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1 **Consistency of the initial and updated version of the Nutri-Score with food-based dietary**
2 **guidelines: a French perspective**

3

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19

20 Abbreviations:

21 CI: confidence interval

22 FBDG: Food-based dietary guidelines

23 FSAm-NPS: modified Food Standard Agency- Nutrient Profiling System

24 uNS-NPS: updated Nutri Score- Nutrient Profiling System

25

26 **Abstract**

27 **Background:** To help consumers to make healthier food choices, seven European countries have
28 implemented the front-of-pack nutrition label Nutri-Score. The algorithm was updated in 2022-2023
29 by the Nutri-Score European scientific committee, based on the current scientific knowledge.

30 **Objective:** The aim of the present study was to investigate the consistency of the newly
31 internationally-developed algorithm with the French food-based dietary guidelines (FBDG) and
32 compare the respective performances of the initial and updated algorithm.

33 **Methods:** Three complementary French food composition databases were used to access extensive
34 coverage of the food supply in France (N=46 752): the Oqali, Open Food Facts, Ciqual databases.
35 Based on the French FBDG, a list of 41 criteria was defined by which the consistency between French
36 FBDG and the Nutri-Score was assessed (e.g. consumption of fresh vegetables is promoted in FBDG,
37 thus the Nutri-Score should rate favourably such products).

38 **Results:** Out of all criteria, the initial algorithm met 63% (26/41) of them while the revised algorithm
39 met 85% (35/41) of them. Improvements achieved by the updated version of the Nutri-Score in
40 terms of alignment with the FBDG were particularly observed for high-fat products (i.e. fatty fish,
41 nuts and seeds), sweet products (i.e. ice creams, sweet spreads), salty products (i.e. savoury snacks,
42 salted nuts), for dairy beverages and for beverages with artificial sweeteners.

43 **Conclusions:** The Nutri-Score's updated nutrient profiling system appeared to rate foods more
44 consistently in regards to the French dietary guidelines and improved the currently existing system.
45 The present work supports the implementation of the updated nutrient profiling system underlying
46 Nutri-Score.

47
48 **Keywords:** Nutri-Score, nutrient-profiling system, dietary guidelines, alignment, public health

49

50 **Background**

51 The development of an epidemic of noncommunicable chronic diseases -such as diabetes,
52 cardiovascular diseases, or cancer- represents one of the most important burdens to healthcare
53 systems in industrialized countries(1). Non-communicable chronic diseases are the leading causes of
54 death worldwide(2) and are a global issue associated with loss of quality of life and premature
55 deaths(3). To tackle this issue, international and national institutions have called for the
56 implementation of policies, targeting known and actionable risk factors for chronic diseases,
57 including diet quality(4). Among multiple measures, expert panels recommended the use of front-of-
58 pack labelling to better inform consumers on the nutritional quality of the food through visible and
59 understandable labels but also to incentivize manufacturers to reformulate the food offer (5).

60 In 2017, based on numerous scientific studies, the French government recommended the use of a
61 summary, graded, color-coded front-of-pack labelling scheme: the Nutri-Score. Initially, the Nutri-
62 Score was developed by the Nutritional Epidemiology Research team, an independent French
63 research group and was refined by the French High Council of Public Health (for the underlying
64 algorithm) and Santé publique France, the French national public health agency (for its graphical
65 design). The underlying score computation system - referred herein to as the algorithm- was based
66 on a nutrient profiling system: the modified Food Standard Agency-Nutrient Profiling System (or
67 FSAm-NPS), which was initially developed in the United Kingdom to regulate television advertising
68 toward children(6). Since its implementation in France, several other European countries endorsed
69 the system: Belgium, Switzerland, Spain, Germany, Luxembourg, and the Netherlands. In 2021, an
70 international Scientific Committee was appointed by the seven countries supporting the
71 implementation of the Nutri-Score(7). The Scientific Committee, including scientists from all seven
72 countries, was tasked to update the algorithm underpinning the Nutri-Score, following the
73 acknowledged standards for public policies which require regular updates. In 2022-2023, an updated
74 version of the algorithm (uNS-NPS) was released. The revised calculation system was accompanied by

75 an analysis investigating the distribution of the initial and updated Nutri-Score in databases from four
76 countries and the coherence of the modifications with national food-based dietary guidelines (FBDG),
77 considering that the update was aimed at increasing the consistency of the system with FBDG in an
78 international perspective (8,9). Following the conceptual framework developed by Townsend (10),
79 the validation for this new algorithm would require first an evaluation of the ability of this nutrient
80 profiling system to be consistent in regard to the current nutrition knowledge, to confirm its content
81 and convergent validity.

82 To evaluate the adequacy of the classification, a common method consists of comparing national
83 food-based dietary guidelines (FBDG) or classification of foods by experts with the assessment
84 provided by the labelling scheme. However, conceptually, FBDG and the Nutri-Score rely on different
85 approaches. FBDG provide the general framework for a healthy diet, which results from the
86 consumption of a combination of foods, both in quantity and quality(11). The guidelines provide
87 practical advice to consumers on what is considered a healthy diet, giving general information on the
88 consumption of broad food groups (i.e. which groups should be encouraged or limited). Front-of-
89 pack labelling schemes, including the Nutri-Score, on the other hand, inform consumers on specific
90 foods, and help them to compare foods of the same category and/or similar foods of different
91 brands(5). While it is possible to identify dietary patterns associated with better health outcomes and
92 reduced mortality, this approach may not necessarily be directly transposed to individual foods that
93 constitute each a fraction of the diet. Indeed, no specific food is *per se* harmful to health and only
94 their habitual combination within diets may qualify its relative healthiness(12). On the opposite, the
95 objective of the Nutri-Score is thus not to characterize a food as “healthy” or “unhealthy” in absolute
96 terms, but rather to indicate which products are of better or worse nutritional composition in a given
97 food group (e.g. fish or dairy products), by considering the intra-group variability. Within food groups
98 recommended by FBDG, nutritional composition may greatly vary, especially if there is an addition of
99 fat, sugar or salt; hence, the relevance of a front-of-pack labelling scheme. In this regard, it appears
100 relevant to assess the potential consistency between FBDG and the Nutri-Score.

