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Anouk Reuzé, Caroline Méjean, Lucie Sirieix, Julia Baudry, Emmanuelle Kesse-Guyot, et al.. Stages of change toward meat reduction: associations with motives and longitudinal dietary data on animal-based and plant-based food intakes in French adults. *Journal of Nutrition*, 2023, 153 (11), pp.3295-3307. 10.1016/j.tjnut.2023.09.017 . hal-04222209

HAL Id: hal-04222209

<https://hal.inrae.fr/hal-04222209v1>

Submitted on 4 Oct 2023

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1 **Stages of change toward meat reduction: Associations with motives and longitudinal**
2 **dietary data on animal-based and plant-based food intakes in French adults**

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9 **Postprint** :Reuzé A., Méjean C., Sirieix L., Baudry J., Kesse-Guyot E., Druésne-Pecollo N.,
10 Brunin J., Hercberg S., Touvier M., Péneau S., Allès B. (2023). Stages of change toward
11 meat reduction: associations with motives and longitudinal dietary data on animal-based and
12 plant-based food intakes in French adults. Journal of Nutrition:
13 <https://doi.org/10.1016/j.tjnut.2023.09.017>

14 **Sources of support for the work**

15 The NutriNet-Santé study is supported by the French Ministry of Solidarity and Health, the
16 National Agency for Public Health (Santé Publique France), the National Institute for Health
17 and Medical Research (INSERM), the National Research Institute for Agriculture, Food and
18 Environment (INRAE), the National Conservatory of Arts and Crafts (CNAM), the Centre for
19 Epidemiological Research and Statistics (CRESS) and Sorbonne Paris Nord University. The
20 funders had no role in the design of the study, in the collection, analysis, or interpretation of
21 data, in the writing of the manuscript, or in the decision to publish the results.

22 **Conflict of interest**

23 Anouk Reuzé, no conflicts of interest

24 Caroline Méjean, no conflicts of interest

Lucie Sirieix, no conflicts of interest

Julia Baudry, no conflicts of interest

Emmanuelle Kesse-Guyot, no conflicts of interest

25 Nathalie Druesne-Pecollo, no conflicts of interest

26 Joséphine Brunin, no conflicts of interest

27 Serge Hercberg, no conflicts of interest

28 Mathilde Touvier, no conflicts of interest

29 Sandrine Péneau, no conflicts of interest

30 Benjamin Allès, no conflicts of interest

31

32 **Ethics approval and consent to participate**

33 The NutriNet-Santé study complies with the Declaration of Helsinki guidelines and was
34 approved by the Institutional Review Board of the French Institute for Health and Medical
35 Research (IRB Inserm No. 0000388FWA00005831) and the French data protection authority
36 (Commission Nationale de l'Informatique et des Libertés, CNIL No. 908450/ No. 909216).

37 The study protocol is registered at ClinicalTrials.gov under the number NCT03335644. All
38 subjects provided informed consent.

39

40 **Consent for publication**

41 Not applicable

42

43 **Availability of data and materials**

44 The datasets generated and/or analyzed in this study are secure under health data regulations
45 set by the French data protection authority (Commission Nationale de l'Informatique et des
46 Libertés, CNIL) and are not publicly available. The data are available upon reasonable request
47 to the study's operational manager, Nathalie Druesne-Pecollo (n.pecollo@eren.smbh.univ-
48 paris13.fr), for review by the NutriNet-Santé study steering committee.

49

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59

60 **Running title**

61 Stages of change and motives toward meat reduction

62 **List of abbreviations**

63 BMI: body mass index; PDI: plant-based diet index; SEM: standard error of the mean; SD:

64 standard deviation; TEI: total energy intake; TTM: transtheoretical model.

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71 **Abstract**

72 **Background:** Reducing meat consumption is advocated for healthier and more sustainable
73 diets. However, behavioral studies are needed to better understand the mechanisms underlying
74 meat-reducing dietary changes.

75 **Objective:** The main aim of this study was to compare the motives associated with stages of
76 change toward meat reduction in French adults, using the transtheoretical model (TTM). A
77 second aim was to investigate the associations between stages of change and adherence to
78 dietary patterns favoring a better balance of animal and plant food consumption over time.

79 **Methods:** This longitudinal study included 25,143 non-vegetarian participants of the web-
80 based NutriNet-Santé cohort with a mean follow-up of 6.2 (SD = 2.6) years. Dietary data
81 were obtained from 24-hour dietary records over the period 2009–2019. Contribution of meat
82 to total energy intake and scores measuring the contribution of healthy and unhealthy plant-
83 based foods to the diet were computed. A questionnaire completed in 2018 allowed us to
84 identify the TTM stages of change related to meat reduction (precontemplation,
85 contemplation, preparation, action, maintenance), and recorded motives related to meat
86 consumption. We used multivariate linear mixed models for repeated data to assess
87 associations between food intake changes and stages, and logistic regression for motives,
88 presented as adjusted frequencies.

89 **Results:** Participants in late stages were characterized by a significantly higher decrease in
90 meat intake over time, compared to the earliest stage (e.g., $\beta_{\text{maintenance*time}} = -0.08, p < 0.0001$),
91 and a higher increase in the healthy plant-based food consumption score over time
92 (e.g., $\beta_{\text{maintenance*time}} = 0.11, p < 0.0001$). Concerns about health, nutrition, and the environment
93 were the most frequently cited motives for reducing meat consumption at all stages.

94 **Conclusions:** Individuals who had already initiated meat reduction adhered to healthier and
95 more sustainable diets than meat continuers. Characterizing motives according to readiness to
96 reduce meat consumption could support tailored public health campaigns.

97 **Clinical Trial Registry**

98 Clinical Trial Registry: NCT03335644

99 <https://clinicaltrials.gov/ct2/show/NCT03335644>

100

101 **Key words**

102 Longitudinal study; Epidemiology; Meat reduction; Transtheoretical model; Motives

103 **Highlights**

- 104 • Participants with higher levels of readiness were more likely to reduce their meat
105 consumption for health, nutritional, and environmental motives than those with lower
106 levels of readiness.
- 107 • Higher level of readiness to reduce meat consumption (i.e., action and maintenance
108 stages of the TTM) was associated with a greater increase in healthy plant-based food
109 consumption over time.
- 110 • Stages of change toward meat reduction were in line with observed changes in meat
111 and meat product intakes measured by repeated 24 h dietary records.

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118 **Introduction**

119 One pathway for sustainable nutrition transition is a healthier balance of animal-based
120 and plant-based foods. High meat consumption is associated with high environmental
121 pressure (1), animal welfare issues (2), and adverse effects on human health (1). Dietary
122 guidelines have been released in several countries to curb the consumption of meat and
123 processed meat products (3–6). However, in most countries of the world, current levels of
124 meat and meat product consumption remain above recommended ceilings for both human
125 health and the environment (1,7,8). Even so, consumer intention to reduce meat consumption
126 has recently increased (9,10). For example, in a recent study from the NutriNet-Santé cohort,
127 we identified a shift toward more sustainable and healthier diets, in particular reduced meat
128 consumption (11,12). More research is needed to gain a better understanding of how meat
129 consumption is changing.

