Grunert et al. *(34)*, and all the steps identified in the framework were explored: perception, understanding and use in purchasing situations.

PERCEPTION AND OBJECTIVE UNDERSTANDING

The prerequisites for label use – perception and understanding – were assessed in participants in the NutriNet-Santé cohort study, using self-administered questionnaires *(58, 59)*. Four formats were compared, each corresponding to a specific type of

FIG. 4. TYPES OF FRONT-OF-PACK NUTRITION LABEL IN USE WORLDWIDE



Note: the circled images were used in the comparative study on perception, understanding and use of front-of-pack systems.

front-of-pack label: nutrient-specific numeric (GDA), nutrient-specific colour-coded (Multiple Traffic Lights), endorsement scheme (Tick, similar to the Nordic Green Keyhole and the Dutch Choices) and graded summary (5-CNL, the former graphical format for the Nutri-Score).

Several dimensions of perception were explored: liking, attractiveness and perceived cognitive workload. The 5-CNL label was the easiest to identify and the most likely to be found easy and quick to understand. The GDA label was considered the least easy to identify and the one entailing the heaviest cognitive workload in both complexity and processing time *(59)*. Over half of the participants reported that none of the presented labels made them uncomfortable.

A second study on the perception of front-of-pack labels compared the Nutri-Score to labels proposed in the French debate on front-of-pack labelling. Similar results were found: the Nutri-Score had the highest support in the population in general (preferred format on a set of variables for 43% of the sample) and more particularly in subjects with low adherence to nutritional recommendations *(60)*.

Objective understanding was assessed by asking participants to rate the nutritional quality of three products based on the information provided by the front-of-pack system. Compared to not having a label, all labels significantly increased the likelihood of correctly ranking the products. Overall, the 5-CNL was the most effective label (64.6% of correct answers), followed by the Multiple Traffic Lights (56.4%), GDA (50.2%) and Tick (29.4%) labels *(59)*. The likelihood of correctly ranking products according to the information provided was significantly higher for the 5-CNL, followed by the Multiple Traffic Lights and GDA and the Tick labels *(58)*. In particular, in populations at risk of having less healthy diets, the odds ratio of correctly ranking products with the 5-CNL compared to a control situation ranged from 9.91 (95% CI: 8.91–11) for subjects with up to secondary-level education to 20.2 (95% CI: 13.2–31.1) for subjects with no perceived nutrition knowledge.

The studies conducted on the Nutri-Score/5-CNL used a comparative assessment of various graphical formats of front-of-pack labels. This is important to disentangle the effects associated with any front-of-pack label from the effects of specific front-of-pack labels. However, the studies did not include a qualitative assessment of the label, which would have allowed investigation of consumers' interpretations of the various features of the label. In particular, investigation of the healthiness of products assessed using the Nutri-Score/5-CNL would have provided insights into consumers' interpretation. Moreover, studies were conducted in the NutriNet-Santé cohort study, which includes adults volunteering to provide long-term nutritional information. The study population is thus subject to selection bias and, in particular, participants may be more aware of nutritional issues and favourable to nutrition labelling. Replication of the studies using different recruitment methodologies, and more specifically including vulnerable populations, would be of importance to generalize results.

USE IN PURCHASING SITUATIONS

Use of the label on consumer purchasing intentions was evaluated in several studies, using various types of methodology. First, a randomized study with an experimental online supermarket comparatively assessed the impact of four types of label (5-CNL, Multiple Traffic Lights, GDA and Check) in the NutriNet-Santé study (N=11 981). Among the various formats tested, the 5-CNL significantly led to the lowest FSA-NPS scores — that is, the highest nutritional quality of the selected items in the shopping cart (FSA mean score: 8.72±2.75) — followed by Multiple Traffic Lights (8.97±2.68) and Tick (8.99±2.71), compared with the control (9.34±2.57) *(61)*. Notably, no effect was observed in the number of items purchased or the price of the shopping cart.

An experimental study using a physical experimental supermarket (N=901) found that implementation of the 5-CNL, combined with a leaflet explaining the purpose and use of the label, was associated with a higher nutritional quality of purchased sweet biscuits. No significant effect was observed for breakfast cereals or appetizers *(62)*. Again, no effect was observed on the number of items purchased.

