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The Initial Dietary Pattern Should Be Considered when Changing Protein Food Portion Sizes to Increase Nutrient Adequacy in French Adults

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1 The initial dietary pattern should be considered when
2 changing protein food portion sizes to increase nutrient
3 adequacy in French adults^{1,2,3,4}

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⁴ Abbreviations used: ANCOVA, analysis of covariance; AS, Adequacy Sub-score of the PANDiet; DHA, Docosahexaenoic Acid; EI, energy intake (without alcohol); EPA, Eicosapentaenoic acid; INCA2, Second Individual and National Study on Food Consumption Survey; LA, Linoleic Acid; MS, Moderation Sub-score of the PANDiet; PA, Probability of Adequacy; S1, first scenario; S2, second scenario. SFA, Saturated Fatty Acid

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11 **Abstract**

12 *Background.* Patterns of protein food intake are undergoing a transition in Western countries
13 but little is known about how dietary changes to protein intake impact nutrient adequacy of the
14 diet.

15 *Objectives.* Our objective was to identify simple modifications to protein food intake that can
16 gradually increase overall nutrient adequacy.

17 *Methods.* We identified patterns of dietary protein intake in 1,678 adults from a representative
18 French national dietary survey. For each individual, we identified the increase in portion size
19 of one protein food paired with a decrease in portion size of another protein food that would
20 best increase nutrient adequacy (using PANDiet probabilistic scoring). Then, such an optimum
21 simple dual change was iterated 20 times for each individual according to two scenarios, either
22 by manipulating the intake of foods already consumed (Scenario 1, S1) or by enabling the
23 introduction of foods consumed by >10% of individuals with the same protein pattern (Scenario
24 2, S2).

25 *Results.* The optimum stepwise changes to protein intake primarily consisted in reducing
26 portions of delicatessen (both scenarios), sandwiches and cheese (S2), while increasing
27 portions of fatty fish and lean poultry (both scenarios) and legumes (S2). However, these
28 changes differed depending on the initial dietary protein pattern of the individual. For example,
29 in S2, legume intake increased among 'Poultry' and 'Fish' eaters only and low-fat meat among
30 'Take-away eaters' and 'Milk drinkers' only. The improvements in overall nutrient adequacy
31 were similar among the different initial dietary patterns, but this was the result of changes to
32 the adequacy of different specific nutrients.

33 *Conclusions.* Beyond generic changes to protein intake in the entire French adult population,
34 the initial dietary protein pattern is key to identifying the food groups most likely to improve
35 overall nutrient adequacy, and the profile of nutrients whose adequacy can easily be increased.

36 **Keywords:** Protein intake, dietary patterns, nutrient adequacy, portion size, simple changes

37 **Introduction**

38 After long-term trends following World War II, dietary patterns related to sources of
39 protein have been evolving in recent years in western countries (1). Total meat consumption
40 has fallen in France since the early 2000s (2, 3), with different trends depending on the meat
41 considered - beef intakes tended to decrease (-15%) and poultry intakes tended to increase
42 (+24%) between 2000 and 2015 in the Organization for Economic Co-operation and
43 Development (OECD) countries (4). Moreover, the number of people adopting dietary patterns
44 based on the consumption of specific protein foods, like vegetarians, have risen in France and
45 other western countries (5, 6). Furthermore, French and U.S. national dietary guidelines have
46 recommended a reduction in animal proteins (e.g. meat and processed meat) and an increase
47 in the consumption of plant proteins (e.g. legumes) (7, 8). We can therefore expect that a
48 rearrangement of dietary protein sources will continue in the coming years. However, because
49 the nutrient profiles of different protein foods vary considerably (9, 10), patterns of protein food
50 intake are important determinants of the nutrient profile of diets (11-14). Therefore, future
51 changes in protein intake could be expected to affect the nutrient adequacy of the diet, and
52 this effect would vary depending on the initial dietary profile of the individual.

53 Generic dietary guidelines are based on models designed to optimize diets with
54 constraints to meet nutrient and dietary reference values while taking into account individual
55 dietary habits (7, 8, 15). However the level of compliance with these guidelines is low (16, 17).
56 One explanation is that generic guidelines do not account for the different dietary patterns of
57 individuals, or the trajectory which should be adopted to move from their initial diets to an
58 optimized diet. This goes in particular for the first changes that should be made that are mostly
59 dependent on the initial diet. In this context, it seems relevant to study the effects of simple
60 and operable changes to individual diets, such as changes to portion size. Indeed, portion
61 sizes have been identified as acceptable and realistic levers to change consumption behavior
62 (18-20). Furthermore, even if the introduction of new foods is acknowledged as a classic barrier
63 to change, it is also well known to be an efficient lever for the nutritional improvement of diets

64 (21, 22). It is therefore expected that the way and extent of improvements to the nutrient
65 adequacy of the diet will vary depending on initial individual dietary profiles.

66 We saw that protein sources appear to be a part of the diet that is undergoing a
67 transition, and portions sizes are acknowledged as being the best lever to modify food patterns.
68 Our objective was to model a rearrangement of protein foods by simple modifications to portion
69 sizes in order to increase the overall nutrient adequacy of French diets and study the degree
70 to which the improvement might be sensitive to the initial pattern of protein intake.

71 **Methods**

72 *Population, food intake and dietary composition*

73 The population studied was derived from that covered by the second individual and
74 national food consumption study (INCA2⁵) performed in 2006-2007, as previously described
75 (23). Briefly, we excluded adults over 65 years old (whose nutrient requirements differed from
76 that of younger adults) and under- and over-reporters, which led to a final sample of 1,678
77 adults (717 men and 961 women). Under and over-reporters were identified by comparison of
78 the reported energy intake and the basal metabolic rate, as estimated using Henry equations
79 (24), and a cut off-value as defined by Black et al. (25). Food intakes were derived from 7-day
80 food records, and individual characteristics from self-reported and face-to-face questionnaires,
81 as described by Dubuisson et al. (26) (**Supplemental Table 1**). The nutrient composition of
82 the foods has been previously described in detail (11). Briefly, the data was extracted from the
83 2016 CIQUAL (*Centre d'Information sur la Qualité des Aliments* – Centre for Information on
84 Food Quality) database, an amino acid database as previously described (23), and databases
85 on phytate (27), and heme and non-heme iron in animal foods (28-30). Protein digestibility (23)
86 and the bioavailability of iron (31, 32) and zinc (33) were taken into account. The food groups
87 presented in this paper were adapted from the INCA2 food groups, taking into account their
88 fat content. Indeed, meat (excluding poultry) and poultry were both split into two groups
89 depending on whether fat contributed to more than 35% of energy intake or not; 71% of meat
90 foods were “fatty meat” and 61% of poultry foods were “fatty poultry”. Fish was considered as
91 “fatty fish” if the EPA+DHA content was >1g/100g (7); 34% of fish foods were deemed to be
92 “fatty fish”.

⁵ Abbreviations used: ANCOVA, analysis of covariance; AS, Adequacy Sub-score of the PANDiet; DHA, Docosahexaenoic Acid; EI, energy intake (without alcohol); EPA, Eicosapentaenoic acid; INCA2, Second Individual and National Study on Food Consumption Survey; LA, Linoleic Acid; MS, Moderation Sub-score of the PANDiet; PA, Probability of Adequacy; S1, first scenario; S2, second scenario. SFA, Saturated Fatty Acid

93 Based on the INCA2 population, eight clusters of individuals were identified in terms of
94 their patterns of protein food intake (Processed meat eaters, Poultry eaters, Pork eaters,
95 Traditional eaters, Milk drinkers, Take-away eaters, Beef eaters and Fish eaters), as described
96 previously (11).

97 *Nutrient adequacy*

98 Nutrient adequacy was assessed using PANDiet probabilistic scoring (34), as
99 described previously (11), with some modifications to implement the most recently published
100 nutrient dietary reference values (**Supplemental Method 1**). Briefly, the PANDiet score is
101 calculated as the mean of an Adequacy Sub-score (AS), which is the average of the
102 probabilities of adequacy (PAs) of nutrients for which an Estimated Average Requirement is
103 defined, and a Moderation Sub-score (MS), which is the average of the PAs of nutrients with
104 an existing upper bound reference value. The reference values applied were mainly the most
105 recent values published by Anses (35). As a result, we calculated for each individual the
106 PANDiet score (from 0 to 100), in which a higher score reflects a higher overall nutrient
107 adequacy of the diet.

108 *Statistical analyses and models*

109 Stepwise dietary models of changes were used to improve the initial PANDiet score
110 calculated for each individual. The models consisted of a paired increase in the portion size of
111 a protein food with a reduction in the portion size of another protein food in the 7-day diets of
112 the INCA2 individuals. Every possible paired modification was simulated, and the PANDiet
113 score was calculated. The paired modification that most markedly increased the PANDiet
114 score was selected and virtually integrated in the diet of the individual, and this process was
115 iterated 20 times. We arbitrarily limited the models to 20 steps in order to avoid any drastic
116 change to the rearrangements of the diets. Two different scenarios were implemented,
117 depending on the possibility to broaden the food repertoire of the individuals.

118 In the first scenario (S1), individuals could only have paired modifications between two
119 protein foods that they already consumed, and the introduction of “new” foods outside their

120 food repertoire was forbidden. In the second scenario (S2), the introduction of new foods was
121 permitted, but only if these foods were consumed by individuals with a similar patterns of
122 protein food intake, as we had defined previously in the same population (11). In other words,
123 the portion size of a protein food consumed by an individual could be reduced, and paired with
124 the introduction at the portion size step (see below) of a protein food consumed by 10% of the
125 cluster to which the individual belonged.

126 Protein foods were defined as INCA2 food items which met two criteria: 1) the
127 percentage energy from protein was >10%, which refers to their intrinsic protein content, 2)
128 the level of intake at the 90th percentile was >5g protein/portion, which refers to their potential
129 contribution to protein intake at a relatively high level. The percentages of protein foods in each
130 food group are detailed in **Supplemental Table 2**, and the detailed method about the paired
131 modifications of portion sizes, adapted from Bianchi et al. (21), is presented in **Supplemental**
132 **Method 2** and **Supplemental Figure 1**. An example of an individual food record before and
133 after 20 steps of the S2 is presented in **Supplemental Table 5**.

134 Data are means \pm SDs. An overall α level of 5% was used for statistical tests. All means
135 are weighted to account for the study design and ensure the representativeness of the sample
136 as described by Dubuisson et al. (26). ANCOVAs adjusted for sex were used to test the
137 significance of the differences between the initial (observed) and each of the 2 final (simulated)
138 diets in the contributions of food groups to protein intake, and in the probabilities of adequacy
139 when the difference was tested in clusters. ANCOVAs adjusted for sex were also used to test
140 the significance of the difference between each cluster and the overall sample for the
141 increments of probabilities of adequacy, and to test the association between the increment of
142 PANDiet, the initial number of protein food groups consumed, and the initial PANDiet score.
143 Differences in increments of PANDiet, AS or MS scores were also tested using ANCOVA
144 adjusted for sex, with additional adjustments for the initial PANDiet score and the number of
145 initial protein food groups.

146 Statistical analyses and modelling were performed using SAS 9.1.3 (version 9.1.3, SAS
147 Institute Inc., Cary, NC).

148 Results

149 For clarity purposes, the results on clusters are only reported here for four of the eight
150 clusters that were identified, as these clusters differed more markedly from the overall
151 population than the others. The results of all clusters are detailed in **Supplemental Tables 3-**
152 **4.**

153 *Extent of rearrangements of the diets*

154 The diets of individuals involved 152.1 ± 42.9 acts of consumption recorded over 7
155 days, including 28.6 ± 9.3 concerning animal protein foods and 15.1 ± 6.6 relating to plant
156 protein foods. The 20 steps in the stepwise model, making 40 possible modifications to portions
157 of acts of consumption of the diets, led to 17.8 ± 3.9 modifications to different acts of
158 consumption in S1 and 23.0 ± 4.4 in S2, which means that there was approximately two
159 increases or decreases of portion size per act of consumption. In S1, recommended changes
160 consisted of smaller portions of 5.4 ± 2.3 animal protein and 3.3 ± 2.6 plant protein foods, with
161 a mean reduction of 2.6 ± 1.1 portion size steps per protein food. Likewise, in S2, changes
162 consisted of smaller portions of 6.4 ± 2.5 animal and 3.7 ± 3.0 plant protein foods, with a mean
163 reduction of 2.1 ± 0.8 portion size steps per protein food. In S1, larger portions of 5.7 ± 2.1
164 animal protein and 3.9 ± 2.3 plant protein foods were recommended, with 2.2 ± 0.7
165 supplementary portion size steps in each case. In S2, 10.1 ± 3.5 animal protein and 2.0 ± 1.9
166 plant protein foods not originally consumed by the individuals were introduced, resulting in a
167 mean of 1.6 ± 0.4 supplementary portion size steps. Almost no foods already consumed by
168 the individuals increased in S2. Lastly, most of the acts of consumption of the diets were
169 unaffected by the modifications (88.3% and 86.0% for S1 and S2, respectively) (**Figure 1**).