101 The consistency of the initial version of the Nutri-Score with dietary guidelines and its performances
102 in terms of variability within food groups has already been studied in various contexts and countries,
103 and studies have reported that the Nutri-Score is consistent with FBDG overall and able to show the
104 wide variability in nutritional quality of foods within the same category (13–18). During the process
105 of updating the Nutri-Score algorithm, the aim of the Scientific Committee for the Nutri-Score was to
106 make evidence-based adjustments in alignment with FBDG. However, while the Scientific Committee
107 analysed the impact of the modifications overall, it did not investigate extensively the updated
108 algorithm in light with the respective national FBDG. Thus, the purpose of this study was to assess in
109 detail the consistency of the updated version of the Nutri-Score with the French FBDG and compare
110 its performance with the initial version of the Nutri-Score.

111

112 **Methods**

113 ***Nutri-Score computation***

114 Briefly, the initial algorithm allocates points based on the nutritional composition of the food as sold
115 per 100g of food: points for unfavourable elements (energy (kJ), saturated fat (g), sugar (g) and salt
116 (g) or sodium(mg)) and points for favourable elements (protein (g), fibre (g),
117 fruits/vegetables/pulses/nuts and olive, walnut and canola oils (%)). Then, the points from the
118 “favourable” component are subtracted from the points from the “unfavourable” component,
119 leading to a final score. The final score is then converted into a grade from A to E associated with a
120 colour from dark green to dark orange. Of note, higher scores lead to lower product ratings (i.e. D or
121 E).

122

123 The updated version of the algorithm functions similarly to its predecessor. There have been
124 adaptations such as an increase of the maximum number of points for the sugar and salt component,
125 stricter allocation of points for fibre and protein and modified thresholds for the attribution of

126 points. Additionally, specific rules were also set for red meat as well as beverages containing at least
127 one non-nutritive sweetener.

128 To compute the FSAm-NPS and uNS-NPS, we followed guidelines as indicated by the French Public
129 Health Agency (Santé publique France) (19) and both calculation methods are described in
130 Supplementary Material 1.

131

132 ***Food data***

133 In order to represent all food groups covered by the Nutri-Score, i.e. prepacked foods displaying a
134 nutritional declaration, several databases were used. First, Data from the French Food Observatory
135 (Oqali) were used(20). The Oqali team collected data through on-pack information sent by food
136 industry professionals or through packaging photographs of products found in partner stores.
137 Campaigns to collect data used in the study were conducted between 2009 and 2020, periodically
138 repeated depending on the category. The Oqali team assessed, when possible, the fruit and
139 vegetable component based on either the declaration on-pack from the food manufacturer or from
140 the ingredients list. Using the ingredients list, the Oqali team was also able to identify beverages with
141 non-nutritive sweeteners. If there were any missing values for any element used in the Nutri-Score
142 computation, products were excluded from the analyses.

143 Then, considering that not all food sectors are covered by the Oqali database, complementary data
144 was retrieved from the OpenFoodFacts database(21), which is an international collaborative project
145 coordinated in France to gather food composition data present on the packaging. Data from
146 OpenFoodFacts was only used for food groups that were not covered by the Oqali database and was
147 restricted to products sold on the French market. Missing values in the OpenFoodFacts database
148 were treated as follows:

- 149 • In case of missing values for a mandatory nutrient on the label, products were excluded.

150 • In case of missing fibre values, two possibilities were considered. First, if products belonged
151 to a group with on average no or little fibre (e.g. fats and oils), then 0g was imputed for the
152 missing fibre value. Otherwise products with missing fibre value belonging to a group with
153 products that could contain more than 0.9g of fibre/100g of product were excluded (first
154 fibre content threshold for the computation of the Nutri-Score).

155 • In case of missing values for the fruit and vegetable component, three possibilities were
156 considered. First, if products belonged to a group with no apparent element from the fruit
157 and vegetable component, 0% was imputed to all products with missing values in the
158 category (i.e. pasta, bread, rice, fish, fats and oils with exceptions for some vegetable oils).
159 Then, for mono-ingredient products in groups belonging to the fruit and vegetable
160 component (e.g. nuts or olive oil), 100% was imputed. Finally, products that did not fall in the
161 two first cases were excluded.

162 Products with nutrients below the 1st and above the 99th percentiles in their food groups were
163 manually checked and excluded if values were erroneous. When several composition data existed for
164 a same product at different dates in the OpenFoodFacts database, only the most recent product was
165 kept to take into account the potential reformulation.

166 The definition of the fruit and vegetable component is different for the two tested algorithms. They
167 differ by the inclusion of nuts or some oils in the component that are used in the initial version and
168 not in the updated version. For mono-ingredients with high content of these ingredients (nuts, olive,
169 canola and walnut oils), values for the component were set at 100% for the initial version of the
170 algorithm and at 0% for the updated version. For other products (e.g. ready-to-eat meals or breakfast
171 cereals), we assumed nuts and oils accounted for a marginal proportion of the fruit and vegetable
172 elements, we therefore used the same estimates for the component for both algorithms.

173 Finally, to complete the analyses, data for unprocessed products, such as unprocessed meat, fruits,
174 or vegetables, were collected using the Ciqual database, which is the generic food composition

175 database in France representative of the foods consumed in France (22) and produced by the French
176 Agency for Food, Environmental and Occupational Health & Safety (ANSES). While the Nutri-Score
177 was not aimed initially to be used on unprocessed foods, the 2019 French National Nutrition Program
178 plans to extend the use of the Nutri-Score to products sold in bulk (with no nutritional
179 declaration)(23). The database provides values for raw and cooked products and for the analyses,
180 only raw products were used as unprocessed products are usually sold not prepared. Products with
181 missing values used in the calculation were excluded. For unprocessed meat, products were classified
182 as poultry or red meat, to apply a penalty to red meat as intended in the uNS-NPS. For meat, 0% was
183 imputed for all products for the fruit and vegetable component. For fruits, vegetables and pulses,
184 100% was imputed for all products for the fruit and vegetable component.

185 In Supplementary Material 2, detailed information regarding the origin and composition of each food
186 group used in the analysis is provided.