Two studies using an experimental economy design found that the Nutri-Score was associated with the highest improvement in the nutritional quality of the shopping cart. The first study (N=255) compared the Nutri-Score to Multiple Traffic Lights and Reference Intakes, while the second (N=691) compared it to the Health Star Rating system, Multiple Traffic Lights, *Système d'Etiquetage Nutritionnel Simplifié* (SENS) (a format proposed by retailers) and a modified version of the Reference Intakes *(63, 64)*. In both studies, the Nutri-Score performed best at improving the nutritional quality of the purchased items, followed by Multiple Traffic Lights. In the second study, the nutritional quality of the shopping cart was improved by 9.3% for Nutri-Score, 6.6% for the Health Star Rating System and 4.8% for Multiple Traffic Lights *(65)*. Moreover, the Nutri-Score performed best in households with the lowest income.

Finally, a large-scale trial in real conditions was performed in 60 supermarkets: 10 for each of the four proposed labels (Nutri-Score, Multiple Traffic Lights, SENS and the modified

Reference Intakes) and 20 controls. The first results showed that the Nutri-Score was associated with the largest improvement in the nutritional quality of the purchased items, followed by Multiple Traffic Lights and SENS. Moreover, the Nutri-Score was associated with an improvement in all subgroups of the population (in particular subjects buying discount brands), while other formats led to mixed results, with the nutritional quality of their purchased items deteriorating among some subgroups *(66)*.

The studies conducted in France used various methodologies, combining experimental designs, randomized trials on experimental platforms and a large-scale trial. Overall, all studies provided consistent results, strengthening the validity of the Nutri-Score/5-CNL as a front-of-pack nutrition label. Such consistent results suggest that the use of experimental designs may be appropriate, and that large-scale trials may not be necessary. Indeed, implementation of large-scale trials is challenging, as they require extensive participation of economic actors and are hindered by very high logistic costs (€2 million for the supermarket trial in France). Although large-scale real-life trials yield insights as to the actual use of a front-of-pack label by consumers, they may be considered too constraining to implement. Experimental designs may therefore be considered viable options for policy-makers, with valid results.

CONCLUSION

The Nutri-Score (5-CNL) front-of-pack nutrition label was developed based on current knowledge pertaining to front-of-pack systems *(13)*. Reviews underlined the need for scientific validations of front-of-pack nutrition labelling systems *(14, 16, 34)*. In the case of summary systems, validation pertains to two aspects of the front-of-pack label: the nutrient profiling system underlying the label *(33)* and the actual format *(34)*. The series of studies presented herein and evaluating the Nutri-Score/5-CNL provide evidence as to these two aspects of the validation process.

In particular, transposition of the nutrient profiling system from foods to diets provides very useful information about the extent to which the model may be considered a valid measure of nutritional quality, as it widens the validity of the profile to overall diets. Such transposition is rarely performed, and studies in this specific area should be encouraged whenever possible.

As to the format of front-of-pack nutrition labels, the reviews all stressed the importance of following a theoretical framework and providing evidence on perception, understanding and use of a label. Moreover, very few studies allowed for comparisons across label formats, hindering the capacity to order the various systems in terms of effectiveness in the population. In this aspect, the studies described here provide comparative information pertaining to perception understanding and use, emphasizing the potential of the Nutri-Score/5-CNL as an effective tool to help consumers make healthier food choices, more specifically in the French context. In particular, the Nutri-Score/5-CNL appears to have a positive impact in disadvantaged populations, as shown in the subgroup analyses investigated in the various studies.

The development of the Nutri-Score/5-CNL front-of-pack nutrition labelling system was associated with validation studies on the various aspects of the label, giving strong scientific support to a public health nutrition initiative, prompting its adoption at the national level in France. Moreover, validation studies were conducted by independent research teams, with publications in peer-reviewed journals, which may help disseminate the results and replicate the developmental phases of the label in other settings considering implementation of a front-of-pack label. This approach appears somewhat unique, as in most cases research is undertaken after the implementation of a front-of-pack label. The French experience would appear to be useful for policy-makers considering implementing a front-of-pack nutrition label.