130 Emerging behaviors and the need to accelerate the sustainable food transition for as
131 many consumers as possible call for a better understanding of how intention becomes
132 behavior change. Studies focusing on behavior change have applied theories and models
133 drawn from psychology and sociology to the question of meat reduction (13). Some theories,
134 such as the theory of planned behavior, evaluate behavior change as a continuum process such
135 as the theory of planned behavior (14–16). Others, such as the transtheoretical model (TTM)
136 and the model of self-regulated behavior (16,17) view it as a sequence of discrete stages (18).
137 The TTM is one of the most commonly used behavior change models in health (19) and
138 defines behavior change as a sequence of five temporal stages of change, representing
139 different levels of readiness, from a lack of awareness to intention and behavior change, based
140 on past behavior and an action plan. These successive stages are (a) precontemplation (no
141 intention of reducing meat consumption, no awareness of the adverse effects associated with
142 eating meat), (b) contemplation (awareness of the adverse effects associated with eating meat,

143 intention to reduce meat), preparation (intention to reduce meat, action plan), action (recent
144 modifications to meat consumption), and maintenance (long-term modifications to meat
145 consumption) (18).

146 Though widely used, the TTM and stage-based models in general have been
147 challenged (20–22). Some studies have criticized the stepwise modeling of the behavior
148 change process, one stage following another, and its unidirectionality, which does not let an
149 individual relapse into an earlier stage (14,23,80). The cut-off points on continuous variables
150 (time and intention) defining stages of change have also been criticized for their arbitrariness
151 (20,21). Even so, the TTM gives insights into the process of intentional behavior change and
152 the scope of intervention (13,23). As meat consumption is frequently a norm in Western
153 culture, changing it may require a conscious decision (24). Intention and actual behavior
154 could conflict, and individual progress towards those stages that lead to behavior change
155 needs to be studied (13).

156 To date, few studies have investigated the process of meat reduction across stages of change
157 (13,25–28) and little is known about the link between the TTM for meat reduction and actual
158 dietary intakes. A few cross-sectional studies have suggested that individuals in later stages of
159 change consume less meat than those in earlier stages (13,26,27). However, these studies did
160 not use validated food questionnaires and large-scale longitudinal studies to assess changes in
161 food consumption across these stages. Also, in the context of sustainable food transition, to
162 the best of our knowledge, no study has examined whether reducing meat consumption
163 among non-vegetarians implies a shift toward a more plant-based diet over time.

164 To gain a better understanding of the process of behavior change, many studies have
165 set out to identify factors influencing the reduction of meat consumption. Among these
166 factors, several food choice motives have frequently been reported as inducing or hindering
167 meat reduction, whether related to health (13,26,29–34), taste preferences (26,34), the

168 environment (13,26,29,30,34), animal welfare (26,30), or price (29,31–33). Social norms
169 (13,26,33) and representations (33), and motives related to external factors, such as food
170 convenience and accessibility (35) have also been described. Although many potential
171 motives for and against meat reduction have been identified in the literature, few studies have
172 investigated them in relation to individuals' levels of readiness to reduce their meat
173 consumption (13,26). A recent Danish study has suggested that motives may vary across the
174 stages of change toward meat reduction (13).

175 The main aim of this study was to compare motives for reducing or continuing meat
176 consumption according to individual levels of readiness toward meat reduction in a
177 population of non-vegetarian French adults. A secondary objective of this longitudinal study
178 was to investigate the associations between stages of change and adherence to dietary patterns
179 favoring a more desirable balance of animal-based and plant-based food consumption.

180

181 **Methods**

182 **a. Study population**

183 The NutriNet-Santé study is a web-based prospective observational French cohort study
184 launched in May 2009 to investigate the relationship between nutrition and health, especially
185 chronic disease risk, and the determinants of dietary behavior and nutritional status. Briefly,
186 participants are Internet-using adult volunteers prospectively recruited among the general
187 population. The study design is described elsewhere (36). It complies with the Declaration of
188 Helsinki and was approved by the Institutional Review Board of the French Institute for
189 Health and Medical Research and the French data protection authority (Commission
190 Nationale de l'Informatique et des Libertés, CNIL 908,450 and 909,216). All the participants

191 signed an electronic informed consent statement. The ClinicalTrials identifier is
192 NCT03335644.

193 **b. Self-reported reduction or continuation of meat consumption**

194 A questionnaire on the motives and individual readiness for reducing consumption of animal-
195 based foods in diet was developed, based on a previous questionnaire on food choice motives
196 (37–39). It was built jointly by epidemiology, nutrition, and social marketing researchers.

197 This non-mandatory questionnaire was sent in August 2018 to NutriNet-Santé participants. As
198 meat, particularly ruminant meat, is a major concern for food sustainability and human health
199 (1), we focused on changing consumption of meat, defined as beef, minced or roast steak, rib
200 steak, stew, ground beef in a dish such as lasagna or spaghetti Bolognese, veal, lamb, pork,
201 offal, breaded meat, game, rabbit or hare and all processed meats or derived products. This
202 definition excludes poultry (turkey, chicken, duck, quail, pigeon). For detailed information
203 about this questionnaire, see a previous study (34).

204 *Stages of change*

205 The questionnaire included a section on individual level of readiness to change meat
206 consumption. Two questions classified participants into five groups corresponding to the five
207 stages of change in the TTM (18). First, each participant was asked to pick one answer to the
208 question: “*In recent years, have you reduced your meat consumption?*” from eight possible
209 answers comprising five items related to the stages of change, and two items to include
210 participants’ situations outside the stages of change process. Participants who picked one of
211 the five items related to stages of change were classified as follows: precontemplation stage
212 (“*No, I don’t see the point*”), contemplation stage (“*No, but I plan to do so soon although I*
213 *don’t know exactly how*” and “*No, but I’ve already considered doing so although I haven’t*
214 *changed my meat consumption*”), preparation stage (“*No, but I’m considering doing it soon*

215 *and I know how*). Participants who gave a favorable response (“*Yes*”) to the question were
216 classified in one of the two subsequent stages, namely action and maintenance, and were
217 asked a second question on how long they had been reducing their meat consumption, “*Could*
218 *you please tell us roughly how long you’ve been reducing your meat consumption?*”. In the
219 TTM, the boundary between the action and maintenance stages is defined by how long ago
220 the behavior change occurred; in the original model it was set at 6 months (18). However,
221 many authors have criticized the arbitrariness with which this value was set (see for example
222 (21)), and its inappropriateness in certain contexts, particularly dietary change (13,40,41). To
223 choose the most appropriate boundary value for our context, we conducted sensitivity
224 analyses based on how long ago the change in behavior occurred. We compared three lengths
225 of time (less than 1 year, 1–2 years, more than 2 years) with the daily mean food intakes (in
226 g/day). We observed significant differences between mean food consumptions for participants
227 who made a change less than 2 years ago and those who did so more than 2 years ago. We
228 therefore set the boundary at 2 years. Participants who answered that they had reduced their
229 meat consumption for less than 2 years were classified in the action stage and those who had
230 reduced their meat consumption for longer than 2 years were classified in the maintenance
231 stage.