170 *Evolution of the contribution of protein food groups to protein intake*

171 Mean plant protein intakes remained stable from 31.3% (± 8.1) of total protein intake in
172 the initial situation to 31.5% (± 8.4) in S1 and decreased to 30.0% (± 7.6) in S2. Under both
173 scenarios, the main contribution to protein intake of low-fat meat (women only), low-fat poultry,

174 fatty fish, eggs and derivatives (men only), pizzas and quiches and legumes (women only)
175 increased, as opposed to high-fat meat (women only), delicatessen and bread (women only)
176 which decreased (**Figure 2**). In S1 only, the contributions of pasta and lean fish to protein
177 intake increased, while in S2 only, the contribution of yogurts to protein intake increased, and
178 that of high-fat poultry and sandwiches decreased. In S1, the highest rates of increases in the
179 contribution to protein intake concerned lean poultry (+45% compared to the initial
180 contribution), pasta (+40%), legumes (+31%), fatty fish (+26%) and lean meat (+25%),
181 whereas the greatest reductions involved delicatessen (-54%), high-fat meat (-10%) and
182 prepared dishes (-8%). Likewise in S2, the highest increases were for legumes (+225%), fatty
183 fish (+152%), lean poultry (+82%), pizzas and quiches (+61%) and yogurts (+34%) and the
184 most marked reductions concerned delicatessen (-52%), sandwiches (-31%) and cheese (-
185 25%).

186 The rearrangements to protein intake varied according to the four different clusters of
187 dietary protein patterns presented. Indeed, although some food groups were rearranged
188 similarly in all clusters (reduction in delicatessen in both scenarios, reduction of high-fat meat
189 and bread in S2, increase in lean poultry in S2 and pasta in S1), some rearrangements were
190 specific to certain clusters (**Figure 3**). The contribution of lean meat to protein intake increased
191 in S2 among 'Take-away eaters' and in both scenarios among 'Milk drinkers'. Lean poultry
192 increased among 'Milk drinkers' only in S1. Fatty poultry consumption fell in S2 among 'Poultry
193 eaters' and 'Fish eaters'. The contribution of fatty fish increased in all clusters except 'Take-
194 away' eaters in both scenarios and 'Fish eaters' in S1. That of prepared dishes decreased in
195 S2 among all clusters except for 'Take-away' eaters for which it increased. The contribution of
196 pizzas and quiches increased in S2 for 'Take-away eaters' only. That of sandwiches decreased
197 in S2 among all clusters except for 'Fish eaters'. The contribution of bread increased in S1 in
198 all clusters, but not among 'Fish eaters'. Finally, the contribution of vegetables increased
199 among 'Milk drinkers' only, and that of legumes increased in S2 among 'Poultry' and 'Fish
200 eaters' only. The results for all eight clusters are presented in **Supplemental Table 3**.

201 *Changes in nutrient adequacy*

202 In S1 the increment in the PANDiet score (compared to the initial situation) was
203 significantly associated with the initial number of protein food groups ($\beta = 0.15$, $P < 0.0001$) and
204 the initial PANDiet score ($\beta = -0.10$, $P < 0.0001$), independently of the sex and cluster. In S2,
205 the increment in the PANDiet was significantly associated with the initial number of protein
206 food groups ($\beta = -0.08$, $P < 0.0001$) and the initial PANDiet score ($\beta = -0.22$, $P < 0.0001$),
207 independently of the sex and cluster.

208 The mean PANDiet score rose by $3.6 (\pm 1.7)$ after 20 iterations in S1, and by $7.5 (\pm 2.6)$
209 in S2. Without adjustment for initial PANDiet score and initial number of protein food groups,
210 'Poultry eaters' saw a greater increase than the overall sample (8.6 ± 3.0 , $P < 0.0001$) and 'Milk
211 drinkers' a lower increase than the overall sample (6.7 ± 2.1 , $P < 0.0001$) in S2 (**Supplemental**
212 **Figure 2**). In S1, the mean Adequacy Sub-score (AS) of the PANDiet score increased by 2.9
213 (± 2.7). The most important increases of PA were that of vitamin B-6 (7.4 ± 11.2), vitamin B-
214 12 (7.3 ± 12.7) and EPA + DHA (7.0 ± 12.9). The mean MS increased by 4.41 ± 3.4 . The most
215 important increases of PA were that of SFA (9.8 ± 11.9), total fat (7.7 ± 13.4) and sodium (6.6
216 ± 9.9). In S2, the mean AS increased from 64.4 to 74.1 (9.7 ± 4.6). The most important
217 increases of PA were that of EPA+DHA (43.7 ± 37.1), vitamin B-6 (19.2 ± 22.2) and vitamin B-
218 12 (18.7 ± 24.1). The mean MS rose from 63.5 to 68.7 (5.2 ± 3.8). The most important
219 increases of PA were that of SFA (12.7 ± 14.1), total fat (10.1 ± 16.4) and sodium (7.2 ± 10.7).
220 After adjustment for the initial PANDiet score and the initial number of protein food groups,
221 'Poultry eaters' and 'Fish eaters' had a higher increase of PANDiet than the overall sample,
222 and 'Milk drinkers' and 'Take-away eaters' a lower increase in S2.

223 The increments varied depending on the initial cluster. Indeed, although the PAs of total
224 fat and vitamin B-12 increased in all clusters and all scenarios and the PAs of copper, iron,
225 iodine, riboflavin, folate and vitamin B-6 increased in all clusters in S2, some PAs increased in
226 some clusters but not others (**Figure 4**). The PAs of EPA+DHA and sodium increased in S2 in
227 all clusters except for 'Take-away eaters'. The PA of fiber increased among 'Poultry' and 'Fish

228 eaters' but not in the other clusters in S2, and the PA of zinc increased among 'Take-away
229 eaters' and 'Milk drinkers', but not in the other clusters in S2. The PAs of calcium, potassium
230 and vitamin A increased in S2 in all clusters except for 'Fish eaters'. The results for all eight
231 clusters are presented in **Supplemental Table 4**.

232 In S2, the increase in the AS and MS was higher among 'Poultry eaters' than in the
233 overall population (respectively 10.7 ± 5.2 , $P < 0.001$ and 6.5 ± 4.5 , $P < 0.0001$), due to higher
234 increases in PAs for riboflavin, folate, vitamin B-6, B-12, fiber and SFA. The increment in the
235 AS was lower among 'Milk drinkers' than in the overall population (7.7 ± 3.6 , $P < 0.0001$) due to
236 lower increments of PAs for fiber, folate and vitamin B-6. The increment in the MS was smaller
237 among 'Take-away eaters' than in the overall population (4.2 ± 4.4 , $P < 0.01$), due to the lower
238 PA for sodium. This cluster had lower PAs for folate, EPA+DHA and fiber but higher PAs for
239 vitamin A, zinc and LA. Finally, the increments in the AS and MS among 'Fish eaters' did not
240 differ significantly from those in the overall population, but the increments in fiber and Vitamin
241 B-12 were higher than in the overall population (**Supplemental Figure 3**).

242 **Discussion**

243 We showed that the nutrient adequacy of the diet could be increased by means of small
244 and a priori acceptable rearrangements to the protein intake of the diet. Another important
245 finding was that some changes were common to most individuals whereas others were specific
246 to the initial pattern of protein intake. This is explained by the presence or absence of certain
247 levers in the food repertoire, and by the initial profile of nutrient adequacy. Accordingly,
248 although the overall improvement was the same, the final profile of nutrient adequacy was
249 closely dependent on the initial pattern of protein intake of the individuals.

250 *Characteristics of dietary rearrangements*

251 Because the actual number of modified acts of consumption was limited (11.7% and 14.0%
252 of the total acts of consumption in the 7-day food records in S1 and S2 respectively), and as
253 the modifications often concerned the same food groups (e.g. 31 and 28% of the foods whose
254 portions were reduced were delicatessen in S1 and S2, respectively), it could be considered
255 that the changes simulated in the models constituted very moderate rearrangements of the
256 diets that could be well accepted. Furthermore, the changes were based on modifications to
257 portion sizes, which was acknowledged as being an acceptable lever to modify the dietary
258 structure of the protein sources consumed (18, 36, 37). Experiments have shown that
259 modifying the portion sizes of meat products can change the food behaviors of consumers
260 without affecting their satisfaction (19) and without the need for any compensation (20).

261 In S2, almost all the increases in portion sizes actually consisted in introducing new foods
262 from the cluster food repertoire. This showed that, even though it seemed more acceptable to
263 simply change the portion sizes of foods already consumed (as in S1), the introduction of new
264 foods (as in S2) is required for a higher increase in nutrient adequacy.

265 *Nature and impacts of the rearrangements*

266 In the overall population, we were able to identify certain food groups that were critical to
267 the improvement of nutrient adequacy when portion sizes were modified, whatever the

268 specificity of the initial protein intake. These findings add important data to the debate on the
269 nutritional value of protein sources (9, 10, 38-41) and could have practical implications for the
270 development of dietary guidelines that advocate changes to protein intake.

271 When using only protein foods already consumed by the individuals (S1), improvements in
272 nutrient adequacy were mainly due to the reduction of nutrients whose intake needed to be
273 moderated (moderation sub-score), namely SFA, total fat and sodium. This was mainly
274 explained by the reduction in portion sizes of delicatessen in the overall population and fatty
275 meat in women. The parallel increases in portion sizes (mainly of lean poultry and pasta) were
276 sufficient to maintain the intakes of indispensable nutrients, but resulted in a moderate increase
277 in the adequacy sub-score. It thus appeared that when limited to the food repertoires of
278 individuals, a rearrangement of protein intake to achieve a better overall nutrient adequacy
279 was mainly driven by reductions in the portions of “unhealthy” foods for everyone (namely
280 delicatessen).

281 By contrast, when allowing the introduction of protein foods consumed by individuals with
282 similar patterns of protein intake (S2), an improvement in nutrient adequacy could be explained
283 by an increase in both the sub-scores of moderation (MS) and adequacy (AS). It appeared that
284 beneficial rearrangements of protein food intake were largely dependent on the presence or
285 absence of certain food groups in the food repertoire of the clusters. Indeed, as ‘Fish’ and
286 ‘Poultry’ eaters had legumes in their food repertoire, respectively 35% and 29% of the
287 increases in portion size concerned legumes in these clusters, and the PAs for fiber increased
288 more compared to the overall population. After adjustment for the initial PANDiet score and
289 initial number of protein food groups, the increments of PANDiet were higher in these clusters
290 than in the overall population. Conversely, legumes were not included in the cluster repertoire
291 of ‘Milk drinkers’ whereas vegetables (mostly spinach) and fatty fish were. This resulted in the
292 fact that 12% and 16% of the total increases in portions were vegetables and fatty fish
293 (respectively), leading to greater improvements in the adequacy of intakes for EPA and DHA
294 when compared to the overall population. Finally, legumes, vegetables or fatty fish were not in

295 the repertoire of 'Take-away eaters', but prepared dishes (mostly chicken cordon bleu) and
296 lean meat were. Therefore 19% and 15% of the total increases in portions were made up of
297 prepared dishes and lean meat. The improvements in adequacy for zinc, vitamin B-6 and LA
298 were higher, but the improvement in adequacy for sodium was lower among 'Take-away
299 eaters' than in the overall population. Finally, after adjustment for the initial PANDiet score and
300 the initial number of protein groups, the increments of AS and PANDiet were lower among 'Milk
301 drinkers' and 'Take-away eaters', and the increment of MS was lower among 'Take-away
302 eaters' than in the overall population. More globally, the increment in the PANDiet score was
303 much higher when expanding the habitual protein food repertory of individuals, which is in line
304 with a general idea proposed in previous studies (21, 22). Our results clearly showed that the
305 improvement in nutrient adequacy was closely dependent on the initial pattern of protein intake.
306 This initial pattern was itself associated with a specific nutrient profile, and with the likelihood
307 of introducing certain specific alternative foods that did not constitute part of the basic structure
308 of intake. Accordingly, the highest relative increments of AS were seen in clusters that included
309 legumes in their repertoires. The ability to expand the type of protein intake is critical in
310 achieving the correct path towards nutritional improvement.

311 The adequacy of the intakes of some nutrients was unaffected among most of the clusters,
312 either because the PAs were originally close to 100% (e.g. potassium, niacin) or because the
313 rearrangements to protein intake were independent of their effect on the adequacy of these
314 nutrients (e.g. LA or ALA). This indeed points at a separate rearrangement of specific sources
315 of fats such as oils, as it is classically advocated in dietary guidelines (8, 42).

316 It is difficult to compare the changes to protein intake identified here with general dietary
317 guidelines, because the latter are built on a modelled diet (7, 8, 15, 43) that takes into account
318 all food groups and parameters apart from nutrient adequacy, such as epidemiological risk
319 (e.g. limiting intakes of red meat and delicatessen). Furthermore, in the reference diets that
320 support general guidelines, nutrient adequacy is usually a constraint, whereas in our stepwise
321 approach, improved nutrient adequacy is the objective. Indeed, the aim of the present research

322 was to characterize the first changes that would need to be made regarding protein choices to
323 achieve better nutrient adequacy, while taking into account the obstacles linked to
324 consumption habits, rather than focusing on a distant general optimal diet. However, these
325 pathways towards improvement do not contradict general guidelines. This is shown by our
326 finding on the importance of reducing the intake of delicatessen and increasing that of legumes,
327 vegetables, fatty fish and yogurts, which have been advocated by the French Food Agency
328 and the 2015-2020 US dietary guidelines (7, 8).

329 Some limitations affecting our study methodology should be underlined. Our models did
330 not lead to a reduction in total meat intake (except for delicatessen meat), because no specific
331 epidemiological-based target for reduction was implemented. Moreover, the initial meat
332 consumption was moderate, and the substitution of fatty meat by lean meat improved overall
333 nutrient adequacy. The PAs of nutrients in the MS have more weight in the PANDiet score
334 than the nutrients of the AS, as there are fewer nutrients in the MS than in the AS. This may
335 partly explain why the rearrangements mostly seemed to be driven by the PAs of SFA and Na
336 in the simulations. However, the rationale for the construction of the PANDiet score is to
337 achieve an equal balance between positive and negative sub-scores, and this also ensures a
338 weak association with energy intake.