Adoption of the Nutri-Score in France will depend on the scheme's uptake by retailers and manufacturers, as it can only be voluntary, based on EU regulations. Societal demand for a simplified front-of-pack nutrition label is growing: a petition on the platform change.org supporting the Nutri-Score received more than 250 000 signatures, and a second petition asking retailers and manufacturers to adopt the scheme on the same platform received more than 44 000 signatures. After a notification to the EU Commission, the decree backing the Nutri-Score was finally signed on October 31st, 2017 by the Ministers of Health, Agriculture and Economy and finance. So far, three large retailers and three manufacturers have agreed in a voluntary commitment charter to implement the Nutri-Score across all their products. Early adoption by large companies may prompt others to join the scheme in the near future.

This uptake by companies needs to be accompanied by large communication campaigns targeting the population, so that consumers understand and use the system in their food choices. Moreover, however efficient the Nutri-Score might be in helping consumers make healthier choices at the point of purchase, a front-of-pack nutrition label can only be one of many interventions aimed at tackling obesity and chronic diseases in the framework of a larger prevention programme.

Conflicts of interest: None declared.

Disclaimer: The views expressed in this publication are those of the authors alone, and do not necessarily represent the decisions or policies of World Health Organization.

Authorship contribution: CJ and SH analysed the data and drafted and revised the paper. All authors had full access to all the data in the study and can take responsibility for the integrity of the data. All authors read and approved the final manuscript.

ABBREVIATIONS

5-CNL	five-colour nutrition label
CVD	cardiovascular disease
ENNS	Etude Nationale Nutrition Santé
EU	European Union
FSA	Food Standards Agency
GDA	Guideline Daily Amount
NPS	nutrient profiling system
PNNS	Programme National Nutrition Santé [National Nutrition and Health Programme]
SENS	Système d'Etiquetage Nutritionnel Simplifié
SU.VI.MAX	Supplémentation en Vitamines et Minéraux AntioXydants

REFERENCES

1. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012; 380:2224–60.
2. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. Geneva: World Health Organization; 2000 (WHO Technical Report Series 894; http://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/, accessed 15 November 2017).
3. Diet, nutrition and the prevention of chronic diseases. Report of a joint WHO/FAO expert consultation. Geneva: World Health Organization; 2003 (WHO Technical Report Series 916; http://www.who.int/nutrition/publications/obesity/WHO_TRS_916/en/, accessed 15 November 2017).
4. Global strategy on diet, physical activity and health. Geneva: World Health Organization; 2004 (WHA57.17; http://www.who.int/nmh/wha/59/dpas/en/, accessed 15 November 2017).
5. Global health risks: mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization; 2009 (http://apps.who.int/iris/handle/10665/44203, accessed 15 November 2017).
6. GBD 2016 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017; 390:1345–422.
7. Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2020. Geneva: World Health Organization; 2013 (http://www.who.int/nmh/events/ncd_action_plan/en/, accessed 15 November 2017).
8. Hughes R. Competencies for effective public health nutrition practice: a developing consensus. Public Health Nutr. 2004; 7:683–91.
9. Lachat C, Van Camp J, De Henauw S, Matthys C, Larondelle Y, Remaut-De Winter AM et al. A concise overview of national nutrition action plans in the European Union Member States. Public Health Nutr. 2005; 8:266–74.
10. Liu PJ, Wisdom J, Roberto CA, Liu LJ, Ubel PA. Using behavioral economics to design more effective food policies to address obesity. Appl Econ Perspect Policy. 2014; 36:6–24.
11. Promoting sustainable consumption – good practices in OECD countries. Paris: OECD Publishing; 2008 (http://www.oecd.org/greengrowth/sustainabledevelopmentkeyreports.htm, accessed 15 November 2017).
12. Serra-Majem L. Moving forward in public health nutrition – the I World Congress of Public Health Nutrition – Introduction. Nutr Rev. 2009; 67:S2–S6.
13. Hercberg S. Propositions pour un nouvel élan de la politique nutritionnelle française de santé publique dans le cadre de la stratégie nationale de santé. 1ère partie: mesures concernant la prévention nutritionnelle. Paris: Ministère des Solidarités et de la Santé; (http://www.ladocumentationfrancaise.fr/rapports-publics/144000068/, accessed 20 November 2017).
14. Grunert KG, Fernandez-Celemin L, Wills JM, Storcksdieck Genannt BS, Nureeva L. Use and understanding of nutrition information on food labels in six European countries. Z Gesundh Wiss. 2010; 18:261–77.
15. Hawley KL, Roberto CA, Bragg MA, Liu PJ, Schwartz MB, Brownell KD. The science on front-of-package food labels. Public Health Nutr. 2013; 16:430–9.
16. Hersey JC, Wohlgenant KC, Arsenault JE, Kosa KM, Muth MK. Effects of front-of-package and shelf nutrition labeling systems on consumers. Nutr Rev. 2013; 71:1–14.