187 ***Alignment with French 2017-food-based dietary guidelines***

188 To assess the consistency between the 2017 French FBDG and the Nutri-Score, a list of criteria was
189 derived from 1/ documents from Santé publique France (24), designed to communicate FBDG to the
190 general public for the main recommendations and 2/ the report of the High council of Public
191 health(25), from which FBDG were established, for more detailed recommendations. The
192 methodology used was based on the approach from Ter Borg et al.(15), which was adapted to French
193 FBDG with the aim of systematizing the comparison between nutrient profiling and FBDG using
194 quantitative indicators. In Supplementary Material 3, the method used to elaborate the criteria is
195 described in detail.

196 First, Santé publique France expressed the FBDG under three concepts: food groups to increase, to
197 reduce or “to move towards”. For food groups to increase, we considered that their evaluation
198 should be rather favourable (Nutri-Score A or B) and for those to reduce, their evaluation should be
199 rather unfavourable (Nutri-Score D or E). Finally, the group “To move towards” includes food groups

200 to prefer over others (e.g. whole-grain cereals over refined cereals), food groups for which a similar
201 number of servings is recommended (i.e. lean and oily fish) and finally food groups that should be
202 consumed but not in excessive proportions (i.e. dairy products). To establish criteria for this group, a
203 case-by-case analysis was conducted (see Supplementary Material 3).

204 Using the report of the High council of Public health, all items pertaining to food recommendations
205 were listed and interpreted. If consumption guidelines for groups recommended consuming a
206 minimum amount (i.e. "At least X a day/week"), we considered that the evaluation should be
207 favourable to consider the Nutri-Score and the guidelines to be aligned. Conversely, if groups were
208 said to be limited, we considered that the evaluation should be unfavourable to consider the Nutri-
209 Score and the guidelines to be aligned. If groups were said to be preferred over others, we
210 considered that the Nutri-Score should be able to discriminate the groups in question.

211 Finally, criteria were categorized into three groups:

- 212 • Position criteria: criteria which require to have products rated favourably (resp.
213 unfavourably). For example, guidelines recommend to increase the intake of fruits and
214 vegetables. Thus, we considered that the Nutri-Score would be consistent with the guidelines
215 if fruits and vegetables would be rated favourably.
- 216 • Group discrimination criteria: criteria which require a group to be discriminated over another
217 group. For example, guidelines recommend in the processed meat category to prefer the
218 consumption of ham over other processed meat products. Thus, we considered that the
219 Nutri-Score would be consistent with the guidelines if ham and other processed meat
220 products were discriminated from each other on the Nutri-Score grading system.
- 221 • Nutrient discrimination criteria: criteria which require products in a group to be
222 discriminated based on a nutrient of interest. For example, guidelines recommend limiting
223 intake of salt through a reduced intake of salty foods (e.g. cheeses). Thus, we considered that

224 the Nutri-Score would be consistent with the guidelines if cheeses of varying salt content
225 received a different rating.

226

227 ***Statistical analysis***

228 The FSAm-NPS score and the uNS-NPS score were calculated for each food (N=46 369). The
229 distribution of products in each category of the Nutri-Score was assessed (from A for the healthier
230 products and E for the less healthy).

231 For position criteria, the proportion of products in the A and B classes (resp. in the D and E classes)
232 was computed. As Ter Borg et al.(15), we considered that if at least 80% of products in a group were
233 classified according to the criteria set, the group would be classified adequately.

234 For discrimination between food groups, the modal Nutri-Score class was presented for each food
235 group (i.e. Nutri-Score class with the highest percentage in the distribution). In the case where
236 products were distributed in multiple Nutri-Score classes with less than 5 percentage point difference
237 between most represented classes, the several most represented classes were presented. We
238 considered that a criterion was met if the modal Nutri-Score classes were distinct between the food
239 groups that were required to be discriminated.

240 For nutrient discrimination criteria, two separate analyses were conducted. First, to identify if each
241 version was able to discriminate products of varying critical nutrient content (in g of nutrient per
242 100g of product), a Kruskal-Wallis test was performed between the critical nutrient and the
243 classification. Then, to assess how the update impacted the classification relatively to the initial
244 version, multinomial logistic regressions were conducted to identify the nutritional characteristics of
245 products more likely to see their rating affected. The dependent variable was a three-category
246 variable, which measured the evolution of the class of the Nutri-Score between the initial and
247 updated version of the algorithm (either the class did not change, or the class deteriorated, or the

248 class improved), and the independent variable was the content in nutrient of interest. If a modality of
249 the dependent variable contained less than 5 observations, the modality was removed from the
250 analysis.

251 All statistical tests conducted were two-sided and were considered significant if the p-value<0.05 and
252 were two-sided. Data management and Nutri-Score computation were conducted with SAS software
253 version 9.4 (SAS Institute, Inc., Cary NC, USA). Plots were obtained using R version 3.6.2 (R
254 Foundation, Vienna, Austria).

255 **Results**

256 Table 1 presents the list of criteria used to assess to which extent each version of the Nutri-Score
257 labelling scheme was consistent with the French FBDG. A total of 41 criteria were obtained after
258 analysis of the guidelines distributed in 26 food groups. Out of the 41 criteria, 46% (19/41) were
259 position criteria, 34% (14/41) were discrimination between groups criteria and 20% (8/41) were
260 nutrient discrimination criteria.

261 To assess the consistency between FBDG and both versions of the Nutri-Score, 19 475 products were
262 retrieved from the OQALI database, 26 969 from the OpenFoodFacts database and 308 items from
263 the generic Ciqual database. Tables 2, 3, 4 and 5 provide results according to the criteria in Table 1. A
264 detailed table of all food groups used in the analysis is also provided in Supplementary Material 4 as
265 well as a comparative table summarising results for all criteria in Supplementary Material 5.

266 Out of all 41 criteria, the initial algorithm met 63% (26/41) of them while the updated algorithm met
267 85% (35/41) of them. For position criteria, the initial algorithm met 12/19 criteria and the updated
268 algorithm met 15/19 criteria. For group discrimination criteria, the initial algorithm met 8/14 criteria
269 and the updated algorithm met 12/14 criteria. For nutrient discrimination criteria, the initial
270 algorithm met 6/8 criteria and the updated algorithm met 8/8 criteria. For the nutrient
271 discrimination criteria, the comparison between the updated and initial algorithm showed that the

272 updated algorithm was more discriminatory than the initial one against critical nutrients for 63%
273 (5/8) of the criteria.