339 The type of scenarios for the changes (based on either the individual or cluster repertoires)
340 exerted a strong influence on the results of this study. Indeed, interpretation of the results of
341 the cluster repertoire scenario (S2) relative to the general population could not seem relevant
342 as it was driven by the cluster repertoires. However, the S2 could be interpreted as a
343 probabilistic approach to identifying protein foods that individuals do consume occasionally but
344 that were not captured in the 7-day food record. Indeed, although this food record method is
345 relevant to studying food intakes at a population level, it involves some uncertainties when
346 trying to evaluate the usual food repertoire of individuals using a record of a few days at a
347 certain time of the year. Our approach using the cluster repertoire could therefore offer a
348 means to include foods that are “probably/possibly consumed” by individuals. Finally, the

349 cluster repertoire may represent a scenario for changes to the intake of protein foods that might
350 be acceptable to the individuals concerned.

351 The rules of compatibility between food groups were established to avoid paired
352 modifications that were not relevant (e.g. an increase in yogurt intake paired with a reduction
353 in delicatessen intake) and also influenced the results. Indeed, because milk portions could
354 only be replaced by other milks or plant-based milk, the milk intake remained constant in all
355 scenarios. However, these rules were necessary to ensure that the modifications made sense
356 in the prevailing diet context, and that they were acceptable and realistic. A study identified
357 empirically which foods are usually replaced by other foods in the current dietary context and
358 validated some of our rules: for example, bread can be replaced by rusks or viennoiseries at
359 breakfast, and by other foods such as potatoes at lunchtime (44).

360 To conclude, we identified nutritional levers to increase nutrient adequacy using simple
361 and in principle acceptable rearrangements of protein food intakes based on changes to
362 portion sizes in the diets of a representative French population. We found that minor
363 rearrangements to protein food intakes were efficient in significantly improving the overall
364 nutrient adequacy of the diets. Changes to the portion size of some food groups were efficient
365 in the overall population, and consisted in reducing the portions of delicatessen, sandwiches
366 and cheese, and increasing the portions of legumes, fatty fish and lean poultry. However, the
367 food groups that proved to be efficient nutritional levers differed depending on the initial pattern
368 of protein intake, and ultimately the type of improvement to nutrient adequacy differed between
369 the clusters of protein intake. This could mainly be ascribed to the presence or absence of food
370 groups in the food repertoires of individuals, which did or did not offer easy and efficient
371 solutions to improve the specific profile of nutrient adequacy associated with their pattern of
372 protein intake. Therefore, in order to better address the rearrangements of consumption that
373 individuals could implement, it seems important to increase their willingness to consume a
374 large number of protein foods that are levers for nutritional adequacy.

375 This work thus showed that changes to the type of protein intake offer an efficient
376 means to improve nutrient adequacy of the diet, while advocating the importance of developing
377 guidelines for optimum choices among protein foods. We also showed that the variety of initial
378 patterns might limit the practical applicability of food dietary guidelines in an overall population.
379 Identification of the dietary background profile using patterns of protein intake proved to be
380 useful to indicate the practical best options of changes from the various initial patterns of
381 protein intake.

382

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384 E.G., F.M. and J-F.H. designed the study. E.G. analyzed the data, performed the statistical
385 analysis and wrote the first draft of the manuscript; F.M., J-F.H., H.F. contributed to writing the
386 manuscript and offered critical comments; E.G., F.M., J-F.H. and H.F. interpreted the results;
387 E.G. and F.M. had primary responsibility for final content; and all authors read and approved
388 the final manuscript.

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Legends for figures

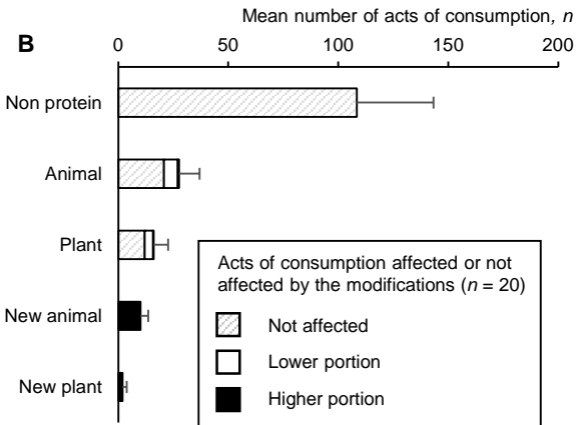
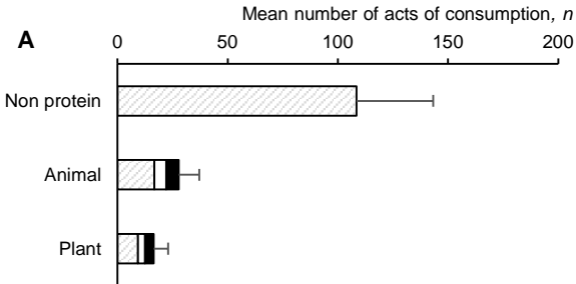
FIGURE 1. Mean number of acts of consumption of non-protein, animal protein and plant protein foods affected or not by rearrangements of the diets after 20 steps of the stepwise model in the INCA2 population ($n=1,678$). The bars are means and the error bars are the standard deviation of the total numbers acts of consumption. In Scenario 1 (A), dual changes in portion size (i.e. reduction in one protein food and increase in another) were only permitted between foods already consumed by the individuals, and in Scenario 2 (B) “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged. Therefore, acts of consumption involving “new” animal and plant protein foods involved those consumed by 10% of the cluster but not originally consumed by the individuals. As “new” foods refer to foods not originally consumed, they are not presented as a part of the initial bar of acts of consumption, but as a new bar in the figure. Protein foods were considered to be “animal” or “plant” if >50% of protein in the food originated from animal or plant sources.

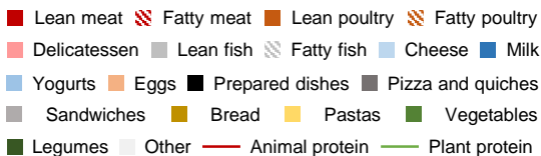
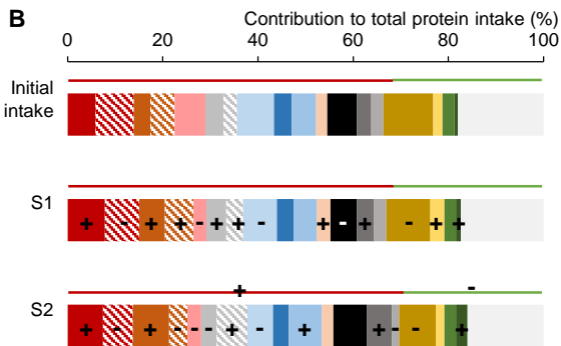
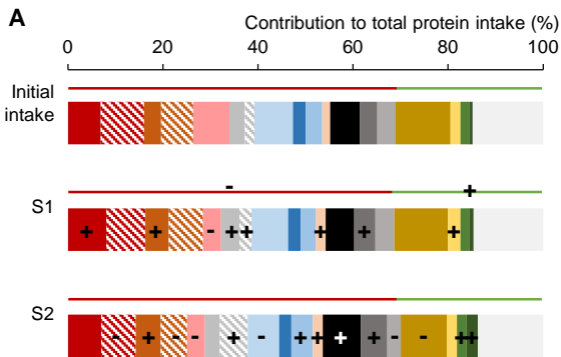
FIGURE 2. Mean contributions of different food groups to protein intake (%) in the initial situation and after 20 steps of the stepwise models in men (A) and women (B) in the INCA2 population (2006-2007) ($n=1,678$). In S1 (Scenario 1), dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals, and in S2 (Scenario 2) “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged. “+” means that the mean contribution was higher than in the initial situation and “-“ means it was lower ($P<0.05$). For example, after 20 steps in the scenario S1, lean meat contributed to 8.0% of total protein intake in men, which is significantly higher than the 6.9% in the initial situation. The food groups shown contributed to >2% of total protein intake in at least one gender in the initial situation, S1, or S2, and gained or lost >1% in S1 or S2.

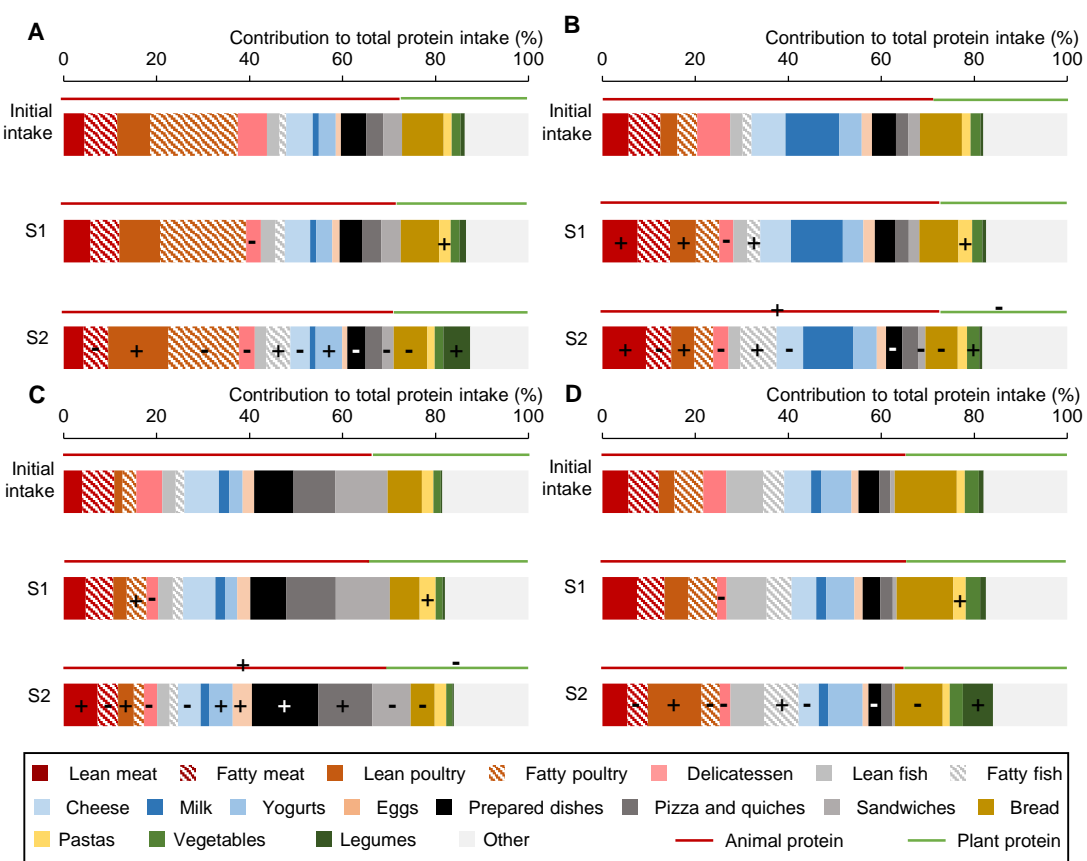
FIGURE 3. Mean contributions of different food groups to protein intake (%) in the initial situation and after 20 steps of the stepwise models in four of the eight clusters of protein intake in the INCA2 population (2006-2007) ($n=1,678$). A, Poultry eaters; B, Milk drinkers; C, Take-away eaters; D, Fish eaters. In S1 (Scenario 1), dual changes in portion size (i.e. reduction in one protein food and increase in another) were only permitted between foods already consumed by the individuals, and in S2 (Scenario 2) “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged. “+” means that the mean contribution was higher than in the initial situation and “-“ that it was lower ($P<0.05$, adjusted for sex). For example, after 20 steps in the scenario S1, delicatessen meat contributed to 3.3% of total protein intake among ‘Poultry eaters’, which is significantly lower than the 6.3% in the initial situation. The food groups shown contributed to >2% of total protein intake in at least one of the eight clusters in S1 or S2, and gained or lost >1% in S1 or S2.