232 Participants whose responses did not correspond to any stage of change (“*No, it’s for another*
233 *reason*” and “*No, because I don’t eat much meat anyway*”) were categorized in a group
234 designated “other”. Following the aim of this study, data for this group are not presented.

235

236 ***Change-inducing and change-hindering motives toward meat reduction***

237 Participants were asked to respond to the following two statements by “*Yes*” or “*No*”: “*I’ve*
238 *reduced, or already thought about reducing my meat consumption*” (meat reduction) and “*I’ve*
239 *always kept my meat consumption, I’ve never felt like reducing it*” (meat continuation).

240 For either reduction or continuation of meat consumption, a set of motives was proposed,
241 including taste, health, environment, animal protection, and sociocultural influences (see all
242 items in **Supplemental Table 1**). We used the literature to select motives in the questionnaire
243 (30,42).

244 Motives: For each motive, participants who declared a change/continuation in their meat
245 consumption were asked to rate their corresponding motives on a 5-point Likert scale, from
246 “*Strongly disagree*” to “*Strongly agree*”, including “*Neither agree nor disagree*”, plus an “*I*
247 *don’t know*” answer. For example, participants who declared a reduction of their meat
248 consumption, were asked to rate statements such as “*I care about animal welfare and the lives*
249 *of animals*” or “*I think it’s healthier not to eat too much meat*”.

250 Change-inducing and change-hindering motives: If participants gave a favorable response to
251 one motive (“*Somewhat agree*” or “*Strongly agree*”), a second statement “*and it encourages*
252 *me to reduce my meat consumption*” was proposed to assess whether this motive induced a
253 change in consumption, on a separate 5-point Likert scale. Similarly, for meat continuation
254 motives, a second statement “*and this is one reason why I’m not reducing my meat*
255 *consumption*” was proposed to assess whether this motive hindered a change in consumption.

256 Both Likert scales, for the motive and for the change-inducing or change-hindering motive,
257 were then recoded to compute agreement scores ranging from 0 to 5 and from 1 to 5,
258 respectively.

259 Using the same method as described previously (34), participants were then classified into
260 three groups representing different types of motive, based on their answers to each motive:

261 – “No motive”: Participants were considered to have “no motive” if they gave an
262 unfavorable response (“*Strongly disagree*”, “*Somewhat disagree*”, “*Neither agree nor*
263 *disagree*” and “*I don’t know*”) for the motive.

264 For participants in this group, the motive related to animal welfare was thus not felt to
265 be important.

266 – “Motive, not change-inducing”: Participants with a “motive, not change-inducing”
267 were those who gave a favorable response (“*Strongly agree*” and “*Somewhat agree*”)
268 to the motive but an unfavorable one (“*Strongly disagree*”, “*Somewhat disagree*”,
269 “*Neither agree nor disagree*”) to the statement that the motive had induced a change
270 in consumption.

271 For participants in this group, the motive related to animal welfare was thus felt to be
272 important but was not declared as change-inducing.

273 – “Change-inducing motive”: Participants who gave favorable responses to both sets of
274 statements were considered as having a “change-inducing motive”.

275 For participants in this this group, the motive related to animal-welfare was thus felt to
276 be important and did lead to a change.

277 Similarly, for each motive related to meat continuation, participants were classified into three
278 groups representing different types of motive: “no motive”, “motive, not change-hindering”,
279 “change-hindering motive”.

280 **c. Dietary data**

281 *Dietary intake assessment*

282 Dietary data were collected through web-based, self-administered 24 h dietary records using
283 validated tools (43,44). At baseline and every 6 months, participants were asked to provide
284 three non-consecutive-day 24 h dietary records (here, the term “follow-up” refers to each time
285 that the three dietary records were completed). These three records were randomly assigned
286 over a two-week period (two weekdays and one weekend day) to take into account the intra-
287 variability of the daily intake. The dietary assessment method took a meal-based approach,

288 reporting all foods and beverages consumed at any eating occasion. After filling in names of
289 all food items, portion size for each item was estimated using standard measurements or
290 photographs from a validated picture manual (45). Mean daily quantities of food groups (in
291 g/d for solid and mL/d for liquid) were calculated from 24 h dietary records, weighted
292 according to the day (week or weekend) for each follow-up. Energy, macronutrient and
293 micronutrient values from the dietary questionnaire were estimated by the NutriNet-Santé
294 food composition table listing more than 3500 different foods (46).

295 Food and beverages were classified into 12 plant-based and 6 animal-based food groups
296 considering nutrients and culinary similarities, as developed by Satija et al. (47), and was
297 adapted for the NutriNet Santé database to match French consumption habits more closely
298 (48) (**Supplemental Table 2**). Owing to the increased diversity of plant foods consumed, we
299 also estimated intakes of the following food groups: “Plant-based drinks” (e.g., soy, almond,
300 or rice), “Miscellaneous plant-based food” including subgroups such as “Meat and processed
301 meat substitutes” (abbreviated “meat substitutes”), “Dairy dessert and cheese substitutes”
302 (abbreviated “dairy substitutes”) and “Fermented or coagulated foods” (e.g., tempeh, tofu),
303 and “Uncooked cereals and seeds” (e.g., oatmeal, sesame seeds). Three indices including the
304 contribution of meat, processed meat, and meat products to total energy intake were also
305 computed.

306 *Plant-based diet indices*

307 The three plant-based diet indices developed by Satija et al. were used to assess the
308 contribution of plant-based foods to the diet (47). These indices measure the impact of plant-
309 based foods on health: the plant-based diet index (PDI), the healthy plant-based diet index
310 (healthy PDI) and the unhealthy plant-based diet index (unhealthy PDI). These indices were
311 computed based on the consumption of the 18 food groups (12 plant-based foods and 6
312 animal-based food groups) mentioned above. For each food group, the participants' intakes

313 were classified into quintiles. The 18 food groups were classified into three categories
314 according to their source (animal or plant) and nutritional quality: healthy plant-based foods,
315 unhealthy plant-based foods, and animal-based foods. For a given individual, a sub-score for
316 each of the food groups was assigned based on the category of the food group and the quintile
317 of consumption of the food group. The sub-scores for the 18 food groups were then summed
318 to obtain the final scores (range 18–90). To compute PDIs, positive scores were given to the
319 healthy and unhealthy plant-based food categories (score of 1 for the first quintile and score of
320 5 for the fifth quintile) and reverse scores to animal-based food category (score of 1 for the
321 fifth quintile and score of 5 for the first quintile). The same method was used for healthy
322 PDIs, with positive scores for healthy plant-based food groups and reverse scores for
323 unhealthy plant-based food and animal-based food groups, and for unhealthy PDIs, with
324 positive scores for unhealthy plant-based food and reverse scores for healthy plant-based food
325 and animal-based food groups. A higher PDI thus reflected higher consumption of plant-based
326 foods and lower consumption of animal-based foods compared to the sample. A higher
327 healthy PDI reflected higher consumption of healthy plant-based foods. A higher unhealthy
328 PDI reflected higher consumption of unhealthy plant-based foods.