274 Overall, the distribution of the various food groups within Nutri-Score classes with both versions of
275 the algorithm was aligned with French dietary guidelines. Groups for which it is recommended to
276 increase consumption were favourably rated, such as unprocessed fruits, unprocessed vegetables,
277 pulses, and unsalted nuts. Conversely, food groups for which consumption should be limited received
278 unfavourable ratings, such as processed meat, savoury snacks, animal fats, sweet products
279 (confectionery, chocolate products, fine bakery ware...). In addition, the updated algorithm improved
280 the initial classification with an increased penalty of savoury snacks, ice creams and sorbets,
281 sweetened dairy beverages and sweet spreads and to a lesser extent sweet dairy desserts and sweet
282 breakfast cereals. Both versions of the algorithm remained not entirely aligned with the
283 recommendation of limiting red meat intake, with a rather significant proportion of unprocessed red
284 meat rated favourably, even though this proportion was reduced with the update.

285 Second, the ability for both algorithms to discriminate food groups distinguished in the FBDG was
286 observed in groups such as among fats and oils, dairy products, breads, nuts and processed meat. In
287 other groups, the update of the algorithm improved the initial situation by introducing a
288 discrimination that was lacking previously (for poultry and red meat, rice and dairy beverages) or by
289 rating similarly foods placed on equal footing in the FDBG while they were initially discriminated
290 (lean and oily fishes). However, the update did not resolve the lack of discrimination between whole
291 grain and refined pasta.

292 Regarding the discrimination in food groups based on specific critical nutrients (mainly salt and
293 sugars), both algorithms were able to distinguish products of varying nutrient content – with the
294 exception of protein content in cheeses and salt in cold sauces for the initial algorithm. The updated
295 version of the Nutri-Score tended to deteriorate more heavily the rating of breads, cheeses and
296 sauces (cold and warm) higher in salt and compotes higher in sugars while no significant difference

297 for salt discrimination was observed for soups and prepared dishes and for sugars discrimination for
298 canned fruits. Among minimally sweetened breakfast cereals, those with a higher content of fibre
299 were less likely to receive a poorer rating when compared with the initial rating, which was
300 consistent with FBDG.

301 **Discussion**

302 The present study is the first that assesses the effect of the update of the Nutri-Score algorithm on its
303 consistency with the recommendations of the French FBDG. It showed that the revised algorithm is
304 classifying food products consistently in regard to French FBDG. Furthermore, the comparison
305 indicated that the classification of the updated algorithm was more aligned with FBDG than the initial
306 version in several food groups, suggesting that the update constitutes an improvement for the
307 nutritional profile in regard to French FBDG.

308 Past studies, which looked comprehensively at the relation between FBDG and the initial Nutri-Score,
309 found that overall the system was in line with the FBDG in the Netherlands, Germany, Greece and
310 Portugal (15–18,26,27). A cross-sectional study in 8 countries also confirmed that the classification
311 provided by the initial Nutri-Score was consistent with national dietary recommendations (14). The
312 results in all studies are consistent, observing that the relative classification of food groups is overall
313 aligned with food pyramids (i.e. fruits, vegetables and legumes are among the best rated and foods
314 high in salt, fat and sugar are poorly rated), especially the Mediterranean diet pyramid(27). Then, the
315 update of the Nutri-Score by the Scientific Committee was performed to increase the consistency
316 between the classification in the system and FBDG from an international perspective, including
317 countries with different food cultures(8,9). Though the reports from the scientific committee
318 included the distribution of various food groups in the updated Nutri-Score in food composition
319 databases from four countries, this study is the first in our knowledge to investigate in-depth the
320 updated Nutri-Score with specific FBDG.

321 The update of the Nutri-Score is characterized by its greater stringency, with few and targeted food
322 groups having their ratings improved. On the one hand, the algorithm became stricter with sweet
323 and highly salty products, with the increase in the maximal number of points in the sugar and salt
324 component, while higher amounts of fibre and protein are required to receive points for the positive
325 components. Our results show that these modifications led in many food groups to a shift from more
326 favourable classes to less favourable ones, especially for products with addition of salt and sugar (e.g.
327 savoury snacks, breakfast cereals, ice creams, sweet spreads, prepared dishes) and contributed to a
328 better consistency with the FBDG. In the beverage category, modifications allowed to discriminate
329 adequately plain and sweetened dairy beverages and to reduce the number of artificially-sweetened
330 beverages in favourable classes. On the other hand, some food groups have seen their rating being
331 improved with the update – namely, oily fish and vegetable oils and some hard cheeses. This
332 improvement for hard cheeses and fish can be explained by the increase in the maximum number of
333 points granted for protein content, which compensates the relatively high caloric density of these
334 foods that contain high amount of some important micronutrients (namely calcium in hard cheeses
335 and omega-3 in oily fish).

336 Specifically, in the added fats category, FBDG recommend to favour the consumption of vegetable
337 oils and especially olive oil and oils rich in alpha-linolenic acid. While according to the criteria set in
338 this study for added fats (i.e. discrimination between vegetable and animal fats) the update of the
339 algorithm did not improve the consistency with FBDG, it could be argued that the shift by one class
340 up for most vegetable oils is relevant, leading the most favourable oils to reach a favourable category
341 (i.e. B category). Consumption of olive oil as well as intake of dietary alpha-linolenic acid - was
342 associated with reduced risks of all-cause mortality (28,29) and vegetable oils, in particularly olive oil,
343 have shown to have beneficial effects on health(28,30).

344 The FBDG advise to prefer the consumption of whole grain cereals and products over refined
345 equivalents. The lack of discrimination between whole grain and refined products have been pointed

346 out by past research (15,31). As the uNS-NPS is much more severe in regard to fibre content, a
347 degradation of the rating of white bread and white rice was observed. However, some whole grain
348 bread saw their classification deteriorated due to the changes. This phenomenon may be explained
349 by the relative low fibre content of some whole grain products in France, considering that there is no
350 legal composition requirement for whole grain bread in France, with some breads having less than
351 40% wholemeal flour in the final product. Meanwhile, whole grain breads that were rich in fibre were
352 properly discriminated from white bread, suggesting that an increase in proportion of wholemeal
353 flours would lead to a more favourable rating. Finally, the discrimination between whole grain and
354 refined pasta was not affected by the update and a lack of discrimination between these two groups
355 was still observed, which may limit the ability of consumers to orient their consumption towards
356 wholegrain cereals while they are recommended within FBDG.