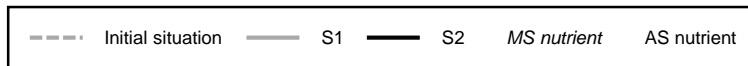
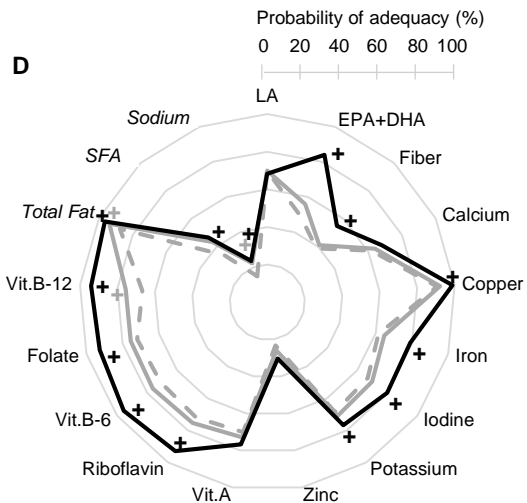
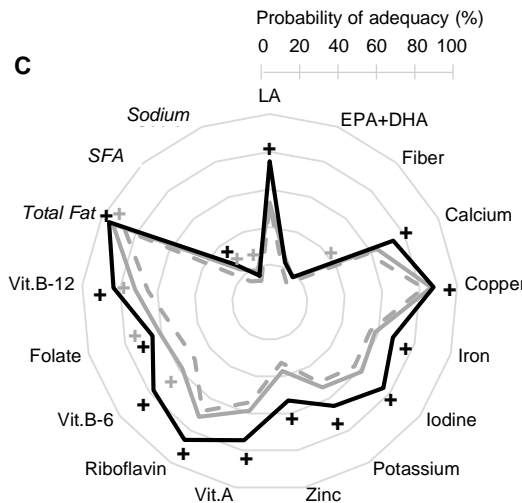
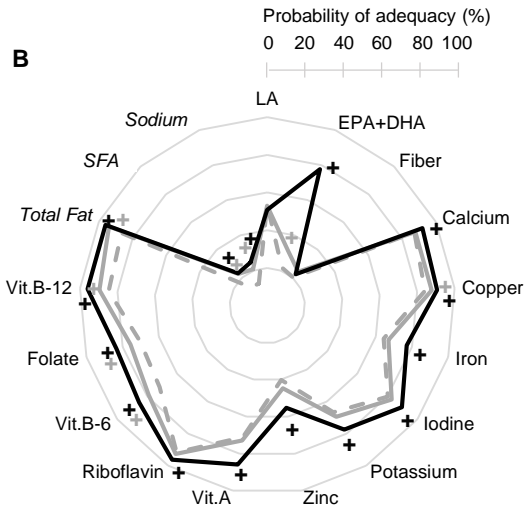
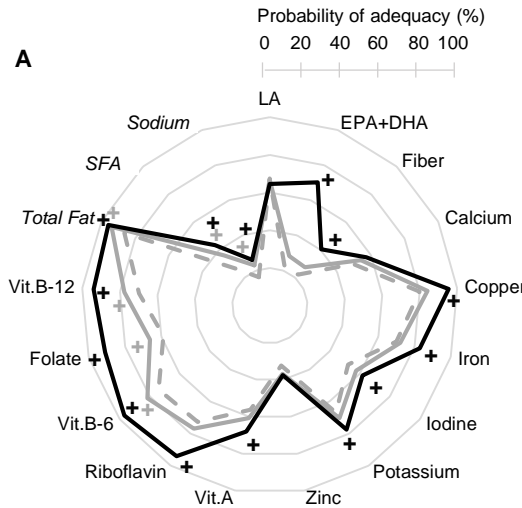
FIGURE 4. Mean probabilities of adequacy of nutrients making the most contribution to changes in the PANDiet score in four of the eight clusters of protein intake in the INCA2 population (2006-2007) ($n=1,678$), in the initial situation, and the two scenarios for a rearrangement of protein intake. A, Poultry eaters; B, Milk drinkers; C, Take-away eaters; D, Fish eaters. In S1 (Scenario 1), dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals, and in S2 (Scenario 2) “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged. For example, the probability of adequacy of EPA+DHA was 70.2% after 20 steps in the scenario S2, which is significantly higher than 21.9% in the initial situation. The probabilities of adequacy that contributed to <0.5 to the increase in the adequacy or moderation sub-scores of the PANDiet score were not shown. AS, Adequacy Sub-score of the PANDiet; Chol, Cholesterol; DHA, Docosahexaenoic Acid; EI, Energy Intake (without alcohol); EPA, Eicosapentaenoic acid; LA, Linoleic Acid; MS,

Moderation Sub-score of the PANDiet; SFA, Saturated Fatty Acid. “+” means that the mean contribution was greater than in the initial situation and “-“ means it was lower ($P<0.05$).









Supplementary Data

Supplemental Table 1. Socio-demographic characteristics and food groups intake of men and women in the INCA2 population ($n=1,678$).

	Men ($n=717$)	Women ($n=961$)
Age¹ (%)		
18-24	14.1	15.0
25-34	18.7	23.4
35-49	35.2	33.0
50-65	31.9	28.6
Body Mass Index (%)		
≤ 25	59.8	76.1
25 < BMI ≤ 30	30.9	18.1
> 30	9.3	5.8
Size of agglomeration (%)		
≤ 2,000	29.5	20.2
> 2,000 - 20,000	15.4	17.1
> 20,000 - 100,000	11.1	15.8
> 100,000	25.2	32.9
Paris agglomeration	18.8	13.4
Occupational category (%)		
Farmer	3.0	2.0
Craft and related trades workers	7.3	5.8
Managers and higher intellectual occupations	12.9	15.7
Intermediate occupations	16.3	19.0
Service and sales workers	9.4	15.5
Manual workers	30.7	20.3
Retirees	18.6	17.2
Other non-economically active	1.87	4.6
Food groups intake² (g/j)		
Bread and bread products	149.0 ± 87.9	102.1 ± 52.3
Breakfast cereals	8.6 ± 27.9	12.8 ± 27.1
Pastas	169.2 ± 130.6	119.8 ± 87.3
Rice or wheat	110.7 ± 111.5	81.4 ± 76.0
Other cereals	2.7 ± 23.0	3.2 ± 25.0
Viennoisery	40.5 ± 54.8	33.7 ± 37.8
Sweet or savory cookies and bars	28.0 ± 41.8	25.3 ± 28.6
Pastries and cakes	117.5 ± 120.7	114.8 ± 84.9
Milk	108.9 ± 165.6	112.3 ± 138.0
Dairy products	125.3 ± 115.3	129.9 ± 77.8
Cheese	60.7 ± 40.6	46.5 ± 31.9
Eggs and derivatives	67.4 ± 83.6	66.6 ± 63.9
Butter	16.3 ± 14.2	13.8 ± 9.7
Oil	14.5 ± 12.3	16.4 ± 10.8
Margarine	4.8 ± 9.1	5.7 ± 7.9
Other fat	0.5 ± 3.6	0.2 ± 1.5
Lean meat (excl. poultry)	96.6 ± 93.5	72.0 ± 66.2

Supplementary Data

High-fat meat (excl. poultry)	118.5 ± 84.8	89.4 ± 59.4
Lean poultry and game	62.4 ± 91.2	44.8 ± 55.1
High-fat poultry and game	103.4 ± 133.0	66.9 ± 86.2
Offal	16.2 ± 48.8	13.9 ± 35.4
Delicatessen meat	90.5 ± 60.1	63.5 ± 40.9
Lean fish	69.9 ± 82.4	61.7 ± 64.5
Fatty fish	43.9 ± 74.9	46.6 ± 59.1
Crustaceans and mollusks	20.6 ± 43.8	20.2 ± 35.5
Vegetables (excl. potatoes)	165.7 ± 86.8	164.1 ± 72.6
Potatoes and related	167.7 ± 107.8	134.9 ± 78.7
Legumes	57.0 ± 104.3	40.8 ± 73.8
Fruit	170.7 ± 156.6	183.1 ± 128.4
Dried fruits and oilseeds	11.8 ± 27.6	8.1 ± 16.8
Ice cream and frozen desserts	31.6 ± 62.6	35.1 ± 52.4
Chocolate	18.5 ± 35.7	17.4 ± 27.2
Sugars and derivatives	24.0 ± 23.3	24.3 ± 20.6
Water	787.6 ± 568.1	826.8 ± 530.6
Nonalcoholic soft drinks	261.1 ± 299.9	214.2 ± 205.6
Alcoholic beverages	351.2 ± 338.0	152.7 ± 199.1
Coffee	326.1 ± 312.2	272.5 ± 292.5
Other hot drinks	104.4 ± 189.1	216.6 ± 267.1
Pizzas, quiches and salted pastries	147.6 ± 177.5	108.7 ± 127.1
Sandwiches, snacks	99.0 ± 142.2	63.8 ± 92.9
Soups and broths	150.7 ± 212.6	192.5 ± 195.0
Prepared dishes	243.2 ± 188.5	178.4 ± 121.0
Desserts, puddings and milk jelly	83.3 ± 101.9	75.0 ± 74.4
Stewed fruit and compote	36.9 ± 77.3	57.5 ± 88.4
Condiments and sauces	33.4 ± 27.3	29.8 ± 18.5
Foods intended for particular nutritional uses	2.4 ± 26.3	2.5 ± 27.4

¹ Percentage of men and women in the categories of age, body mass index, size of agglomeration and occupational category.

² Food groups intake are presented as means ± SDs.

Supplementary Data

Supplemental Table 2. Percentage of food items considered as “protein foods” by food group of the INCA2 nomenclature.

Food groups	Number of protein food items¹ (as % of total food items in the food group)
Bread and bread products	18 (72%)
Breakfast cereals	5 (21%)
Pastas	3 (60%)
Rice or wheat	2 (50%)
Other cereals	1 (25%)
Viennoisery	1 (8%)
Sweet or savory cookies and bars	1 (3%)
Pastries and cakes	4 (9%)
Milk	15 (71%)
Dairy products	36 (59%)
Cheese	91 (87%)
Eggs and derivatives	11 (85%)
Butter	0 (0%)
Oil	0 (0%)
Margarine	0 (0%)
Other fat	1 (17%)
Meat	35 (100%)
Poultry and game	23 (100%)
Offal	15 (88%)
Delicatessen meat	53 (96%)
Fish	71 (93%)
Crustaceans and mollusks	18 (90%)
Vegetables (excl. potatoes)	10 (10%)
Potatoes and related	2 (17%)
Legumes	10 (91%)
Fruit	0 (0%)
Dried fruits and oilseeds	8 (32%)
Ice cream and frozen desserts	0 (0%)
Chocolate	0 (0%)
Sugars and derivatives	0 (0%)
Water	0 (0%)
Nonalcoholic soft drinks	1 (2%)
Alcoholic beverages	0 (0%)
Coffee	1 (14%)
Other hot drinks	3 (27%)
Pizzas, quiches and salted pastries	17 (81%)
Sandwiches, snacks	29 (100%)
Soups and broths	6 (32%)
Prepared dishes	69 (88%)
Desserts, puddings and milk jelly	13 (41%)
Stewed fruit and compote	0 (0%)
Condiments and sauces	0 (0%)
Foods intended for particular nutritional uses	6 (37%)

¹Some foods were excluded as they were ingredients (e.g. gelatin) (n = 9), or were considered to be too expensive (e.g. lobster) (n = 6). Finally, 564 protein foods were accounted for in the models.

Supplementary Data

Supplemental Method 1. Implementation of the PANDiet score to the present study. The PANDiet score, expressed as the average of an adequacy subscore (accounting for 27 nutrients), and a moderation subscore (accounting for six nutrients, plus 12 potential penalty values). DHA and EPA + DHA are weighted by 1/2 as DHA is counted twice. Niacin equivalents were calculated as the sum of dietary niacin and 1/60 dietary tryptophan. The upper reference value for sugars excludes lactose. The tolerable upper intake limit for vitamin A concerns retinol only. ALA, Alpha Linolenic Acid. bw, body weight. DHA, Docosahexaenoic Acid. EIEA, Energy Intake Excluding Alcohol. EPA, Eicosapentaenoic acid. LA, Linoleic Acid. NE, Niacin Equivalent. SFA, Saturated Fatty Acid.

PANDiet score			
Average of Adequacy and Moderation subscores			
Adequacy subscore			
Nutrient	Reference value (/day)	Variability	Source
Protein	0.66 g/kg bw	12.5%	(1)
LA	3.08% EIEA	15%	(3)
ALA	0.769% EIEA	15%	(3)
DHA	0.192 g	15%	(3)
EPA + DHA	0.385 g	15%	(3)
Fiber	23 g	15%	(2)
Vitamin A	570 or 490 µg	15%	(2)
Thiamin	0.3 mg/1000 kcal	20%	(4)
Riboflavin	1.3 mg	15%	(5)
Niacin	5.44 mg NE/1000kcal	10%	(2)
Panthenic acid	3.62 or 2.94 mg	30%	(2)
Vitamin B-6	1.5 or 1.3 mg	10%	(6)
Folate	250 µg	15%	(2)
Vitamin B-12	3.33 µg	10%	(2)
Vitamin C	90 mg	10%	(2)
Vitamin D	10 µg	25%	(2)
Vitamin E	5.8 or 5.5 mg	40%	(2)
Calcium	860 (<= 24 y.o.) or 750 (>24 y.o.)	15% or 13%	(2)
Copper	1.0 or 0.8 mg	15%	(2)
Iodine	107 µg	20%	(2)
Bioavailable iron	See formula in de Gavelle et al. (7)		(2)
Magnesium	5 mg/kg bw	15%	(2)
Manganese	1.56 or 1.39 mg	40%	(2)
Phosphorus	Calcium (mmol) / 1.65 c.f. phosphorus section in de Gavelle et al. (7)	7.5% + CV Calcium (mg)	(8)
Potassium	2692 mg	15%	(9)
Selenium	54 µg	15%	(2)
Bioavailable zinc	0.642 + 0.038 b.w.	10%	(2)

Moderation subscore			
Nutrient	Reference value (/day)	Variability	Source
Protein	2.2 g/kg bw	12.5%	(2)
Total fat	44% EIEA	5%	(2)
SFA	12% EIEA	15%	(3)
Carbohydrates	60.5% EIEA	5%	(2)
Sugars	100 g	15%	(2)
Sodium	3312 or 2483 mg	30%	(2)

Tolerable Upper Intake Limits		Source
Vitamin A	3000 µg	(2)
Niacin	900 mg	(2)
Vitamin B6	25 mg	(2)
Folate	1170 µg	(2)
Vitamin D	100 µg	(2)
Vitamin E	300 mg	(2)
Calcium	2500 mg	(2)
Copper	10 mg	(2)
Iodine	600 µg	(2)
Dissociable magnesium	250 mg	(2)
Selenium	300 µg	(2)
Zinc	25 mg	(2)

The modifications of the PANDiet score from the previous version (7), are as follows:

- the cholesterol reference value was removed from the Moderation sub-score of the PANDiet score, as no reference value was set in the most recent opinions by the French (3) or the European Food Safety Authority (EFSA) (10) or in the Dietary Guidelines for Americans (11),
- the reference values for riboflavin and potassium were updated as the EFSA in recent opinions (5, 9), so we updated these references in the PANDiet score,
- the reference values for total fat and carbohydrates were updated to ensure a 97.5% of probability of adequacy for the upper limit of the confidence interval defined by Anses (2), considering a small coefficient of variation of 5%. As a result, for 44% Energy Intake Excluding Alcohol (EIEA) of total fat and 60.5% EIEA of carbohydrates, the probability of adequacy of an individual would be 50%.