329 **d. Sociodemographic, anthropometric, and lifestyle data**

330 At baseline and once a year thereafter, participants were invited to fill out a set of self-
331 administered questionnaires on sociodemographic, anthropometric, and lifestyle
332 characteristics. For this study, characteristics collected closest to the questionnaire on changes
333 in meat consumption were used. Data collected included sex, age, occupational category
334 (unemployed/self-employed, farmer, employee, manual worker/intermediate
335 profession/managerial staff, intellectual profession/no occupation) corresponding to their last
336 occupational category before retirement, educational level (none or
337 primary/secondary/undergraduate and others/postgraduate), household composition (alone

338 without children/alone with at least one child/two adults living as a couple without children/
339 two adults living as a couple with at least one child/two or more adults without children), size
340 of urban residence unit (rural/<20,000 inhabitants/20,000–200,000 inhabitants/>200,000
341 inhabitants). Monthly income per household unit was obtained per household consumer unit
342 (c.u.). One c.u. was assigned to the first adult in the household, 0.5 c.u. for other persons aged
343 14 or older and 0.3 c.u. for children under 14. Five categories were defined and were assigned
344 to participants: <1200 € per c.u./1200–1800 € per c.u./1800–2700 € per c.u./>2700 € per
345 c.u./refused to declare). The date of the most recent weight-loss diet followed was collected,
346 and individuals were classified into three groups: no weight-loss diet, <5 years, >5 years.
347 Self-reported height and weight measurements were collected. Body mass index (BMI) was
348 calculated as weight (kg) per height squared (m²), and participants were classified into three
349 categories, according to World Health Organization (WHO) criteria: underweight
350 (<18.5 kg/m²), normal (18.5–25 kg/m²), overweight (excluding obesity) (25–30 kg/m²), obese
351 (≥30 kg/m²) (49). Self-reported height and weight measurements were validated against
352 clinical measurements (50). Level of physical activity was assessed using the International
353 Physical Activity Questionnaire (IPAQ) (51), and three categories were defined.

354 **e. Statistical analysis**

355 We included participants who had dietary data at least at two different follow-up times,
356 from their inclusion in the cohort study until 6 months after the questionnaire on changes in
357 meat consumption (included between 2009 and 2019). In addition, only follow-ups with two
358 or three 24-hour dietary records were considered. Self-reported vegetarians and vegans
359 together with those declaring they had eaten no meat in recent years were excluded from the
360 study ($n = 3162$), giving a final sample of 25,143 participants. More details of selection
361 criteria can be found in the flowchart (**Supplemental Figure 1**).

362 ***Sociodemographic, anthropometric, and lifestyle characteristics***

363 Sociodemographic, anthropometric, and lifestyle characteristics were described in the
364 total sample and compared across groups of individuals corresponding to stages of change
365 using chi2 and ANOVA tests.

366 *Food consumption*

367 We collected all dietary data from each complete follow-up over the period from
368 inclusion in the cohort study until 6 months after the questionnaire on changes in meat
369 consumption. For each follow-up, we computed mean daily food consumptions based on
370 available 24 h dietary records, together with the six dietary indices in relation to animal-based
371 and plant-based food consumptions: daily mean contributions of meat, processed meat, and
372 meat products to total energy intake, PDIs, healthy PDIs, and unhealthy PDIs. For each
373 follow-up, PDIs, healthy PDIs, and unhealthy PDIs were calculated according to the
374 consumption quintiles of the dietary data collected in 2009 and 2010.

375 First, we compared the mean daily consumption of meat, processed meat and meat
376 products at inclusion and at the latest follow-up available for each participant, for the five
377 stages of change.

378 Secondly, we assessed the mean daily food consumption over the period 2009–2019
379 by computing the average of the mean daily food consumptions of each follow-up. These
380 means were adjusted for sex, age, and total energy intake for the mean daily food
381 consumptions and mean PDIs, healthy PDIs, and unhealthy PDIs, and for sex and age for the
382 mean daily contributions of meat, processed meat, and meat products to total energy intake
383 using linear regression models.

384 The above two analyses included adjustments to correct potential estimation bias but
385 did not include comparison tests. Accordingly, we conducted additional analyses using
386 multivariate linear mixed models. These models were run to assess the association between
387 the six dietary indices related to animal-based and plant-based food consumptions in the diet

388 over time (as outcomes) and stages of change (as the main explanatory variable, with the
389 precontemplation stage as reference). This approach provides a more robust assessment of
390 potential changes in dietary behaviors over time. Mixed models for repeated measures were
391 used (PROC MIXED in the statistical software SAS®), with dietary indices as fixed effects,
392 and intercept and time as random effects. In our analysis, the variable “time” refers to the
393 length of time between the completion of the baseline dietary questionnaire and the
394 completion of another questionnaire during the follow-up. The value of “time” corresponds to
395 the date on which the baseline dietary questionnaire was completed. Given the non-normal
396 distribution of the contributions of meat, processed meat, and meat products to the total
397 energy intake, logarithmic transformations (Napierian) were computed and used as
398 normalized dependent variables in the three corresponding models. The beta coefficient for
399 stages of change represents the difference between the dietary index of a given stage and the
400 precontemplation stage of change (reference) at baseline. The beta coefficient for stages of
401 change \times time interaction represents the difference in slope between the curve representing
402 the dietary index over time for a given stage of change and the curve for the reference stage of
403 change. Models were adjusted for sex and for characteristics collected closest to the
404 questionnaire on changes in meat consumption, including age (continuous), educational level,
405 number of follow-up times at which dietary data were recorded, monthly household income
406 classes, occupational category, household composition, size of urban residence unit, BMI
407 category, date of most recent weight-loss diet and physical activity level. Models for PDI,
408 healthy PDI, and unhealthy PDI were also adjusted on the total energy intake, collected at the
409 latest available follow-up. Models for contribution of meat, processed meat, and meat
410 products to the total energy intake were run on the total sample, excluding participants who
411 did not consume the food product measured by the index.