357 Regarding the meat category, it was observed that unprocessed meat received almost systematically
358 a more favourable rating than processed alternatives, which contain added fat or salt. Indeed,
359 unprocessed meat were rated A, B or C, meat preparations were rated C or D, and processed meat
360 mostly D or E. The respective rating of these groups follows a progressive gradient in salt and
361 saturated fat content. In turn, unprocessed meat, especially red meat, was rather favourably rated by
362 both versions of the Nutri-Score (initial algorithm: beef: 78% rated A or B, pork:87%, poultry: 100%;
363 updated algorithm: beef: 47% rated A or B, pork:67%, poultry: 100%). This observation is in conflict
364 with French FBDG, which recommend to limit red meat intake, but also with the objective of
365 promoting sustainable diet (32,33). While the update of the Nutri-Score reduced the proportion of
366 unprocessed red meat in the favourable classes (by 31% for beef and 20% for pork), very few reached
367 the D and E category. It should nonetheless be noted that unprocessed red meat has a favourable
368 nutritional profile (i.e. low sugar and salt content, a low fat content for the leaner cuts of meat, and a
369 high protein content), which explains the rather favourable rating, and is an important contributor in
370 the French population to protein and micronutrient intake- iron, zinc, vitamins-(34). The
371 environmental issues related to meat consumption is also of relevance, but the Nutri-Score only

372 informs consumer on the nutritional quality of foods. The creation and use of other indicators in
373 conjunction with the Nutri-Score may be appropriate to inform consumers on different dimensions
374 (e.g. nutritional and environmental) of the food they consume. However, to date, only two studies
375 looked at the conjunction of an environmental indicator and the Nutri-Score with conflicting results
376 (35,36). As for all information systems when combined, research needs to firstly assess how they
377 interact and how consumers would react in case of conflicting information.

378 The update of the Nutri-Score algorithm impacted the classification of beverages, through three main
379 modifications. First, the inclusion of dairy beverages in the “Beverage” category of the algorithm
380 allowed for the discrimination between unsweetened and sweetened dairy beverages, while in the
381 past they received a similar rating. Then, sugar-sweetened beverages received an overall more
382 favourable rating with the updated algorithm relatively to the initial algorithm. Indeed, the
383 unfavourable sugar component following the addition of dairy beverages in the “Beverage” category
384 became less strict, specifically for beverages with low sugar content. For beverages which contain
385 only water and sugar, products rated B contained up to 2g of sugar per 100mL whereas they
386 contained 0g of sugar per 100mL before the update, which explains why the proportion of flavoured
387 waters slightly increased in the B category. However, it should be noted that soft drinks with high
388 amounts of sugar, such as colas or lemonades remained rated equally unfavourably. While the FBDG
389 recommend to limit the consumption of sugar-sweetened beverages regardless of their sugar
390 content, this change of rating could be seen as a potential limitation of the update of the Nutri-Score
391 algorithm. However, this updated classification may also incentivize manufacturers to reformulate as
392 nutritional targets may be easier to reach. Finally, the application of a specific penalization on non-
393 nutritive sweeteners in beverages prevented artificially-sweetened beverages from being rated B,
394 which aligns with the objective of not promoting this type of beverages within FBDGs. Longitudinal
395 analyses in contexts where a front-of-pack labelling penalized the presence of sugars but not
396 alternatives, observed an increase in the use of non-nutritive sweeteners following the
397 implementation of the scheme(37,38).

398 At this point, some limitations of our study should be acknowledged. First, even though the
399 methodology developed in the study was aimed to systematize the analysis of the consistency
400 between FBDG and the Nutri-Score, it should be noted that there is no gold-standard method. As
401 suggested by Townsend (10), in the validation framework for nutrient profiling systems, analyses at
402 food-level using expert opinion on the classification of foods as a gold standard are subject to
403 professional biases due to the qualitative nature of evaluation of foods by experts. To limit potential
404 biases, the translation of dietary guidelines was collectively discussed before conducting the analysis
405 and quantitative criteria were established beforehand. Then, the validation was realized in the
406 French context but other studies should replicate our methodology in other countries in which the
407 Nutri-Score is being used. Additionally, we were not able to assess the representativeness of the
408 databases in comparison with the food supply. However, according to the sectoral analyses
409 conducted by the Oqali, the data collected by the observatory represents between 70% and up to
410 90% of market purchases depending on the category at time of data collection. For OpenFoodFacts,
411 while volunteers contributing to the data collection have the possibility to scan any product,
412 products representing a greater market are more likely to be scanned and hence is likely to provide
413 an adequate coverage of the food market. Finally, the CIQUAL database is developed in order to be
414 representative of the foods usually consumed in France. Finally, the treatment of missing values led
415 to the exclusion of products present in the databases -mainly the OpenFoodFacts database-, and may
416 have influenced the results. However, we preferred to maintain a conservative approach and we
417 excluded products when data was missing and was not easily imputable as there is no one gold-
418 standard method. Indeed, studies in the past computing the Nutri-Score treated missing fibre values
419 by either calculating the fibre content based on the energy as declared(39), by imputing to the mean
420 fibre content of the category(15), by imputing a null value(27) or by excluding any product with
421 missing fibre values(26). Despite its limitations, the present study is the first one on the effect of the
422 update of the Nutri-Score algorithm on the consistency with FBDG, which used a systematized
423 method to approach and provided a quantitative measurement. Then, several databases were used

424 to cover extensively the French food market, including unprocessed products, which are not usually
425 included in such analyses. Finally, the Oqali database -the primary source of data- is a reliable source
426 of data as products are individually and manually checked(20).

427 **Conclusion**

428 The updated version of the Nutri-Score by its international Scientific Committee was shown to have
429 an increased consistency with French FBDG. The validation of the updated nutrient profiling system
430 underlying Nutri-Score in the French context also support the applicability of the scheme in the
431 European Union, given that FBDG in Europe share the same overarching structure.