17. Van Kleef E, Dagevos H. The growing role of front-of-pack nutrition profile labeling: a consumer perspective on key issues and controversies. Crit Rev Food Sci Nutr. 2015; 55:291–303.

18. Vyth EL, Steenhuis IHM, Roodenburg AJC, Brug J, Seidell JC. Front-of-pack nutrition label stimulates healthier product development: a quantitative analysis. Int J Behav Nutr Phys Act. 2010; 7:65.

19. Ni MC, Eyles H, Choi YH. Effects of a voluntary front-of-pack nutrition labelling system on packaged food reformulation: the health star rating system in New Zealand. Nutrients. 2017; 9(8):918.

20. Asp NG, Bryngelsson S. Health claims in the labelling and marketing of food products: the Swedish food sector's Code of Practice in a European perspective. Scand J Food Nutr. 2007; 51(3):107–26.

21. Vyth EL, Steenhuis IHM, Mallant SF, Mol ZL, Brug J, Temminghoff M et al. A front-of-pack nutrition logo: a quantitative and qualitative process evaluation in the Netherlands. J Health Commun. 2009; 14:631–45.

22. Signposting and traffic light labelling [website]. London: Food Standards Agency; 2010 (http://www.food.gov.uk/northern-ireland/nutritionni/niyoungpeople/survivorform/bestreadbefore/signposting, accessed 15 November 2017).

23. Health Star Rating System [website]. Canberra: Commonwealth of Australia; 2017 (http://healthstarrating.gov.au/internet/healthstarrating/publishing.nsf/content/home, accessed 15 November 2017).

24. Understanding the label. In: Reference Intakes [website]. Brussels: FoodDrinkEurope; 2014 (http://referenceintakes.eu/understanding-label.html, accessed 20 November 2017).

25. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. O. J. E. U. 2011, L 304.18 (http://europa.eu/legislation_summaries/consumers/product_labelling_and_packaging/co0019_en.htm, accessed 15 November 2017).

26. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. O. J. E. U. 2011, L 404.9 (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1469535322312&uri=CELEX:32006R1924, accessed 15 November 2017).

27. Chauliac M, Hercberg S. Changing the food environment: the French experience. Adv Nutr. 2012; 3:605S–10S.

28. Hercberg S, Chat-Yung S, Chauliac M. The French National Nutrition and Health Program: 2001–2006–2010. Int J Public Health. 2008; 53:68–77.

29. Projet de loi n°2302 relatif à la Santé, présenté au nom de M. Manuel Valls, Premier ministre, par Mme Marisol Touraine, ministre des affaires sociales, de la santé et des droits des femmes. Exposé des motifs. Paris: Assemblée Nationale; 2014 (http://www.assemblee-nationale.fr/14/projets/pl2302.asp, accessed 15 November 2017).

30. Rayner M, Scarborough P, Stockley L, Boxer A. Nutrient profiles: development of final model. London: Food Standards Agency; 2005 (http://webarchive.nationalarchives.gov.uk/20111207035647/http://www.food.gov.uk/multimedia/pdfs/nutprofr.pdf, accessed 15 November 2017).

31. Rayner M, Scarborough P, Stockley L. Nutrient profiles: applicability of currently proposed model for uses in relation to promotion of foods in children aged 5–10 and adults. London: Food Standards Agency; 2005 (https://www.researchgate.net/publication/267952402_Nutrient_profiles_Applicability_of_currently_proposed_model_for_uses_in_relation_to_promotion_of_food_to_children_aged_5-10_and_adults, accessed 15 November 2017).

32. Rayner M, Scarborough P, Lobstein T. The UK Ofcom Nutrient Profiling Model – Defining "healthy" and "unhealthy" food and drinks for TV advertising to children. London: Food Standards Agency; 2009 (http://www.dph.ox.ac.uk/bhfhprg/publicationsandreports/acad-publications/bhfhprgpublished/nutrientprofilemodel, accessed 15 November 2017).