412 ***Motives related to meat reduction and meat continuation according to stage of change***

413 In contrast to an earlier study conducted by our group (11), we used new variables of
414 motives for meat reduction or continuation using the dedicated questionnaire previously
415 described in the methods, and also described elsewhere (34). In this study, motives for
416 reducing meat were described in the contemplation, preparation, action, and maintenance
417 stages, and motives for continuing meat consumption were assessed for the precontemplation
418 and contemplation stages.

419 For each motive, we ran multivariable logistic regression models between the groups
420 representing different types of motive (no motive; motive, not change-inducing/hindering;
421 change-inducing/hindering motive) and the stages of change. These models were adjusted for
422 sex, age, educational level, monthly household income classes, occupational category,
423 household composition, size of urban residence unit, BMI, date of most recent weight-loss
424 diet and level of physical activity. We then computed the adjusted percentages from these
425 regression models and for either meat reduction or meat continuation, adjusted frequencies of
426 the three groups representing different types of motive were described according to stage of
427 change.

428 All tests were two-sided, and a p -value of <0.05 was considered significant. Statistical
429 analyses were conducted with SAS® (version 9.4, SAS Institute, Inc.) and some of the figures
430 were made with R Studio® (version 3.6.2, RStudio, Inc).

431

432 **Results**

433 **a. Sample selection and description**

434 A total of 25,143 participants were included in this analysis. Characteristics of the sample are
435 given in **Table 1**. Women made up 74.8% of the sample. Mean age at date of completion of
436 the meat consumption questionnaire was 56.4 years (Standard Deviation (SD) = 13.8). More
437 than 70% of the participants were at least undergraduate level, two-thirds belonged to an

438 occupational category corresponding to a higher socioeconomic position (e.g., managerial
439 staff), and a third reported a monthly income per household above 2700 € (Table 1). More
440 than 60% of participants were in one of the two last stages (action and maintenance)
441 (Table 1).

442 Sociodemographic, anthropometric, and lifestyle characteristics were compared according to
443 the five stages of change. Participants in the precontemplation stage included the highest
444 proportion of men, whereas we observed the highest proportion of women in the action stage
445 group. We also observed a higher proportion of older individuals in the precontemplation
446 stage, whereas the contemplation stage group included a higher proportion of younger
447 individuals. Participants in the maintenance stages included the highest proportion of
448 individuals with high educational level. Participants in the preparation stage included the
449 highest proportion of individuals with lower physical activity whereas the maintenance stage
450 included the highest proportion of participants with high level of physical activity (see
451 **Supplemental Table 3** for detailed results).

452 **b. Dietary intakes and indices of healthy and unhealthy plant-based diets according** 453 **to stage of change**

454 Over the period 2009–2019, the median number of follow-up times at which dietary data were
455 recorded was 7 and the mean follow-up period was 6.2 (SD = 2.6) years.

456 Regardless of the stage of change, participants consumed less meat, processed meat,
457 and meat products, comparing consumptions at baseline and at the latest available follow-up
458 (except for processed meat in the preparation stage) (**Figure 1, A**). Mean consumption of
459 meat, processed meat, and meat products gradually decreased between groups from the
460 precontemplation to the maintenance stage, at both inclusion (e.g., for meat, 57.5 (SD = 47.0)
461 g/day for precontemplation stage vs. 41.3 (SD = 40.1) g/day, for maintenance stage) and at
462 the latest available follow-up (e.g. for meat, 51.4 (SD = 46.4) vs. 33.2 (SD=37.0) g/day,

463 respectively). For more detailed results for dietary intakes among consumers, see

464 **Supplemental Table 4.**

465 Over the follow-up period, the adjusted mean daily contributions of meat products,
466 meat, and processed meat to total energy intake gradually decreased between the groups, from
467 precontemplation stage to maintenance stage. Adjusted mean PDI and healthy PDI gradually
468 increased between the groups (for PDI, 47.6, for precontemplation stage, and 51, for
469 maintenance stage; for healthy PDI, 52.7 and 56.3, respectively), while unhealthy PDI was
470 progressively slightly lower (respectively, 58.5 and 56.8) (**Supplemental Figure 2**). We also
471 observed higher consumptions of meat and dairy plant-based analogues (e.g., soy or almond
472 milk, plant-based patties, tofu, etc.) in later stages of meat reduction (see Supplemental Figure
473 2).

474 **c. Evolution of meat intakes and of the contribution of healthy and unhealthy plant-**
475 **based foods to the diet, according to stage of change**

476 At baseline, there was a significant association between the action and maintenance
477 stages and a smaller contribution of meat products to the diet, compared to the
478 precontemplation stage (**Supplemental Table 5**). Only later stages were significantly
479 associated with the slope of meat, processed meat, and meat product consumptions over time,
480 meaning that only these participants showed a higher decrease in their consumption of meat
481 products over time, compared to those in the precontemplation stage (**Figure 1, B**).

482 Stages of change toward meat reduction were all statistically associated with higher scores of
483 PDI and healthy PDI at baseline, compared to the precontemplation stage (**Supplemental**
484 **Table 6**). Only the last two stages were significantly associated with the slope of PDI and
485 healthy PDI over time, compared to the precontemplation stage (Figure 1, B). The action
486 stage was statistically associated with a higher contribution of plant-based foods over time
487 and a higher contribution of healthy plant-based food over time, compared to the

488 precontemplation stage. For the maintenance stage, we also observed a statistically higher
489 contribution of overall plant-based food and healthy plant-based food over time. At baseline,
490 the contribution of unhealthy plant-based food to the diet was statistically lower for
491 participants in the contemplation, preparation, action, and maintenance stages, compared to
492 those in the precontemplation stage.
493 Finally, no significant association was observed between the four stages of change and the
494 slope of unhealthy PDI over time.

495 **d. Motives for meat reduction and meat continuation according to stage of change**

496 *Motives for meat reduction*

497 Concerns about health, nutrition, and preservation of the environment were the motives most
498 frequently declared for reducing meat consumption by participants in the contemplation,
499 preparation, action, and maintenance stages (**Table 2**). Frequencies of participants declaring
500 these motives as change-inducing were even higher between the early and the later stage of
501 change (e.g., for the health motive, 51% for contemplation vs. 75.3% for maintenance in the
502 “change-inducing motive” group). In addition, some motives were felt to be important, but
503 were less frequently declared as encouraging meat reduction in every stage of change. For
504 example, up to 65% of participants in each stage declared they had concerns about animal
505 welfare (participants in “motive, not change-inducing” and “change-inducing motive”
506 groups). However, this motive was declared to have induced meat reduction in fewer than half
507 of participants in all stages (33.1% for contemplation and 47.4% for maintenance, in the
508 “change-inducing motive” group). Also, fewer than 10% of the participants declared motives
509 such as aversion to the taste of meat or doctor’s advice as change-inducing.