Supplementary Data

Supplemental Method 2. Details about the dual modifications of portions sizes of protein foods.

As reported by Bianchi et al. (12), the foods were grouped into “serving size sub-groups” ($n = 132$), which corresponded to the sets of foods items consumed at the same time in similar amounts. As the models allowed an increase or decrease in the quantity consumed of the protein foods, possible variations in quantity were defined for each sub-group as “portion size steps”. The portion size step for some sub-groups, defined for foods sold in units or packs (e.g. yogurts) ($n = 18$), was the quantity in one unit or pack. For the other 114 sub-groups, the portion size step was defined as follows:

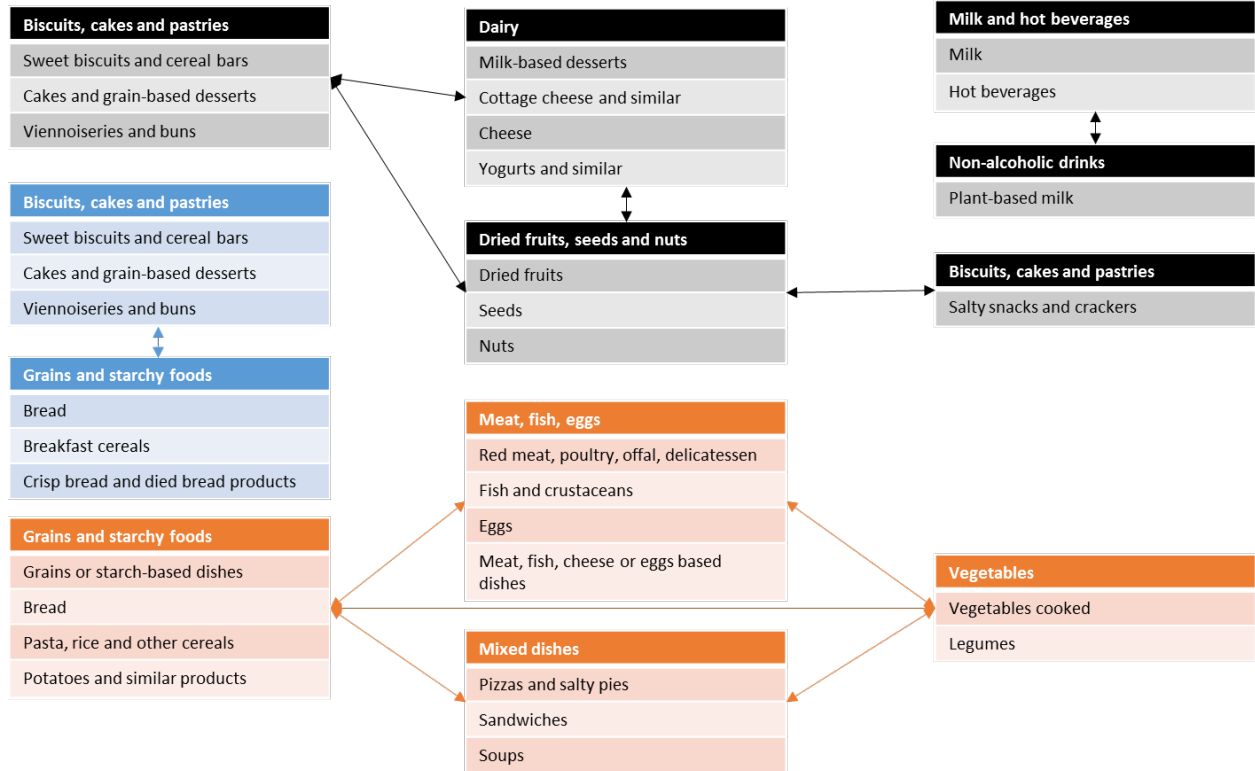
$$STEP_i = \left(\frac{(P25_i - P10_i) + (P50_i - P25_i) + (P75_i - P50_i) + (P90_i - P75_i)}{4} \right)$$

Each step in the models consisted in decreasing (or increasing) the declared serving size by one portion size step lower (or higher). In M2, the quantity of food introduced from outside the food repertoire was one portion size step. The lowest portion permitted when reducing the portion size was 0 g and the highest portion permitted was defined as the 90th percentile of intake of the serving sub-group. The paired modifications of portions were constrained between food groups that could be substituted according to the French cultural meal scheme (e.g. modifications to portions of meat could not be paired with yogurts). The rules of compatibility between food groups for paired modifications, adapted from Bianchi et al. (12), are described in **Supplemental Figure 1**.

Finally, the steps of the model in each individual diet could not lead to an increase or decrease in the initial energy intake of more than 10%, and to protein and indispensable amino acids intakes lower than the Estimated Average Requirement.

Supplementary Data

Supplemental Figure 1. Diagram presenting the possible paired modifications of portion sizes (one protein food gets a lower portion and one protein food gets a higher portion), depending on the meal, between food subgroups belonging to different food groups. The name of the food group is presented in bold in the first row of each box. The names of the food subgroups belonging to the group are presented from the second row to the last row of the box. The paired modifications are allowed between protein foods within the food groups and with other food groups when an arrow connects two food groups only. The paired modifications of portions of protein foods belonging to food subgroups whose name are written in orange are allowed in lunch and dinner only, those whose name are written in blue are allowed in breakfast only and those whose name is written in black are allowed in every occasion.



Supplementary Data

	Meat dishes eaters					Poultry eaters					Pork eaters					Traditional eaters				
	Init ¹	S1 ²	P-value ³	S2 ⁴	P-value ⁵	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value
Lean meat (excl ⁶ poultry)	3.7	5.0	0.0105	3.0	0.1595	4.5	5.8	0.0717	4.3	0.7549	11.1	12.6	0.0915	12.3	0.1996	4.0	5.3	0.0002	3.9	0.952
Fatty meat (excl poultry)	8.5	8.1	0.4911	5.2	<0.0001	7.0	6.2	0.2736	5.3	0.0156	11.7	10.1	0.0307	8.5	<0.0001	5.5	4.7	0.0708	3.7	<0.0001
Lean poultry	3.3	4.5	0.0257	2.6	0.2363	7.1	8.8	0.1493	12.9	<0.0001	2.6	4.0	0.0023	3.2	0.159	4.2	6.3	0.0002	11.5	<0.0001
Fatty poultry	6.4	7.0	0.4478	4.5	0.0109	18.9	18.5	0.7787	15.3	0.0099	4.7	5.6	0.1805	4.2	0.4227	4.4	5.5	0.016	3.4	0.0248
Delicatessen	7.0	3.0	<0.0001	2.6	<0.0001	6.3	3.2	<0.0001	3.3	<0.0001	8.1	4.2	<0.0001	4.2	<0.0001	8.2	4.0	<0.0001	3.8	<0.0001
Lean fish	3.4	4.0	0.2136	2.7	0.1328	2.7	3.1	0.415	2.5	0.7018	3.7	4.1	0.41	3.5	0.6356	4.4	5.0	0.1343	3.7	0.1091
Fatty fish	2.2	2.8	0.0589	6.6	<0.0001	1.4	2.1	0.0904	5.2	<0.0001	2.1	2.7	0.0732	7.5	<0.0001	3.9	4.7	0.0271	6.9	<0.0001
Cheese	6.9	6.2	0.1849	5.0	0.0003	5.7	5.5	0.6256	4.2	0.0044	8.3	8.0	0.602	6.6	0.0018	12.3	11.3	0.0438	9.7	<0.0001
Milk	1.8	1.6	0.7167	1.5	0.3534	1.3	1.3	0.8944	1.3	0.8308	2.5	2.5	0.8526	2.4	0.6807	1.1	1.0	0.6668	1.0	0.4947
Yogurts	3.4	3.3	0.7517	4.5	0.0018	3.7	3.5	0.7339	5.7	<0.0001	3.9	3.6	0.3392	5.4	<0.0001	5.4	5.1	0.364	7.0	<0.0001
Eggs and derivatives	1.9	2.4	0.0109	1.6	0.2076	1.1	1.5	0.0665	1.1	0.757	1.9	2.6	0.0086	2.7	0.0026	2.6	3.0	0.053	2.0	0.0067
Prepared dishes	13.3	13.6	0.806	28.2	<0.0001	5.4	4.8	0.3227	3.9	0.0108	5.1	4.8	0.4151	4.1	0.0147	4.2	3.9	0.4239	2.8	<0.0001
Pizzas, quiches	2.4	3.0	0.1676	3.4	0.0261	3.7	4.1	0.5453	3.7	0.9806	2.1	2.6	0.2396	6.1	<0.0001	2.2	2.7	0.1072	4.2	<0.0001
Sandwiches	1.9	2.0	0.7563	1.2	0.0464	4.0	4.2	0.8039	2.4	0.0136	1.6	1.8	0.4821	1.2	0.19	1.5	1.7	0.2507	1.1	0.0902
Bread	12.4	11.6	0.202	9.5	<0.0001	9.0	8.3	0.3235	7.2	0.0129	11.0	10.7	0.6372	9.0	0.0005	13.8	12.8	0.0406	10.9	<0.0001
Pastas	1.7	2.3	0.003	1.6	0.6155	1.7	2.5	0.0004	1.6	0.7036	2.1	2.9	0.0006	2.1	0.886	1.8	2.5	0.0003	1.6	0.2054
Vegetables	1.9	1.9	0.6812	1.9	0.7526	1.9	1.9	0.9569	1.8	0.4936	2.2	2.3	0.5918	2.6	0.0121	2.7	2.6	0.4042	2.5	0.0241
Legumes	1.0	1.2	0.2679	0.9	0.5548	0.9	1.4	0.1318	5.8	<0.0001	0.7	0.9	0.3169	0.8	0.9166	0.7	0.9	0.2854	5.2	<0.0001
Others	16.8	16.5		13.7		13.7	13.4		12.5		14.6	14.3		13.7		17.3	16.9		15.1	

	Milk drinkers					Take-away eaters					Beef eaters					Fish eaters				
	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value
Lean meat (excl poultry)	5.7	7.6	0.0033	9.4	<0.0001	4.0	4.8	0.3171	7.3	<0.0001	11.2	13.6	0.0037	11.0	0.7624	5.6	7.4	0.0954	5.4	0.8386
Fatty meat (excl poultry)	6.8	7.0	0.7714	5.4	0.0161	6.9	5.9	0.1556	4.4	0.0003	14.1	12.7	0.1143	14.4	0.6719	6.5	6.0	0.5409	4.4	0.0148
Lean poultry	3.6	5.6	<0.0001	5.0	0.0037	1.8	2.9	0.0531	3.3	0.007	2.8	4.2	0.0041	3.6	0.1207	3.4	5.0	0.1268	11.5	<0.0001
Fatty poultry	4.3	5.0	0.1538	4.1	0.6618	3.0	4.3	0.0233	2.2	0.2187	3.2	3.9	0.1611	2.6	0.2039	6.2	6.2	0.9986	4.0	0.0277
Delicatessen	7.1	3.0	<0.0001	3.3	<0.0001	5.6	2.4	<0.0001	2.8	<0.0001	6.8	3.1	<0.0001	3.4	<0.0001	4.9	2.0	<0.0001	2.2	<0.0001
Lean fish	2.7	3.0	0.4059	2.5	0.6324	2.9	3.2	0.5515	2.7	0.6306	3.0	3.3	0.417	2.6	0.1599	7.9	8.6	0.4551	7.3	0.5267
Fatty fish	1.9	2.8	0.0154	7.8	<0.0001	1.8	2.2	0.2834	1.8	0.9227	2.1	2.4	0.2872	6.1	<0.0001	4.6	5.4	0.2437	7.4	<0.0001
Cheese	7.3	6.6	0.1337	5.7	0.0003	7.5	7.0	0.4106	4.9	<0.0001	6.2	6.0	0.5613	4.6	<0.0001	5.8	5.3	0.3802	4.3	0.01
Milk	11.6	11.2	0.3895	10.8	0.1295	2.2	2.0	0.6813	1.8	0.3562	2.3	2.2	0.7134	2.1	0.6095	2.2	2.1	0.9092	2.0	0.7626
Yogurts	4.8	4.3	0.177	5.0	0.5893	2.9	2.6	0.4407	5.1	<0.0001	4.3	4.1	0.5787	6.2	<0.0001	6.5	6.0	0.4229	7.5	0.1108
Eggs and derivatives	2.2	2.5	0.1852	2.0	0.526	2.4	2.8	0.2825	4.1	<0.0001	2.1	2.8	0.0152	2.9	0.0057	1.5	1.9	0.1359	1.2	0.2897
Prepared dishes	5.1	4.4	0.0871	3.4	0.0002	8.5	7.7	0.3852	14.2	<0.0001	4.6	3.9	0.0732	3.0	<0.0001	4.5	3.7	0.2831	2.8	0.0183
Pizzas, quiches	2.7	2.9	0.4573	3.4	0.0504	8.9	10.7	0.0829	11.6	0.0074	3.1	4.0	0.112	7.1	<0.0001	2.3	2.7	0.4655	2.4	0.9584
Sandwiches	2.5	2.3	0.5506	1.6	0.0226	11.3	11.6	0.7408	8.3	0.0042	2.2	2.2	0.9245	1.5	0.0901	1.0	0.9	0.6762	0.6	0.1635
Bread	9.1	8.4	0.1546	7.0	<0.0001	7.4	6.4	0.0573	5.2	<0.0001	11.4	10.7	0.2465	9.3	0.0012	13.4	12.1	0.2841	10.2	0.0069
Pastas	1.8	2.9	<0.0001	2.0	0.4363	2.5	3.4	0.001	2.4	0.8741	2.4	3.1	0.003	2.5	0.6715	1.7	2.7	0.0003	1.5	0.4773

Supplementary Data

Vegetables	2.1	2.2	0.6771	2.6	<0.0001	1.6	1.5	0.6778	1.3	0.0754	2.0	2.0	0.7994	2.5	0.0003	3.1	3.1	0.905	2.8	0.2925
Legumes	0.6	0.8	0.1469	0.7	0.6735	0.4	0.5	0.3044	0.4	0.7578	0.6	0.9	0.1182	0.7	0.6423	1.0	1.2	0.6124	6.5	<0.0001
Others	18.0	17.4		18.3		18.5	18.0		16.0		15.4	14.9		14.0		18.0	17.5		16.0	

Supplemental Table 3. Mean contribution of the main protein containing food categories to protein intake (as % of total protein intake) for the eight clusters of protein food intake identified in the INCA2 population ($n=1,678$), after 20 steps of the stepwise model, in scenarios S1 and S2.