33. Townsend MS. Where is the science? What will it take to show that nutrient profiling systems work? Am J Clin Nutr. 2010; 91:1109S–15S.

34. Grunert KG, Wills JM. A review of European research on consumer response to nutrition information on food labels. J Public Health. 2007; 15:385–99.

35. Julia C, Ducrot P, Peneau S, Deschamps V, Méjean C, Fézeu L et al. Discriminating nutritional quality of foods using the 5-Color nutrition label in the French food market: consistency with nutritional recommendations. Nutr J. 2015; 14:100.

36. Julia C, Kesse-Guyot E, Ducrot P, Péneau S, Touvier M, Méjean C et al. Performance of a five category front-of-pack labelling system – the 5-colour nutrition label – to differentiate nutritional quality of breakfast cereals in France. BMC Public Health. 2015; 15:179.

37. Julia C, Kesse-Guyot E, Touvier M, Mejean C, Fezeu L, Hercberg S. Application of the British Food Standards Agency nutrient profiling system in a French food composition database. Br J Nutr. 2014; 112:1699–705.

38. Coudray B. The contribution of dairy products to micronutrient intakes in France. J Am Coll Nutr. 2011; 30:410S–4S.

39. Evaluation de la faisabilité du calcul d'un score nutritionnel tel qu'élaboré par Rayner et al. Rapport d'appui scientifique et technique. Maisons-Alfort: ANSES; 2015.

40. Information sur la qualité nutritionnelle des produits alimentaires. Paris: Haut Conseil de la Santé Publique; 2015 (http://www.hcsp.fr/Explore.cgi/avisrapportsdomaine?clefr=519, accessed 16 November 2017).

41. Peters SAE, Dunford E, Jones A, Ni Mhurchu C, Crino M, Taylor F et al. Incorporating added sugar improves the performance of the Health Star Rating front-of-pack labelling system in Australia. Nutrients. 2017; 9.