510 *Motives for meat continuation*

511 In both the precontemplation and contemplation stages, the pleasure of eating meat was
512 frequently reported as a motive to continue meat consumption (73.9% and 67.1% for the
513 precontemplation and contemplation stages, respectively, corresponding to the “change-
514 hindering motive” group) (**Table 3**). Other motives such as thinking that meat is a good
515 source of protein (64% and 53.4%), and that meat is part of personal culture (49.7% and 53%)
516 were also fairly frequently declared as motives for not reducing meat consumption.
517 Participants in the precontemplation stage frequently declared that they continued their meat
518 consumption because they thought meat had health benefits (63.6%). Participants in the
519 contemplation stage frequently declared that they continued their meat consumption owing to
520 difficulty changing their meat-eating habits (51.5%).

521

522 **Discussion**

523 Concerns about health, nutrition, and the preservation of the environment motivated
524 individuals to reduce their meat consumption. Liking meat seemed to be one of the main
525 barriers to change. Being in later stages of change toward meat reduction was associated with
526 a higher decrease in the consumption of meat products and a higher increase in the
527 consumption of healthy plant-based foods over time. To the best of our knowledge, this study
528 is the first to examine the association between quantitative measures, which represent an
529 evolution of food intakes, and the TTM, and to investigate a phase model of behavior change
530 related to meat reduction in the French population.

531

532 According to the principles of the TTM applied to meat reduction, individuals in the
533 two last stages of change (action and maintenance) had already started to reduce their meat

534 consumption. Observed meat intakes over time were consistent with self-reported intentions
535 and behavior change, supporting the use of this TTM construct.

536 We observed that individuals who had already started to reduce their meat consumption
537 consumed more plant-based foods, and especially healthy plant-based foods, than animal-
538 based foods over time, compared to those who had no intention of changing their
539 consumption (i.e., the precontemplation stage). Previous data in the same cohort study, using
540 food frequency questionnaires and general food choice motives highlighted a slight trend
541 towards healthier and plant-based diets over time in some parts of the population (12), notably
542 in individuals with sustainability food concerns (11).

543

544 In our study, we found that concerns for health and nutrition were the main effective
545 motives for reducing meat consumption for participants in contemplation through to
546 maintenance stages. These two motives have been widely cited by meat reducers in previous
547 studies (52), and even more among individuals in later stages (53). Yet the same two motives
548 were also declared by participants who continued their meat consumption at the earlier stages
549 of change, especially in the precontemplation stage. This in line with other studies which
550 found that these motives were strongly expressed by meat eaters (31,53–55), for example
551 those in the precontemplation stage (26,30). This paradox or ambivalent role of health and
552 nutrition-related motives has been described previously (31,56,57) and may be partly
553 explained by the evolution of messages derived from dietary guidelines over the last 20 years.
554 These messages have evolved from encouraging meat intake in the early 2000s, to
555 discouraging red meat and processed meat in the late 2010s and setting recommended ceilings
556 (4).

557 Among change-inducing motives, preserving the environment was also frequently
558 declared as a reason for reducing meat consumption, particularly in the later stages. This
559 finding is in line with the recent Danish study (13), although previous studies have reported
560 heterogeneous results (9,29,31,58). Public health campaigns combining health and
561 environmental impacts of meat in their messages could thus be an effective strategy for
562 encouraging meat reduction compared to a message focusing on a single motive, as suggested
563 by a previous British study (59).

564 Concern for the preservation of animal life and for animal welfare was declared with
565 moderate frequency as having induced meat reduction, compared to the previously cited
566 motives. Animal welfare may be a stronger lever in other cultural settings (60) and especially
567 for vegetarians or vegans (61), but we lack results on the effectiveness of this motive in
568 reducing meat consumption in non-vegetarian populations. An intervention study highlighted
569 that information about animal welfare had a strong effect on reducing meat consumption in
570 Germany (55). To provide information about animal welfare, front-of-pack labels were
571 developed (62), but are seldom available on food products in many countries including
572 France. Few results are available on the effectiveness of such labels in influencing food
573 choices (63), but further studies could investigate whether such information can incentivize
574 meat reduction.

575 Among change-hindering motives, enjoying meat was the main motive reported by
576 participants for continuing their meat consumption. This motive was even more often stated
577 by consumers who had no intention of changing their consumption (precontemplation stage).
578 Many previous studies have shown that the sensory attributes of meat, and in particular its
579 taste, were a main lever of meat consumption (54,64), and so formed an important
580 disincentive to meat reduction (61,65). Furthermore, in our study, food habits and culinary
581 traditions seemed to hinder change in meat consumption, especially among individuals who

582 declared their intention to reduce meat (contemplation stage), as previously described (53). As
583 the pleasure of eating is a core value of French food culture, public health authorities could
584 also promote messages following the “less but better” principle (66), that is to say eating less
585 animal-based foods both in quantity and frequency, but choosing those with better overall
586 quality: fair trade, organic, or short circuit supply. To reduce their meat consumption,
587 individuals could replace animal-based dishes by plant-based dishes in their meals, assuming
588 they have the cooking skills and ideas for plant-based food recipes (67). Public health
589 authorities could provide practical advice such as shopping tips, weekly meal planning, and
590 recipes to help consumers add plant-based meals to their food habits such as the “*La Fabrique*
591 *à menus*” in France (68)). Tasty plant-based products such as legumes could also be
592 promoted, in line with previous findings (34).

593 Our study has some limitations. The study population consisted of volunteers,
594 registered to answer questionnaires related to health and nutrition. This population might
595 therefore have been more aware of health and nutrition issues. Although over 60% of the
596 participants declared they had initiated a reduction in meat consumption, the mean intake of
597 meat remained similar to national representative surveys (69). Another limit is the over-
598 representation of women in our study sample compared to the general population (70), as
599 commonly observed in various epidemiological studies (70), possibly producing selection
600 bias. This over-representation could mean an over-representation of individuals reducing or
601 willing to reduce their meat consumption, as it is well-established that sex is associated with
602 changes in meat consumption (52,71). Nevertheless, our study offers the advantage of a large
603 sample size, with over 25,000 participants, enabling us to identify a diverse range of meat
604 consumption behaviors. Besides those who reduced their meat consumption, we identified
605 more than 6,000 participants who reported continuing their meat consumption, of whom

606 51.8% reported no interest in reducing meat. Our analysis was controlled for
607 sociodemographic characteristics, including sex, which helps limit this bias.

608 Secondly, some limitations regarding the use of the TTM can be highlighted, such as the
609 arbitrary boundary between the action and maintenance stages, set at 2 years in this study.
610 These stages are distinguished by the length of time since the behavior change occurred,
611 which can be difficult to define in specific contexts, especially for food behavior (13,40,41).
612 In addition, the definitions of contemplation and preparation stages is heterogeneous in the
613 literature (13). For this study, we defined these stages in line with both the original definition
614 of the TTM and the study of Tobler et al. (30). We note that the use of different thresholds
615 and the variability of definitions in different studies make comparison between findings
616 difficult and so might limit the external validity of our results.