432

433

434 **Declarations**

435 Ethics approval and consent to participate: Not applicable

436

437 Consent for publication: Not applicable

438

439 Competing interests: CJ is the chair of the Scientific Committee in charge of revising Nutri-Score's
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450

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457 [data/data-basis/](https://www.oqali.fr/donnees-data/data-basis/). Details and how to use the Oqali data are given at [https://www.oqali.fr/donnees-](https://www.oqali.fr/donnees-data/data-basis/)

458 publiques/faq/.The OpenFoodFacts data used in the study is available on their website (<https://world.openfoodfacts.org/>, accessed on November 2021) OpenFoodFacts is an open collaborative
459 [//world.openfoodfacts.org/](https://world.openfoodfacts.org/), accessed on November 2021) OpenFoodFacts is an open collaborative
460 database of food products marketed worldwide, licensed under the Open Database License (ODBL).
461 The Ciqua database is freely available on the Ciqua website (<https://ciqua.anses.fr/>).
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588 Table 1: List of the 41 criteria derived from the French dietary guidelines(24,25)

Group	Covered food groups	Type of criteria	Criteria
Fruits and vegetables	Unprocessed fruits Unprocessed vegetables	Position	1) Favourable classification for unprocessed fruits
		Position	2) Favourable classification for unprocessed vegetables
Pulses	Pulses (unprocessed and prepared)	Position	3) Favourable classification for pulses
Cereals	White pasta White rice Whole grain pasta Whole grain rice	Group discrimination	4) Discrimination between whole grain and white pasta
		Group discrimination	5) Discrimination between whole grain and white rice
Bread	White bread Whole grain bread	Group discrimination	6) Discrimination between whole grain and white bread
		Nutrient discrimination	7) Discrimination according to salt content
Savoury snacks	Savoury snacks	Position	8) Unfavourable classification for savoury snacks
Meat (non-processed meat)	Unprocessed beef/ pork/ poultry Meat preparations	Position	9) Unfavourable classification for red meat
		Group discrimination	10) Discrimination between poultry and red meat
Processed meat	Processed meat except ham Ham	Position	11) Unfavourable classification for processed meat
		Group discrimination	12) Discrimination between ham and other processed meat
Cheese	Cheese	Position	13) Unfavourable classification for cheeses with the higher salt content
		Group discrimination	14) Discrimination between cheeses and unsweetened yogurts
		Nutrient discrimination	15) In the cheese category, the best rated products should be those with a lower salt or fat content and those with a high amount of calcium ¹
Nuts	Unsalted nuts Seasoned nuts	Position	16) Favourable classification for unsalted nuts
		Group discrimination	17) Discrimination between unsalted nuts and seasoned nuts
Fats and oils	Olive/ canola /walnut oil Sunflower/coconut oil Cream/ butter	Group discrimination	18) Discrimination between recommended vegetable oils (canola, walnut, olive) and other vegetable oils
		Position	19) Unfavourable classification for animal fats
Fish	Oily fish Lean fish	Group discrimination	20) Similar classification for oily and lean fish (with similar salt content)
Dairy	Unsweetened yogurts	Group	21) Discrimination between

products (except cheeses)	Sweetened yogurts	discrimination	unsweetened and sweetened yogurts
Sauces	Cold sauces Sauces- used warm	Nutrient discrimination	22) Discrimination according to salt content
Soups	Soups and broths	Nutrient discrimination	23) Discrimination according to salt content
Prepared dishes	Prepared dishes	Nutrient discrimination	24) Discrimination according to salt content
Prepared fruits	Canned fruits Compotes	Nutrient discrimination Nutrient discrimination	25) Discrimination according to sugar content for canned fruits 26) Discrimination according to sugar content for compotes
Breakfast cereals	Breakfast cereals	Position Nutrient discrimination	27) Unfavourable classification for sweet breakfast cereals 28) Discrimination according to fibre (proxy of whole grain) content among unsweetened or minimally sweetened breakfast cereals
Fine bakery ware-sweet	Fine bakery ware-sweet	Position	29) Unfavourable classification for fine bakery ware – sweet
Chocolate products	Chocolate products	Position	30) Unfavourable classification for chocolate and chocolate products
Confectionery	Confectionery	Position	31) Unfavourable classification for confectionery
Ice creams	Ice creams and sorbets	Position	32) Unfavourable classification for ice creams
Dairy desserts	Dairy desserts	Position	33) Unfavourable classification for sweet dairy desserts
Sweet spreads	Sweet spreads	Position	34) Unfavourable classification for sweet spreads
Water, tea, coffee, herbal teas	Plain water	Position	35) Favourable classification for plain water
Dairy beverages	Skimmed milk Partially-skimmed milk Whole milk Sweetened flavoured milk Sweetened yogurt to drink	Group discrimination	36) Discrimination between unsweetened milks and sweetened dairy beverages
Sugar and artificially sweetened beverages	Flavoured waters Colas Soft drinks with fruits Lemonades, tonic waters Tea-based beverages Fruit nectars Sweetened flavoured	Position Position	37) Unfavourable classification for sugar-sweetened beverages 38) Unfavourable classification for artificially-sweetened beverages

	milk Sweetened yogurt to drink		
Fruit juices	Fruit juices	Group discrimination Group discrimination Group discrimination	39) Discrimination between fruit juices and fruits and vegetables 40) Discrimination between fruit juices and other sugar-sweetened beverages 41) Discrimination between fruit juices and other artificially- sweetened beverages

589 ¹As calcium data was not available, protein was used as a proxy as proposed by Rayner et al(6). In the
590 French generic food database, Pearson’s correlation coefficient between protein and calcium content
591 among cheeses was 0.71.