¹ Mean initial contribution of the food group to protein intake.

² Mean contribution of the food group to protein intake in scenario 1 in which dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals.

³ P -value of the comparisons between the initial situation and after 20 steps in S1 of the contribution of the food groups to total protein intake, adjusted for sex.

⁴ Mean contribution of the food group to protein intake in scenario 2 in which "new" protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belongs (i.e. consumed by >10% of the cluster population).

⁵ P -value of the comparisons between the initial situation and after 20 steps in S2 of the contribution of the food groups to total protein intake, adjusted for sex.

Supplementary Data

Supplemental Table 4. Mean PANDiet score, Adequacy and Moderation subscores (AS and MS) and mean probabilities of adequacy of the nutrients included in the PANDiet score in the eight clusters of protein dietary intake identified in the INCA2 population ($n=1,678$)¹.

	Meat dishes eaters					Poultry eaters					Pork eaters					Traditional eaters				
	Init ²	S1 ³	P-value ⁴	S2 ⁵	P-value ⁶	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value
PANDiet	64.7	68.3	<0.0001	72.8	<0.0001	63.4	67.3	<0.0001	72.1	<0.0001	63.7	67.4	<0.0001	70.9	<0.0001	64.4	68.2	<0.0001	72.0	<0.0001
AS	64.7	67.4	0.0199	76.2	<0.0001	62.7	65.8	0.022	73.5	<0.0001	64.8	67.6	0.0036	74.2	<0.0001	66.3	69.4	<0.0001	76.3	<0.0001
Protein	96.5	97.2	0.4228	96.6	0.945	93.6	95.5	0.2178	95.4	0.2408	96.5	97.8	0.018	97.6	0.045	97.2	98.1	0.0959	97.9	0.2084
ALA	8.0	8.1	0.9651	6.7	0.4384	8.5	9.0	0.8038	9.1	0.7596	7.5	7.8	0.8824	7.4	0.9238	13.2	13.4	0.9089	12.8	0.8222
LA	59.8	59.4	0.8883	50.3	0.0055	67.4	66.7	0.8503	64.7	0.4392	56.4	55.1	0.6894	52.8	0.2788	60.5	60.0	0.8312	57.1	0.1814
EPA+DHA	27.4	34.0	0.0271	83.9	<0.0001	21.9	28.3	0.0803	70.2	<0.0001	26.4	33.2	0.0108	86.8	<0.0001	40.2	49.8	<0.0001	77.0	<0.0001
DHA	32.2	38.7	0.0355	89.4	<0.0001	27.6	34.6	0.0627	75.8	<0.0001	30.8	38.0	0.0082	90.6	<0.0001	45.4	54.8	0.0001	81.7	<0.0001
Fiber	31.6	35.5	0.264	44.2	0.0003	22.3	27.6	0.1281	40.5	<0.0001	22.0	27.2	0.0481	28.2	0.0187	26.2	31.2	0.0343	43.0	<0.0001
Calcium	51.7	54.2	0.5037	66.1	0.0001	49.5	54.1	0.2724	57.4	0.0586	59.3	63.5	0.1978	74.8	<0.0001	66.4	69.3	0.2123	78.1	<0.0001
Copper	86.3	88.9	0.1077	96.5	<0.0001	79.9	84.1	0.107	95.4	<0.0001	88.5	91.4	0.0263	92.6	0.0017	91.1	93.2	0.0208	98.6	<0.0001
Iron	74.9	77.2	0.2039	91.6	<0.0001	69.9	72.1	0.3172	82.9	<0.0001	72.1	73.9	0.2409	80.2	<0.0001	58.5	61.9	0.0305	76.6	<0.0001
Iodine	54.9	59.7	0.079	77.7	<0.0001	52.1	57.5	0.1392	61.7	0.0086	59.4	64.0	0.057	82.2	<0.0001	62.3	68.3	0.0016	78.2	<0.0001
Potassium	65.3	68.7	0.2749	79.6	<0.0001	66.8	70.4	0.2607	77.4	0.001	70.2	72.7	0.2891	79.7	<0.0001	65.3	69.2	0.0624	77.8	<0.0001
Magnesium	37.1	41.4	0.2115	47.9	0.002	37.4	41.7	0.2905	46.1	0.0346	36.9	41.8	0.1092	45.9	0.0034	42.2	47.7	0.0403	53.8	<0.0001
Manganese	88.2	89.7	0.3076	90.4	0.1376	82.8	84.8	0.2963	88.2	0.0054	86.9	88.9	0.1705	89.4	0.0828	91.7	92.8	0.1624	94.5	0.0008
Phosphorus	100.0	100.0	0.5023	100.0	0.0106	100.0	99.9	0.1522	100.0	0.3883	99.9	99.9	0.6518	100.0	0.2294	99.8	99.8	0.7866	99.9	0.0511
Selenium	91.3	93.4	0.1563	97.6	<0.0001	91.3	93.7	0.1375	99.1	<0.0001	95.6	97.0	0.0598	98.8	<0.0001	94.6	96.4	0.0132	99.3	<0.0001
Zinc	33.7	37.4	0.1726	83.8	<0.0001	32.4	36.9	0.2081	37.6	0.1429	37.0	40.6	0.2318	46.6	0.0016	26.8	31.8	0.028	36.9	<0.0001
Vit.A	69.2	72.1	0.3119	84.8	<0.0001	56.4	60.8	0.2444	68.0	0.0022	66.1	68.7	0.3261	82.5	<0.0001	71.9	73.6	0.4091	79.2	0.0006
Thiamin	98.0	98.0	0.9514	99.5	<0.0001	96.9	96.6	0.5544	99.6	<0.0001	99.0	98.5	0.0183	99.3	0.1432	97.7	97.6	0.7813	99.5	<0.0001
Riboflavin	78.2	81.3	0.1821	90.3	<0.0001	72.7	76.8	0.1493	94.1	<0.0001	78.6	81.8	0.1221	90.5	<0.0001	75.9	78.7	0.1018	95.4	<0.0001
Niacin	100.0	100.0	0.3644	100.0	0.5285	100.0	100.0	0.8232	100.0	0.0343	100.0	100.0	0.8348	100.0	0.9325	100.0	100.0	0.7098	100.0	0.1417
Pantothenic acid	89.6	91.9	0.0845	95.8	<0.0001	90.0	92.6	0.0497	99.3	<0.0001	91.1	93.5	0.0069	96.3	<0.0001	91.6	93.8	0.0014	99.3	<0.0001
Vit.B-6	71.2	78.7	0.0064	88.8	<0.0001	74.1	81.6	0.0039	96.8	<0.0001	72.2	79.1	0.0051	85.1	<0.0001	68.4	77.2	<0.0001	95.3	<0.0001
Folate	64.9	70.6	0.085	74.4	0.0042	58.9	66.2	0.0409	90.9	<0.0001	64.5	70.7	0.0179	81.0	<0.0001	73.1	79.0	0.0008	94.3	<0.0001
Vit.B-12	75.3	83.2	0.0001	92.1	<0.0001	69.7	77.7	0.003	94.1	<0.0001	71.8	79.9	0.0002	92.5	<0.0001	73.2	81.6	<0.0001	94.5	<0.0001
Vit.C	36.3	36.7	0.9173	39.3	0.4633	36.4	36.5	0.9848	36.8	0.9321	33.6	34.8	0.7356	36.1	0.4695	38.5	40.0	0.6012	41.3	0.3398
Vit.D	2.1	3.5	0.1421	5.3	0.0011	2.7	3.5	0.5601	6.9	0.0037	2.5	4.2	0.0979	6.2	0.0003	3.8	5.9	0.0194	6.9	0.0005
Vit.E	86.3	88.1	0.2791	92.9	<0.0001	89.1	90.2	0.4643	90.5	0.3494	86.8	88.2	0.3828	92.3	0.0005	90.7	92.1	0.1777	93.1	0.0226
MS	64.8	69.1	<0.0001	69.4	<0.0001	64.1	68.7	<0.0001	70.7	<0.0001	62.5	67.3	<0.0001	67.7	<0.0001	62.5	66.9	<0.0001	67.7	<0.0001
Protein	98.4	98.7	0.5215	99.7	0.0048	98.9	98.7	0.4449	99.9	0.001	98.8	99.1	0.2853	99.7	0.0017	97.7	98.2	0.2379	99.5	<0.0001
Carbohydrates	98.6	99.0	0.2369	99.4	0.0082	98.3	98.8	0.4639	98.8	0.3954	99.5	99.5	0.8245	99.6	0.5397	98.9	99.3	0.1891	99.4	0.117
Sugar	74.0	74.1	0.9754	71.8	0.4924	65.6	66.0	0.9052	65.4	0.9694	70.2	70.9	0.8169	69.4	0.8025	71.6	72.1	0.8194	71.6	0.9851
Total fat	87.9	93.6	0.0005	96.2	<0.0001	86.4	93.9	0.0003	95.9	<0.0001	81.0	89.3	0.0002	91.1	<0.0001	80.8	90.7	<0.0001	93.8	<0.0001
SFA	26.0	37.8	0.0002	40.7	<0.0001	26.4	36.1	0.0067	43.3	<0.0001	14.9	25.2	<0.0001	27.0	<0.0001	17.9	27.5	<0.0001	30.2	<0.0001
Sodium	10.3	16.6	0.001	13.9	0.0542	16.1	23.0	0.0088	26.0	0.0002	14.2	21.3	0.001	22.1	0.0003	9.7	15.0	0.0005	14.9	0.0006