617 Our study design did not enable us to study the characteristics of individuals who had reduced
618 their meat consumption, but no longer do so, compared to those who were still reducing their
619 consumption. Further research could address this topic.

620 Some authors have questioned the validity of the stages of change, suggesting that finer
621 distinctions within stages may be relevant (72). For example, some authors have suggested
622 subcategories for the precontemplation stage, such as “aware” and “unaware” (73). However,
623 as claimed by one of the original authors of the TTM, the purpose of this model is not to
624 identify a rigidly defined set of stages and prove their existence, but rather to improve our
625 understanding of the process of behavior change and the scope to influence this process (23).
626 Future longitudinal studies could explore diverse decision-making paths.

627 Thirdly, as suggested by the TTM, the process of change involves an individual going through
628 successive stages toward behavioral change. However, this model might not fully capture the
629 complexity of behavior change, as some individuals may skip a stage or stay in one (23,74),
630 or regress to an earlier stage (75). Further studies assessing stages at different time points

631 could specifically explore relapse and other dynamics of the process. However, we observed
632 that stages of change were in line with longitudinal dietary data. Our results support the use of
633 such a model, although we acknowledge that this approach can be completed by other models
634 of food behavior change.

635 Our study has several strengths. First, only a few studies in the literature have used the TTM
636 to explore the process of meat reduction in a large population (13,26–28) or to explore the
637 motives for meat reduction or continuation in the general population (13), although our
638 sample may not be fully representative of the French population.

639 The longitudinal design of our study to explore the evolution of food consumption is another
640 strength. It enabled us to observe changes in meat and meat product consumption over time
641 using validated dietary questionnaires, and to evaluate the nutritional quality of diets across
642 different stages of meat reduction. Further studies on the trajectory of other types of meat,
643 such as poultry, could provide more information on the sustainable food transition. In the
644 literature, certain studies suggest that meat reduction starts with increased poultry
645 consumption (76–78), but other studies, in line with our cross-sectional findings, indicate a
646 steady poultry consumption (31,76,78).

647 Another key strength of our study is that it examines the reduction in meat consumption in the
648 specific context of France, where meat is central in the food culture (79). Meat reduction is
649 thus highly relevant to a sustainable food transition in France. Transitions toward meat
650 reduction may vary across different countries with different cultural and culinary backgrounds
651 (28,80), which limits the comparison of the results. Our study may provide knowledge about
652 Europeans who are less reluctant to reduce meat consumption, as more than 60% declared
653 they were reducing their consumption, whereas in other studies, such as Denmark, only 27,6%

654 of participants did so (13). Country-specific studies are thus essential to ensure the relevance
655 and robustness of results for sustainable food transition.

656 ***Conclusion***

657 In this study, longitudinal dietary data were in line with theoretical assumptions of the
658 TTM, individuals who had already initiated a meat reduction adhering to healthier and more
659 sustainable diets, as defined by the stages of change. Health, nutrition and environmental
660 concerns were associated with reduced meat consumption. Enjoying meat hindered meat
661 reduction, indicating an opportunity to provide advice and practical tools to enhance the
662 attractiveness of plant-based foods, particularly in specific populations who do not yet feel
663 concerned by meat reduction. Further studies quantifying the environmental impacts of diets
664 could evaluate their contributions to enhance the current nutritionally sustainable transition.

665

666 **Acknowledgments**

667 The authors thank all the volunteers of the NutriNet-Santé cohort.

668 We thank Cédric Agaesse, Alexandre De Sa, Rebecca Lutchia (dietitians); Thi Hong Van
669 Duong, Younes Esseddik (IT manager), Régis Gatibelza, Jagatjit Mohinder and Aladi Timera
670 (computer scientists); Julien Allegre, Nathalie Arnault, Laurent Bourhis and Fabien Szabo de
671 Edelenyi, PhD (supervisor) (data-manager/statisticians) for their technical contribution to the
672 NutriNet-Santé study and Nathalie Druesne-Pecollo, PhD (operational coordination).

673 **Statement of authors' contributions to the manuscript**

674 SH, CM, MT, SP, BA, EKG and NDP designed and implement the cohort study; BA, CM, LS
675 and AR designed research and provided essential materials; AR and BA analyzed data or
676 performed statistical analysis; AR drafted the paper; BA had primary responsibility for final
677 content. All the authors have read and approved the final manuscript.

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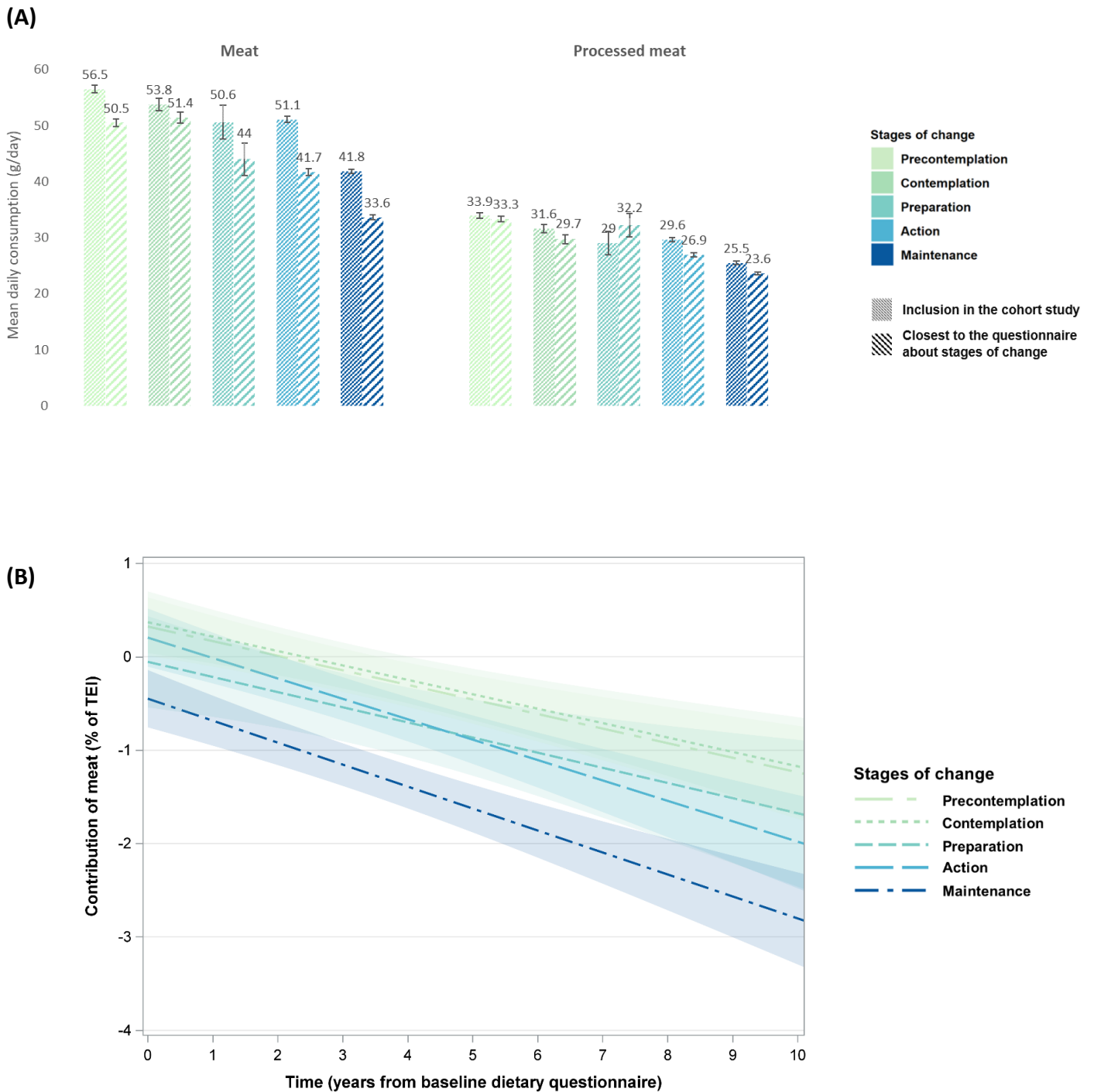
Table 1. Sociodemographic, anthropometric, and lifestyle characteristics of included participants and stages of change, NutriNet-Santé, 2009–2018, $n = 25,143$