42. Julia C, Touvier M, Mejean C, Ducrot P, Péneau S, Hercberg S et al. Development and validation of an individual dietary index based on the British Food Standard Agency nutrient profiling system in a French context. J Nutr. 2014; 144:2009–17.
43. Julia C, Mejean C, Touvier M, Péneau S, Lassale C, Ducrot P et al. Validation of the FSA nutrient profiling system dietary index in French adults-findings from SUVIMAX study. Eur J Nutr. 2015; 55(5):1901–10.
44. Deschamps V, Julia C, Salanave B, Verdot C, Hercberg S, Castetbon K. Score de qualité nutritionnelle des aliments de la Food Standards Agency appliqué aux consommations alimentaires individuelles des adultes en France. Bull Epidemiol Hebd (Paris). 2015;(24–25):466–75.
45. Julia C, Mejean C, Touvier M, Péneau S, Lassale C, Ducrot P et al. Validation of the FSA nutrient profiling system dietary index in French adults – findings from SUVIMAX study. Eur J Nutr. 2016; 55:1901–10.
46. Scarborough P, Arambepola C, Kaur A, Bhatnagar P, Rayner M. Should nutrient profile models be “category specific” or “across-the-board”? A comparison of the two systems using diets of British adults. Eur J Clin Nutr. 2010; 64:553–60.
47. Adriouch S, Julia C, Kesse-Guyot E, Méjean C, Ducrot P, Péneau S et al. Prospective association between a dietary quality index based on a nutrient profiling system and cardiovascular disease risk. Eur J Prev Cardiol. 2016; 23(15):1669–76.
48. Donnenfeld M, Julia C, Kesse-Guyot E, Méjean C, Ducrot P, Péneau S et al. Prospective association between cancer risk and an individual dietary index based on the British Food Standards Agency Nutrient Profiling System. Br J Nutr. 2015; 114(10):1702–10.
49. Julia C, Ducrot P, Lassale C, Fézeu L, Méjean C, Péneau S et al. Prospective associations between a dietary index based on the British Food Standard Agency nutrient profiling system and 13-year weight gain in the SU.VI.MAX cohort. Prev Med. 2015; 81:189–94.
50. Julia C, Mejean C, Vicari F, Peneau S, Hercberg S. Public perception and characteristics related to acceptance of the sugar-sweetened beverage taxation launched in France in 2012. Public Health Nutr. 2015; 18(14):2679–88.
51. Adriouch S, Julia C, Kesse-Guyot E, Ducrot P, Péneau S, Méjean C et al. Association between a dietary quality index based on the food standard agency nutrient profiling system and cardiovascular disease risk among French adults. Int J Cardiol. 2017; 234:22–7.
52. Deschasaux M, Julia C, Kesse-Guyot E, Lécuyer L, Adriouch S, Méjean C et al. Are self-reported unhealthy food choices associated with an increased risk of breast cancer: prospective study using the British Food Standards Agency nutrient profiling system. BMJ Open. 2017; 7(6):e013718.
53. Masset G, Scarborough P, Rayner M, Mishra G, Brunner EJ. Can nutrient profiling help to identify foods which diet variety should be encouraged? Results from the Whitehall II cohort. Br J Nutr. 2015; 113:1800–9.
54. Chiuve SE, Sampson L, Willett WC. The association between a nutritional quality index and risk of chronic disease. Am J Prev Med. 2011; 40:505–13.
55. Reedy J, Kirkpatrick SI. The use of proprietary nutrient profiling tools in nutrition science and policy: a commentary. Am J Prev Med. 2011; 40:581–2.
56. Katz DL, Njike VY, Rhee LQ, Reingold A, Ayoob KT. Performance characteristics of NuVal and the Overall Nutritional Quality Index (ONQI). Am J Clin Nutr. 2010; 91:1102S–8S.
57. Fulgoni VL 3rd, Keast DR, Drewnowski A. Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. J Nutr. 2009; 139:1549–54.
58. Ducrot P, Mejean C, Julia C, Kesse-Guyot E, Touvier M, Fezeu LK et al. Objective understanding of front-of-package nutrition labels among nutritionally at-risk individuals. Nutrients. 2015; 7:7106–25.
59. Ducrot P, Mejean C, Julia C, Kesse-Guyot E, Touvier M, Fezeu L et al. Effectiveness of Front-Of-Pack Nutrition Labels in French Adults: Results from the NutriNet-Santé Cohort Study. PLoS One. 2015; 10(10):e0140898.
60. Julia C, Péneau S, Buscail C, Gonzalez R, Touvier M, Hercberg S et al. Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population: cross-sectional study among the NutriNet-Santé cohort participants. BMJ Open 2017; 7(6):e016108.
61. Ducrot P, Julia C, Méjean C, Kesse-Guyot E, Touvier M, Fezeu LK et al. Impact of different front-of-pack nutrition labels on consumer purchasing intentions: a randomized controlled trial. Am J Prev Med. 2015; 50(5):627–36.
62. Julia C, Blanchet O, Méjean C, Péneau S, Ducrot P, Allès B et al. Impact of the front-of-pack 5-colour nutrition label (5-CNL) on the nutritional quality of purchases: an experimental study. Int J Behav Nutr Phys Act. 2016; 13:1–9.
63. Ruffieux B, Muller L. Etude sur l’influence de divers systèmes d’étiquetage nutritionnel sur la composition du panier d’achat alimentaire. Association Française d’Economie Expérimentale Research paper 2011-01. Grenoble: INRA GAEL; 2011.
64. Crosetto P, Muller L, Ruffieux B. Réponse des consommateurs à trois systèmes d’étiquetage nutritionnel face avant. Cah Nutr Diet. 2016; 51:124–31.

65. Crosetto P, Lacroix A, Muller L, Ruffieux B. Mesure expérimentale en laboratoire des impacts sur la qualité nutritionnelle du panier alimentaire familial de l'apposition de "Systèmes d'étiquetage nutritionnel" en face avant des emballages. Grenoble: INRA GAEL; 2017.

66. Evaluation ex ante de systèmes d'étiquetage nutritionnel graphique simplifié. Rapport final du comité scientifique. Paris: Ministère des Solidarités et de la Santé; 2016 (http://solidarites-sante.gouv.fr/archives/article/l-evaluation-en-conditions-reelles-d-achat-des-systemes-d-information-317290, accessed 16 November 2017). ■