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	Milk drinkers					Take-away eaters					Beef eaters					Fish eaters				
	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value	Init	S1	P-value	S2	P-value
PANDiet	65.5	69.0	<0.0001	72.1	<0.0001	59.8	63.3	<0.0001	66.8	<0.0001	64.2	67.7	<0.0001	71.5	<0.0001	67.1	70.5	0.0002	74.6	<0.0001
AS	67.9	70.4	0.0068	75.6	<0.0001	58.2	61.4	0.0152	68.1	<0.0001	63.1	65.8	0.0074	72.4	<0.0001	68.1	70.4	0.1671	77.5	<0.0001
Protein	98.4	98.6	0.6021	98.7	0.4874	97.1	98.2	0.143	97.7	0.4449	97.4	97.9	0.3561	97.9	0.2699	96.7	98.5	0.0251	98.4	0.0314
ALA	7.9	7.9	0.9875	7.9	0.9863	6.4	6.7	0.834	5.2	0.3149	7.0	6.7	0.8892	6.5	0.7739	19.5	21.1	0.6915	20.7	0.7625
LA	53.7	53.1	0.842	50.9	0.3709	52.4	52.9	0.8839	74.9	<0.0001	56.1	54.7	0.6636	51.9	0.1987	69.8	69.9	0.9694	68.3	0.7398
EPA+DHA	21.7	30.9	0.0016	77.6	<0.0001	18.8	23.6	0.1424	22.6	0.2416	24.0	28.8	0.1141	72.4	<0.0001	49.0	55.9	0.0792	84.0	<0.0001
DHA	25.8	34.6	0.0039	81.3	<0.0001	22.1	27.5	0.1223	26.4	0.2176	28.1	33.0	0.1169	76.8	<0.0001	57.3	63.6	0.1008	89.1	<0.0001
Fiber	20.3	24.3	0.1022	22.5	0.3819	13.4	18.1	0.0471	18.0	0.0539	19.5	23.7	0.0986	24.9	0.0341	38.7	41.0	0.6354	54.9	0.001
Calcium	87.2	87.8	0.7475	92.1	0.0074	58.3	63.5	0.1262	73.3	<0.0001	50.2	54.7	0.1303	70.4	<0.0001	61.7	64.0	0.6606	67.9	0.2335
Copper	84.1	87.8	0.0431	90.7	0.0003	82.1	86.1	0.0739	87.4	0.0179	83.1	86.8	0.0592	87.4	0.0297	90.6	92.1	0.4365	98.9	<0.0001
Iron	64.3	66.9	0.1217	77.0	<0.0001	55.5	58.1	0.2265	68.1	<0.0001	76.0	78.4	0.1164	86.2	<0.0001	61.5	64.7	0.2139	79.0	<0.0001
Iodine	80.2	82.8	0.136	89.6	<0.0001	56.5	61.2	0.1057	75.5	<0.0001	56.5	61.7	0.0372	79.4	<0.0001	66.8	69.8	0.4101	79.8	0.0005
Potassium	66.7	69.5	0.2647	77.6	<0.0001	49.8	53.1	0.3364	64.8	<0.0001	64.5	67.4	0.2687	75.1	<0.0001	68.5	71.0	0.5877	76.7	0.0814
Magnesium	39.7	45.1	0.0661	47.6	0.0079	31.7	35.9	0.2495	42.9	0.0021	37.3	41.1	0.2073	46.1	0.0038	47.9	51.6	0.4761	57.4	0.0717
Manganese	84.4	86.7	0.1351	85.9	0.3038	83.7	86.4	0.1272	85.6	0.2952	85.4	87.5	0.1548	87.8	0.098	92.1	93.0	0.5695	94.5	0.1309
Phosphorus	100.0	100.0	0.3131	100.0	0.3183	99.8	99.9	0.0941	100.0	0.0009	99.7	99.7	0.936	99.8	0.8253	99.9	99.9	0.2693	100.0	0.2572
Selenium	94.4	96.5	0.0111	98.8	<0.0001	91.0	94.1	0.0319	97.6	<0.0001	92.9	95.0	0.0527	98.2	<0.0001	95.7	97.2	0.1654	99.2	0.0017
Zinc	40.2	44.6	0.1283	55.3	<0.0001	32.6	37.1	0.1911	53.1	<0.0001	47.7	53.4	0.0379	62.5	<0.0001	23.3	26.1	0.4891	30.3	0.0794
Vit.A	71.2	72.8	0.5039	85.8	<0.0001	53.9	58.7	0.1758	74.6	<0.0001	53.3	57.0	0.2247	72.3	<0.0001	70.1	73.0	0.526	76.8	0.1473
Thiamin	99.4	99.3	0.2804	99.6	0.2332	96.6	96.3	0.6613	98.3	0.011	96.6	96.4	0.7028	97.9	0.0192	97.0	96.1	0.3532	99.6	0.0062
Riboflavin	91.6	92.7	0.3919	96.2	0.0003	68.0	71.6	0.2015	85.9	<0.0001	75.2	78.2	0.1754	88.6	<0.0001	72.0	75.4	0.3789	93.0	<0.0001
Niacin	100.0	100.0	0.2866	100.0	0.8603	100.0	100.0	0.166	100.0	0.6201	100.0	100.0	0.2064	100.0	0.6022	100.0	100.0	0.0318	100.0	0.597
Pantothenic acid	96.2	97.4	0.0254	98.7	<0.0001	83.0	86.2	0.0549	94.3	<0.0001	90.6	92.9	0.0178	95.1	<0.0001	90.3	91.4	0.5647	99.2	<0.0001
Vit.B-6	71.8	78.9	0.0034	85.4	<0.0001	50.0	58.3	0.0169	77.5	<0.0001	70.9	76.9	0.0191	82.0	<0.0001	70.8	76.1	0.1764	95.5	<0.0001
Folate	70.2	75.7	0.039	83.4	<0.0001	52.7	60.6	0.016	64.8	0.0002	56.6	64.0	0.009	76.9	<0.0001	71.9	75.4	0.3722	92.5	<0.0001
Vit.B-12	84.7	89.6	0.0012	96.0	<0.0001	64.9	71.8	0.0261	83.4	<0.0001	78.3	84.8	0.0001	93.8	<0.0001	66.6	75.6	0.0197	94.0	<0.0001
Vit.C	41.9	42.2	0.9495	42.6	0.8517	26.6	27.0	0.9148	27.3	0.8651	31.9	32.5	0.8685	32.6	0.8377	47.1	48.2	0.8368	49.4	0.6782
Vit.D	3.1	6.5	0.0072	10.3	<0.0001	1.7	2.4	0.294	2.4	0.3175	2.9	4.1	0.2752	4.0	0.3025	2.9	4.0	0.4182	4.7	0.1813
Vit.E	90.1	90.8	0.5744	93.5	0.0082	84.9	86.5	0.3595	92.0	<0.0001	83.3	85.0	0.3254	89.5	0.0002	94.6	95.5	0.5556	95.5	0.5391
MS	63.0	67.6	<0.0001	68.6	<0.0001	61.3	65.3	<0.0001	65.6	<0.0001	65.4	69.6	<0.0001	70.5	<0.0001	66.2	70.5	0.0011	71.7	<0.0001
Protein	98.2	98.4	0.7913	99.5	0.0298	97.1	97.4	0.6456	99.3	0.0019	98.1	98.6	0.2722	99.5	0.0017	97.9	97.3	0.552	99.6	0.0532
Carbohydrates	99.0	99.0	0.9571	99.0	0.8758	96.7	98.0	0.1224	98.6	0.0243	98.0	98.2	0.6032	98.7	0.1581	99.2	98.8	0.2898	99.1	0.6901
Sugar	68.9	70.9	0.5066	70.3	0.6425	60.6	61.0	0.9287	59.5	0.7641	72.7	73.0	0.8995	71.6	0.7122	64.9	66.4	0.7307	65.8	0.8266
Total fat	86.5	94.0	<0.0001	96.0	<0.0001	86.0	93.2	<0.0001	95.4	<0.0001	85.6	93.1	<0.0001	95.5	<0.0001	87.6	93.8	0.0044	96.4	<0.0001
SFA	13.0	22.8	<0.0001	23.1	<0.0001	15.1	23.7	0.0006	26.9	<0.0001	23.2	32.8	0.0006	35.6	<0.0001	34.0	43.4	0.0554	46.6	0.0107
Sodium	12.5	20.8	<0.0001	24.6	<0.0001	12.4	17.5	0.022	15.3	0.1982	15.7	22.9	0.0012	23.9	0.0002	14.8	22.4	0.0121	23.6	0.0037

¹ALA, Alpha-linolenic acid. AS, Adequacy Sub-score. EPA + DHA, Eicosapentaenoic acid + Docosahexaenoic acid. LA, Linoleic acid. MS, Moderation Sub-score. SFA, Saturated Fatty Acids. Vit, Vitamin.

² Mean initial PANDiet, AS, MS or probability of adequacy.

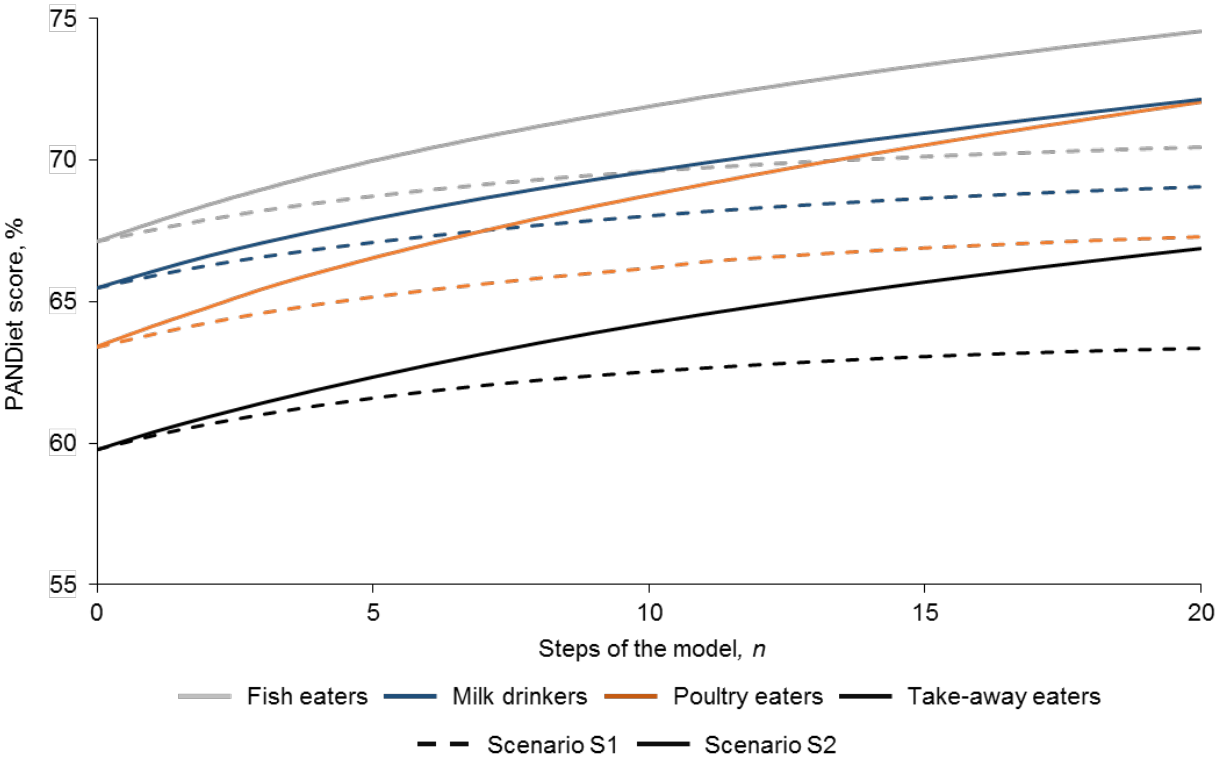
³ Scenario 1 in which dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals.

⁴ P-value of the comparisons between the initial situation and after 20 steps in S1 of the PANDiet scores, AS and MS sub-scores and the probabilities of adequacy, adjusted for sex.

⁵ Scenario 2 in which "new" protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged (i.e. consumed by >10% of the cluster population)..

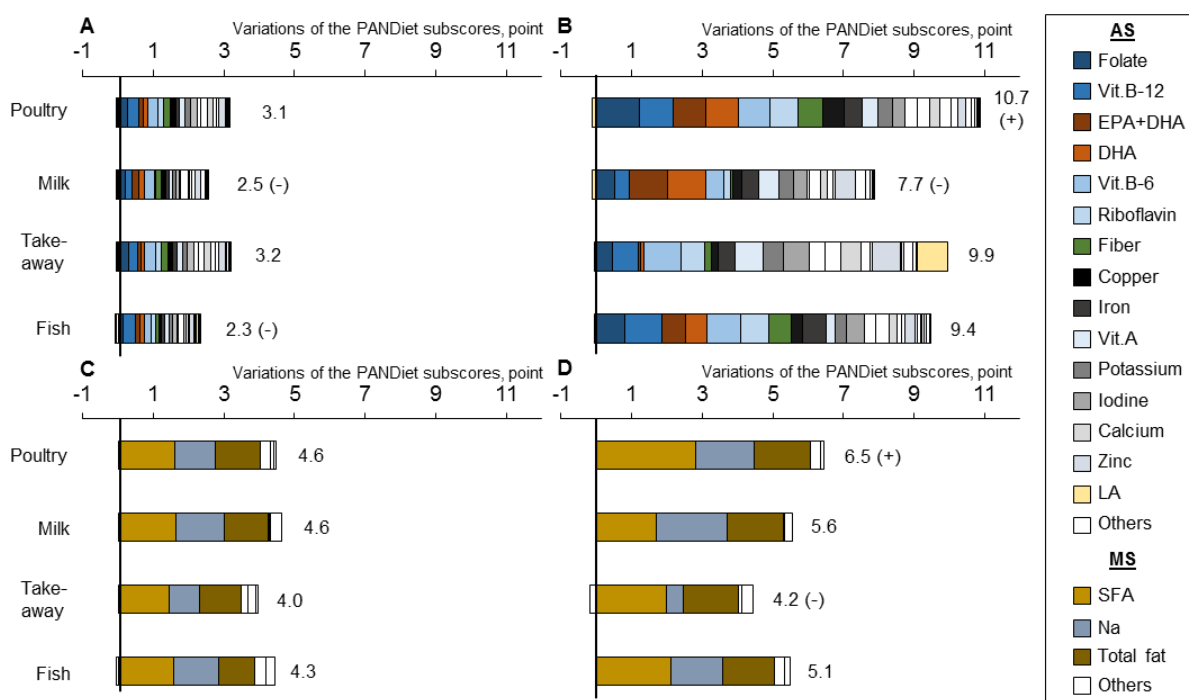
⁶ P-value of the comparisons between the initial situation and after 20 steps in S2 of the PANDiet scores, AS and MS sub-scores and the probabilities of adequacy, adjusted for sex.

Supplementary Data



Supplemental Figure 2. Mean increases of PANDiet along the 20 steps of the stepwise model in the scenarios S1 and S2 for four of the eight clusters of protein food intake in the INCA2 population ($n=1,678$). In Scenario S1, dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals, and in Scenario S2 “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged (i.e. consumed by >10% of the cluster population).

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Supplemental Figure 3. Mean variations of the Adequacy Subscore (AS, A and B) and the Moderation Subscore (MS, C and D) according to scenarios S1 (A and C) and S2 (B and D) as compared with the observed diet, for 4 of the 8 clusters, and the contribution of the probabilities of adequacy (PA) of the nutrients in the INCA2 population ($n=1,678$). In S1 (Scenario 1), dual changes in portion size (i.e. a reduction in one protein food and an increase in another) were only permitted between foods already consumed by the individuals, and in S2 (Scenario 2) “new” protein foods could be introduced to balance reductions in the protein foods consumed, inasmuch as these foods formed part of the food repertoire of the cluster to which the individual belonged (i.e. consumed by >10% of the cluster population). (+) or (-), significantly higher or lower than the mean increment of the overall population ($P < 0.05$). For example, in S2 the probability of adequacy of the AS increased by 10.7 (from 62.7 to 73.5) among ‘Poultry eaters’, and the increase was significantly higher than in the overall population. The increase of the probability of adequacy for folate intake contributed to 1.2 of the 10.7 points of the increase of the AS sub-score. The PA that accounted for <0.5 to the increments of AS or MS were represented in white. DHA and EPA+DHA were weighted as $\frac{1}{2}$ each in the AS as DHA is in both PAs. DHA, Docosahexaenoic Acid; EPA, Eicosapentaenoic acid; LA, Linoleic Acid; SFA, Saturated Fatty Acid; Vit., Vitamin.

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Supplemental Table 5. Example of an individual food record of the INCA2 population before and after 20 steps in the scenario S2.