592

593 Table 2: Proportions of products rated favourably (A or B) or unfavourable (D or E) for food groups
 594 with a position criterion according to the guidelines with the initial and updated version of the Nutri-
 595 Score algorithm

Food groups	N	Percentage of A and B products		Percentage of D and E products	
		Initial	Updated	Initial	Updated
Unprocessed fruits	73	100%	99%	0%	0%
Unprocessed vegetables	113	100%	100%	0%	0%
Unprocessed pulses	33	100%	100%	0%	0%
Prepared pulses	64	100%	100%	0%	0%
Unsalted nuts	1483	90%	92%	0%	0%
Savoury snacks	1309	5%	1%	72%	91%
Unprocessed beef	29	78%	47%	15%	14%
Unprocessed pork	28	87%	67%	3%	3%
Processed meat	971	2%	4%	80%	87%
Cheese high in salt ¹	207	0%	0%	98%	98%
Cream	946	1%	1%	95%	98%
Butter	1399	0%	0%	99%	99%
Fine bakery ware-sweet	2439	1%	0%	92%	98%
Chocolate products	753	7%	1%	92%	92%
Confectionery	273	7%	7%	81%	89%
Ice creams and sorbets	1303	2%	1%	67%	80%
Sweet dairy desserts ²	516	6%	4%	40%	53%
Sweet spreads	440	1%	0%	57%	92%
Sweet breakfast cereals ³	383	9%	0%	37%	61%
Plain water ⁴	-	100%	100%	0%	0%
Flavoured waters ⁵	68/ 20	52%/ 40%	62%/0%	28%/ 0%	0%/ 40%
Tea-based beverages ⁵	104/ 37	1%/ 16%	1%/ 0%	99%/ 24%	71%/ 35%
Colas ⁵	39/ 103	0%/ 30%	0%/ 0%	100%/ 22%	100%/ 22%
Soft drinks with fruits ⁵	461/ 119	0%/ 2%	1%/ 0%	96%/ 42%	92%/ 42%
Lemonades, tonic waters ⁵	80/ 70	0%/ 21%	0%/ 0%	100%/ 55%	100%/ 59%
Fruit nectars	262	0%	0%	98%	98%
Sweetened flavoured milk	94	93%	0%	0%	87%
Sweetened yogurt to drink	308	87%	5%	1%	90%

596 ¹ Cheeses high in salt corresponds to cheese above to the median salt content of cheeses (cut-off
 597 used: 1.41g of salt/100g).

598 ² Sweet dairy desserts correspond to dairy desserts with sugar content above 12g /100g of product,
 599 according to the classification used in the French national nutrition and health study Esteban(40).

600 ³ Sweet breakfast cereals correspond to breakfast cereals with sugar content above 20g /100g of
 601 product, according to the classification used in the French national nutrition and health study
 602 Esteban(40).

603 ⁴ No products were collected for bottled water. Plain water systematically obtains an A.

604 ⁵ For drinks sweetened with either sugar or a non-nutritive sweetener, two proportions are given:
 605 the first is for sugar-sweetened beverages and then for artificially sweetened beverages.
 606

607 Table 3: Comparison of the modal category of food groups with the initial and updated version of the
 608 Nutri-Score algorithm

Food groups	N	Modal category of the Nutri-Score	
		Initial	Updated
Discrimination between whole grain and refined cereals (pasta)			
White pasta	1380	A	A
Whole grain pasta	55	A	A
Discrimination between whole grain and refined cereals (rice)			
White rice	704	A	B
Whole grain rice	77	A	A
Discrimination between whole grain and white bread			
White bread	571	B	C
Whole grain bread	238	A	B-C ³
Discrimination between poultry and red meat			
Unprocessed beef	29	B	C
Unprocessed pork	28	A	B
Unprocessed poultry	32	A	A
Discrimination between ham and other processed meat			
Processed meat except ham	749	E	E
Ham	222	C	D
Discrimination between cheeses and unsweetened yogurts			
Unsweetened yogurts	142	A	A
Cheeses	413	D	D
Discrimination between unsalted nuts and seasoned nuts			
Unsalted nuts	1483	A	A
Seasoned nuts	1248	C	C
Discrimination between recommended vegetable oils and other vegetable oils			
Canola oil	220	C	B
Olive oil	2552	C	B
Walnut oil	204	C	B
Sunflower oil	228	D	C
Coconut oil	387	E	E
Lack of discrimination between oily and lean fish (with similar salt content) ¹			
Lean fish	1101	A	A
Oily fish	2287	A-B-C ³	A
Discrimination between unsweetened and sweetened yogurts			
Unsweetened yogurts	142	A	A
Sweetened yogurts	445	C	C
Discrimination between fruit juices and other sweetened beverages			
Fruit juices	1080	C	C
Flavoured waters ²	68/ 20	B/ C	B/ C
Tea-based beverages ²	104/ 37	D/ C	D/ C
Colas ²	39/ 103	E/ C	E/ C
Soft drinks with fruit ²	461/ 119	E/ C	E/ C
Lemonades, tonic waters ²	80/ 70	E/ D	D-E/ C-E
Sweetened flavoured milk	94	B	E
Sweetened yogurt to drink	308	B	E
Discrimination between fruit juices and fruits and vegetables			

Unprocessed fruits	73	A	A
Unprocessed vegetables	113	A	A
Fruit juices	1080	C	C
Discrimination between unsweetened milks and sweetened dairy beverages			
Skimmed milk	160	B	B
Semi-skimmed milk	1041	B	B
Whole milk	323	B	C
Sweetened flavoured milk	94	B	E
Sweetened yogurt to drink	308	B	E

609 ¹ For fishes, only products with similar salt content were used for the analysis. While the dietary
610 guidelines consider equally fatty fish and lean fish, they also recommend limiting salt intake by
611 reducing consumption of saltier products. Hence, the comparison of the rating of different fishes'
612 groups was done for products with similar and lower salt content. To exclude the saltier products
613 (mainly smoked fatty fish), only fishes with less than the median salt intake for lean fishes (0.9g of
614 salt/100g) were included in the comparison.

615 ² For drinks sweetened with either sugar or a non-nutritive sweetener, two modal classes are given:
616 the first is for sugar-sweetened beverages and then for artificially sweetened beverages.

617 ³In the case where products were distributed in multiple classes with less than 5% difference
618 between most represented classes, several classes were presented.

619

620 Table 4: Ability of the initial and updated Nutri-Score algorithm to discriminate food groups on critical nutrients (mean (in g/100g of product) ±standard
 621 deviation) for food groups with nutrient discrimination criteria per version of the algorithm, and according to the Nutri-Score category.