Day	Meal	Food consumed	Init ¹	S2 ²	Portion ³	Day	Meal	Food consumed	Init	S2	Portion
1	Breakfast ⁴	Bread, French bread, baguette	60	60	23.75	5	Breakfast	Bread, French bread, baguette	30	30	23.75
1	Breakfast	Butter, 82% fat, unsalted	5	5	.	5	Breakfast	Butter, 82% fat, unsalted	2.5	2.5	.
1	Breakfast	Coffee with milk or white coffee or cappuccino, instant coffee or not, without sugar, ready-to-drink	300	300	.	5	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.
1	Breakfast	Jam or marmalade	20	20	.	5	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5
1	Breakfast	Breakfast cereals, popped or puffed wheat grain, with honey or caramel, fortified with vitamins and chemical elements	45	45	.	5	Breakfast	Jam or marmalade	10	10	.
1	Breakfast	Sugar, white	5	5	.	5	Breakfast	Breakfast cereals, popped or puffed wheat grain, with honey or caramel, fortified with vitamins and chemical elements	45	45	.
1	Lunch	White sausage (white pudding), sautéed	50	50	37.5	5	Breakfast	Sugar, white	5	5	.
1	Lunch	Béchamel sauce	37.5	37.5	.	5	Lunch	Bread, French bread, baguette	60	60	23.75
1	Lunch	Pear, pulp and peel, raw	306	306	.	5	Lunch	Cheese	15	15	16.15
1	Lunch	Raisin	7	7	.	5	Lunch	Butter, 82% fat, unsalted	5	5	.
1	Lunch	Water, municipal	300	300	.	5	Lunch	Not instant coffee, without sugar, ready-to-drink	70	70	.
1	Lunch	Carrot, cooked	100	100	.	5	Lunch	Water, municipal	240	240	.
1	Lunch	Garden peas, cooked	175	175	31.25	5	Lunch	Yoghurt with whole milk, fruit, sweet	125	125	125
1	Dinner	Wine, white, 11°	600	600	.	5	Lunch	Trout, farmed, smoked	20	20	35.62
1	Dinner	Bread, French bread, baguette	180	180	23.75	5	Lunch	Sugar, white	6.5	6.5	.
1	Dinner	Fish Quenelle, cooked	120	120	40	5	Afternoon snack	Fruit juice	120	120	.
1	Dinner	Rice, cooked, unsalted	50	50	.	5	Dinner	Clear fruit brandy or eau-de-vie	40	40	.
1	Dinner	Sauce	45	45	.	5	Dinner	Wine, white, 11°	200	200	.
1	Dinner	Sauce	45	45	.	5	Dinner	Wine, red, 11°	200	200	.
1	Dinner	Pineapple, pulp, raw	144	144	.	5	Dinner	Champagne	200	200	.
1	Dinner	Not instant coffee, without sugar, ready-to-drink	70	70	.	5	Dinner	Red wine sauce	30	30	.
1	Dinner	Mineral water	300	300	.	5	Dinner	Saint-Nectaire cheese, from cow's milk	28.5	28.5	14.25
1	Dinner	Water, municipal	300	300	.	5	Dinner	Blueberry, raw	18	18	.
1	Dinner	Asparagus, boiled/cooked in water	40	40	.	5	Dinner	Apple compote	165	165	.
1	Dinner	Pound cake, prepacked	12.5	12.5	.	5	Dinner	Venison (roebuck), roasted/baked	63	63	33
1	Dinner	Meringue	10	10	.	5	Dinner	Chestnut, grilled	140	140	.
1	Dinner	Canapés (toasts w various toppings)	25	25	18.75	5	Dinner	Not instant coffee, without sugar, ready-to-drink	70	70	.
1	Dinner	Salmon, steamed	190	190	35.62	5	Dinner	Mineral water	300	300	.
1	Dinner	Milk chocolate bar	3	3	.	5	Dinner	Eclair	45	45	.
1	Dinner	Sugar, white	2.5	2.5	.	5	Dinner	Salmon in puff pastry	45 ⁵	155	55
1	Dinner	Epoisses cheese	30	30	12.5	5	Dinner	Canapés (toasts w various toppings)	150	150	18.75
1	Dinner	Saint-Félicien cheese	30	30	12.5	5	Dinner	Salmon, smoked	30	30	12.5
1	Dinner	Goat cheese	10	10	10	5	Dinner	Sugar, white	5	5	.
1	Dinner	Other cheese	15	15	12.5	5	Dinner	Ice-cream or sorbet	180	180	.
2	Breakfast	Bread, French bread, baguette	60	12.5	23.75	5	Dinner	Epoisses cheese	30	30	12.5
2	Breakfast	Butter, 82% fat, unsalted	5	5	.	6	Breakfast	Fruit juice	120	120	.
2	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.	6	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.
2	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5	6	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5
2	Breakfast	Jam or marmalade	20	20	.	6	Breakfast	Breakfast cereals, popped or puffed wheat grain, with honey or caramel, fortified with vitamins and chemical elements	60	60	.
2	Breakfast	Breakfast cereals, popped or puffed wheat grain, with honey or caramel, fortified with vitamins and chemical elements	30	30	.	6	Breakfast	Sugar, white	5	5	.
2	Breakfast	Sugar, white	5	5	.	6	Lunch	Champagne kir (Cocktail of champagne with red fruit liqueur)	300	300	.
2	Lunch	Tangerine	90	90	.	6	Lunch	Potato, pre-fried into cubes, frozen, cooked	200	200	.
2	Lunch	Water, municipal	240	240	.	6	Lunch	Wine, white, 11°	300	300	.
2	Lunch	Espresso coffee, not instant coffee, without sugar, ready-to-drink	70	70	.	6	Lunch	Wine, red, 11°	450	450	.

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2	Lunch	French bean, canned, drained	50	50	.
2	Lunch	Candies, all types	5	5	.
2	Lunch	Sugar, brown	6.5	6.5	.
2	Lunch	Duck, magret, cooked in pan	72	72	45.1
2	Lunch	Butter	10	10	.
2	Lunch	Butter	5	5	.
2	Lunch	Olive oil	12	12	.
2	Dinner	Cider, dry	360	360	.
2	Dinner	Waffle	175	175	.
2	Dinner	Jam or marmalade	100	100	.
2	Evening snack	Infusion, brewed, without sugar	250	250	.
2	Evening snack	Sugar, white	5	5	.
3	Breakfast	Bread, French bread, baguette	80	80	23.75
3	Breakfast	Butter, 82% fat, unsalted	5	5	.
3	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.
3	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5
3	Breakfast	Jam or marmalade	20	20	.
3	Breakfast	Sugar, white	5	5	.
3	Morning snack	Milk chocolate filled with praline in tablet	3	3	.
3	Morning snack	Tea, brewed, without sugar	300	300	.
3	Morning snack	Sugar, white	5	5	.
3	Lunch	Bread, French bread, baguette	30	30	23.75
3	Lunch	White sausage (white pudding), sautéed	100	100	37.5
3	Lunch	Water, municipal	120	120	.
3	Lunch	Espresso coffee, not instant coffee, without sugar, ready-to-drink	70	70	.
3	Lunch	Natural yogurt	125	125	125
3	Lunch	Broccoli, cooked	175	232.5	57.5
3	Lunch	Sugar, white	10	10	.
3	Lunch	Sugar, white	2.5	2.5	.
3	Lunch	Olive oil	12	12	.
3	Dinner	Beer, regular (4-5° alcohol)	250	250	.
3	Dinner	Bread, French bread, baguette	30	30	23.75
3	Dinner	White sausage (white pudding), sautéed	50	50	37.5
3	Dinner	Cheese	30	30	16.15
3	Dinner	Toasted ham sandwich topped with grated cheese	100	100	55
3	Dinner	Chocolate mousse (milk-based), refrigerated	120	120	17.5
3	Evening snack	Infusion, brewed, without sugar	250	250	.
3	Evening snack	Sugar, white	5	5	.
4	Breakfast	Bread, French bread, baguette	30	30	23.75
4	Breakfast	Butter, 82% fat, unsalted	2.5	2.5	.
4	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.
4	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5
4	Breakfast	Jam or marmalade	10	10	.
4	Breakfast	Breakfast cereals, popped or puffed wheat grain, with honey or caramel, fortified with vitamins and chemical elements	30	30	.
4	Breakfast	Sugar, white	5	5	.
4	Morning snack	Milk chocolate filled with praline in tablet	3	3	.
4	Morning snack	Wine, white, 11°	120	120	.
4	Lunch	Alcoholic cocktail	120	120	.
4	Lunch	Clear fruit brandy or eau-de-vie	35	35	.
6	Lunch	Bread, French bread, baguette	30	30	23.75
6	Lunch	Country-style bread, French bread (baguette or ball)	40	40	30
6	Lunch	Fourme d'Ambert cheese	60	60	15
6	Lunch	Apple compote	40	40	.
6	Lunch	Prune	32	32	.
6	Lunch	Not instant coffee, without sugar, ready-to-drink	70	70	.
6	Lunch	Water, municipal	300	300	.
6	Lunch	Red cabbage, boiled/cooked in water	200	200	.
6	Lunch	Salmon in puff pastry	60	60	55
6	Lunch	Canapés (toasts w various toppings)	65	65	18.75
6	Lunch	Salmon, smoked	30	30	12.5
6	Lunch	Sugar, white	6.5	6.5	.
6	Lunch	Goose, meat, roasted/baked	500	319.6	45.1
6	Lunch	Lentil, cooked	.	300	60
6	Lunch	Butter	10	10	.
6	Lunch	Butter	5	5	.
6	Lunch	Cream cake	310	310	.
6	Lunch	Epoisses cheese	30	30	12.5
6	Afternoon snack	Fruit soft drink, carbonated (less than 10% of fruit juice), with sugar	150	150	.
7	Breakfast	Bread, French bread, baguette	60	60	23.75
7	Breakfast	Butter, 82% fat, unsalted	5	5	.
7	Breakfast	Not instant coffee, without sugar, ready-to-drink	300	300	.
7	Breakfast	Milk, semi-skimmed, UHT	24	24	81.5
7	Breakfast	Jam or marmalade	20	20	.
7	Breakfast	Sugar, white	5	5	.
7	Lunch	Milk chocolate filled with praline in tablet	3	3	.
7	Lunch	Champagne	200	200	.
7	Lunch	Bread, French bread, baguette	30	30	23.75
7	Lunch	Saint-Nectaire cheese, from cow's milk	38	38	14.25
7	Lunch	Not instant coffee, without sugar, ready-to-drink	70	70	.
7	Lunch	Red cabbage, boiled/cooked in water	250	250	.
7	Lunch	Sugar, white	6.5	6.5	.
7	Lunch	Goose, meat, roasted/baked	400	354.9	45.1
7	Lunch	Spinach, cooked	.	42.5	42.5
7	Lunch	Butter	10	10	.
7	Lunch	Butter	5	5	.
7	Lunch	Cream cake	155	155	.
7	Dinner	Champagne kir (Cocktail of champagne with red fruit liqueur)	200	200	.
7	Dinner	Wine, white, 11°	300	300	.
7	Dinner	Wine, red, 11°	300	300	.
7	Dinner	Fourme d'Ambert cheese	60	60	15
7	Dinner	Not instant coffee, without sugar, ready-to-drink	70	70	.
7	Dinner	Red cabbage, boiled/cooked in water	200	200	.
7	Dinner	Salmon, smoked	30	30	12.5
7	Dinner	Sugar, white	6.5	6.5	.
7	Dinner	Goose, meat, roasted/baked	500	3.9	45.1
7	Dinner	Spinach, cooked	.	42.5	42.5
7	Dinner	Salmon, steamed	.	178.1	35.6
7	Dinner	Butter	10	10	.

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4	Lunch	Wine, red, 10°	600	600	.	7	Dinner	Butter	5	5	.
4	Lunch	Dried pasta, cooked, unsalted	150	212.5	62.5	7	Dinner	Cream cheese	155	155	.
4	Lunch	Shrimp or prawn, cooked	14.4	14.4	12	7	Dinner	Melted cheese 50% fat	60	60	11.25
4	Lunch	Litchi, pitted, canned	50	50	.						
4	Lunch	Not instant coffee, without sugar, ready-to-drink	70	70	.						
4	Lunch	Sweet corn, on the cob, cooked	13.7	13.75	.						
4	Lunch	Mung bean, sprouted or soy spouts, raw	25	25	.						
4	Lunch	Fruit frit	40	40	.						
4	Lunch	Egg roll or Nem	140	30	55						
4	Lunch	Lentil, cooked	.	180	60						
4	Lunch	Salmon, steamed	.	35.62	35.62						
4	Lunch	Shrimps on skewer	80	80	50						
4	Lunch	Green salad, raw, without seasoning	10	10	.						
4	Lunch	Pork, spare-ribs, braised	65	65	20						
4	Lunch	Sugar, white	5	5	.						
4	Lunch	Nougat	40	40	.						
4	Dinner	Beer, regular (4-5° alcohol)	250	250	.						
4	Dinner	Bread, French bread, baguette	30	30	23.75						
4	Dinner	Tomato sauce, with onions, prepacked	30	30	.						
4	Dinner	Tangerine	90	90	.						
4	Dinner	Onion, cooked	30	30	.						
4	Dinner	Crepe, plain, prepacked, room temperature	50	50	.						
4	Dinner	Turkey, meat, roasted/baked	27	27	45.1						
4	Dinner	Butter	10	10	.						
4	Dinner	Olive oil	12	12	.						
4	Evening snack	Infusion, brewed, without sugar	250	250	.						
4	Evening snack	Sugar, white	5	5	.						

¹ Food intake in the initial situation (g)

² Food intake after 20 steps of the scenario S2

³ Portion size step as defined in Supplemental Method 2 (g). The data are shown for protein food only, which are those manipulated.

⁴ Protein foods were highlighted in light grey.

⁵ Protein foods with modified portion sizes were highlighted in dark grey.

Supplementary Data

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