Groups	N	Nutrient (in g/100g of product)	Nutri-Score algorithm	Nutri-Score category ¹					Discrimination ability ²
				A	B	C	D	E	
Bread (whole grain and white)	809	Salt	Initial	1.06 (±0.20)	1.18 (± 0.17)	1.33 (± 0.22)	1.61 (± 1.06)		<0.001
			Updated	0.95 (±0.28)	1.09 (± 0.19)	1.18 (± 0.16)	1.36 (± 0.30)	2.44 (± 1.63)	<0.001
Cheese	413	Salt	Initial			0.81 (± 0.45)	1.43 (± 0.47)	3.07 (± 0.65)	<0.001
			Updated			0.75 (± 0.34)	1.44 (± 0.36)	2.75 (± 0.67)	<0.001
		Fat	Initial			16.9 (± 7.5)	26.3 (± 5.0)	33.1 (± 6.7)	<0.001
			Updated			22.6 (± 8.2)	26.3 (± 4.8)	28.0 (± 9.3)	0.04
		Proteins	Initial			19.0 (± 7.3)	19.6 (± 7.0)	20.5 (± 6.2)	0.90
			Updated			22.9 (± 6.4)	19.4 (± 7.0)	16.5 (± 6.3)	<0.001
Sauces-used warm	370	Salt	Initial	0.83 (± 0.33)	1.10 (± 0.29)	1.31 (± 0.50)	1.85 (± 0.87)	2.64 (± 0.42)	<0.001
			Updated	0.71 (± 0.32)	1.04 (± 0.22)	1.19 (± 0.31)	1.49 (± 0.52)	2.77 (± 0.69)	<0.001
Cold sauces	172	Salt	Initial			1.97 (± 0.48)	2.09 (± 0.48)	2.08 (± 0.55)	0.66
			Updated			1.63 (± 0.24)	2.00 (± 0.40)	2.24 (± 0.61)	0.01
Soups	679	Salt	Initial	0.56 (± 0.23)	0.66 (± 0.12)	0.78 (± 0.19)			<0.001
			Updated	0.48 (± 0.24)	0.64 (± 0.34)	0.74 (± 0.18)			<0.001
Prepared dishes	4729	Salt	Initial	0.69 (± 0.24)	0.87 (± 0.25)	1.04 (± 0.34)	1.52 (± 0.68)	1.52 (± 0.24)	<0.001
			Updated	0.61 (± 0.26)	0.74 (± 0.20)	0.90 (± 0.26)	1.34 (± 0.50)	2.08 (± 0.93)	<0.001
Canned fruits	183	Sugars	Initial	13.6 (± 1.5)	13.1 (± 1.7)	16.0 (± 1.4)			<0.001
			Updated		12.5 (± 1.9)	13.8 (± 1.8)			<0.001
Compotes	754	Sugars	Initial	13.6 (± 3.0)	17.7 (± 6.0)	21.1 (± 5.5)			<0.001
			Updated	13.1 (± 2.4)	19.0 (± 3.4)	18.7 (± 5.9)			<0.001
Unsweetened or minimally sweetened breakfast cereals ³	242	Fibre	Initial	10.1 (± 4.1)	6.7 (± 2.8)	7.0 (± 3.6)	7.1 (± 2.7)		<0.001
			Updated	11.4 (± 4.2)	9.2 (± 2.1)	7.1 (± 3.3)	5.5 (± 2.4)		<0.001

622 ¹Results should be read as follows: “Breads rated A with the initial algorithm contained on average 1.06g of salt per 100g of product.”²For each version of
 623 the algorithm, the ability to discriminate was quantified using Kruskal-Wallis tests between the critical nutrient content and the classification. ³Unsweetened

624 or minimally sweetened breakfast cereals correspond to breakfast cereals with a sugar content below 20g of sugar/100g of product, according to the
625 classification used in the French national nutrition and health study Esteban(40).

626

627 Table 5: Evolution of the rating of products in food groups with a nutrient discrimination criterion
 628 depending on their content in critical nutrient content

629

		N	Category	Odds-ratio ¹ [95% CI]	P-value
Bread (whole grain and white)	Salt	176	Did not change	1	
		633	Was deteriorated	3.21 [1.51-7.06]	0.003
Cheese	Salt	361	Did not change	1	
		22	Was deteriorated	4.52 [2.60-7.88]	<0.001
		30	Was improved	0.02 [0.01-0.07]	<0.001
Cheese	Fat	361	Did not change	1	
		22	Was deteriorated	0.91 [0.85-0.97]	0.004
		30	Was improved	1.07 [1.01-1.13]	0.03
Cheese	Proteins	361	Did not change	1	
		22	Was deteriorated	0.86 [0.80-0.92]	<0.001
		30	Was improved	1.21 [1.12-1.30]	<0.001
Sauces-used warm	Salt	230	Did not change	1	
		139	Was deteriorated	3.28 [2.04-5.26]	<0.001
Cold sauces	Salt	130	Did not change	1	
		42	Was deteriorated	3.18 [1.48-6.85]	0.003
Soups	Salt	479	Did not change	1	
		179	Was deteriorated	1.35 [0.51-3.62]	0.55
Prepared dishes	Salt	2176	Did not change	1	
		2507	Was deteriorated	0.93 [0.82-1.07]	0.28
		46	Was improved	0.67 [0.31-1.45]	0.31
Canned fruits	Sugars	59	Did not change	1	
		124	Was deteriorated	0.88 [0.74-1.03]	0.11
Compotes	Sugars	654	Did not change	1	
		100	Was deteriorated	1.49 [1.38-1.60]	<0.001
Unsweetened or minimally sweetened breakfast cereals ²	Fibre	132	Did not change	1	
		107	Was deteriorated	0.63 [0.55-0.71]	<0.001

630 ¹Results in this column should be read as follows: "For each increase by 1g of the nutrient of interest
 631 per 100g of product in the group, the odds for a product to have its rating being deteriorated (resp.
 632 improved) is increased (or deteriorated) if the odds ratio is greater than 1 (or smaller than 1)". For
 633 example, for each 1g increase in salt content in bread, the odds for bread to have its rating being
 634 deteriorated was increased (odds-ratio was 2.87), i.e. breads with a higher salt content were more
 635 likely to have their rating being deteriorated."

636 ²Unsweetened or minimally sweetened breakfast cereals correspond to breakfast cereals with a
 637 sugar content below 20g of sugar/100g of product, according to the classification used in the French
 638 national nutrition and health study Esteban(40).

639