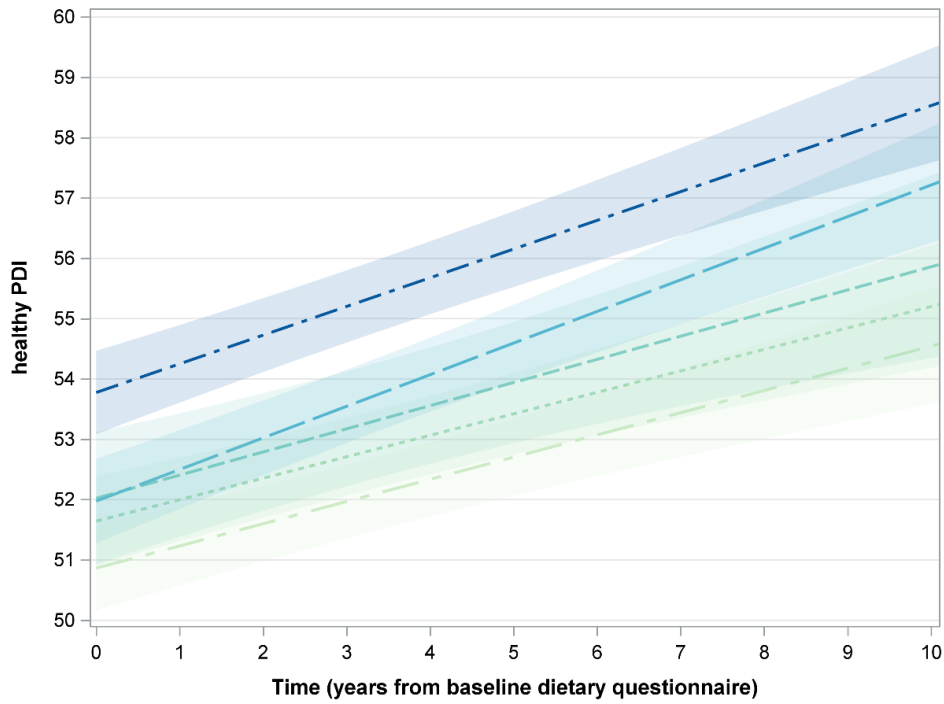
	Total sample (n = 25,143)	
	<i>n</i>	% or mean (SD)
Sex		
Men	6326	25.2
Women	18817	74.8
Age (y)		
		56.4 (13.8)
Age (y, category)		
[18-30[	683	2.7
[30-50[	7127	28.4
[50-65[	8743	34.8
[65+[	8590	34.2
Monthly household income class (per u.c.)		
< 1200 €	3293	13.1
1200–1800 €	5044	20.1
1800–2700 €	5966	23.7
> 2700 €	8478	33.7
Refused to declare	2362	9.4
Occupational category		
Self-employed, farmer, employee, manual worker	6510	25.9
Intermediate profession	6254	24.9
Managerial staff, intellectual profession	10388	41.3
Unemployed	1830	7.3
No occupation	161	0.6
Educational level		
None or primary	428	1.7
Secondary	6696	26.6
Undergraduate and others	8044	32.0
Postgraduate	9975	39.7
Household composition		
Alone without children	4612	18.3
Alone with at least one child	1621	6.5
Two adults living as a couple without children	10800	43.0
Two adults living as a couple with at least one child	7714	30.7
Two or more adult without children	396	1.6
Size of urban residence unit		
Rural	5602	22.3
< 20,000 inhabitants	3877	15.4
20,000–200,000 inhabitants	4707	18.7
> 200,000 inhabitants	10957	43.6
Last weight-loss diet followed		
Not declaring a weight-loss diet	9615	38.2
< 5 years	1700	6.8
> 5 years	13828	55.0
BMI		
Underweight	1040	4.1
Normal	15426	61.4
Overweight	6229	24.8
Obesity	2448	9.7
Physical activity		
Low physical activity	4311	17.2

Moderate physical activity	9840	39.1
High physical activity	10992	43.7
Stages of change		
Precontemplation	3141	12.5
Contemplation ¹	1454	5.8
<i>Participants who declared meat reduction (%)</i>	916	63.0
<i>Participants who declared meat continuation (%)</i>	538	37.0
Preparation	184	0.7
Action	5052	20.1
Maintenance	10509	41.8

¹ Participants identified in the contemplation stage could either respond that they were thinking of reducing their meat consumption or that they were continuing their meat consumption.

Figure 1. Adjusted mean daily consumption of meat and processed meat (and SEM) at the inclusion in the cohort and closest to the questionnaire on stages of change, according to stage of changes ($n = 25,143$) (A)¹ and changes in percent energy intake provided by meat (logarithm of the contribution of the given food to total energy intake, $n = 24,715$) and in healthy PDI ($n = 25,143$) over time according to the group of individuals in stages of change in French adults participating in the NutriNet-Santé cohort (multivariate linear mixed models)² (B).





¹ Mean daily consumptions have been adjusted for sex, age (continuous) and mean total energy intake

² The mean predicted trajectories (solid lines) with 95% confidence intervals (indicated with shading) were plotted for a chosen profile of covariates. We chose the mean number of dietary records (7.8), of an average study participant profile at the date of the questionnaire on stages of change: a woman, aged 56.4 years, with a total energy intake equal to 1832 kcal (for hPDI only), with an educational level higher than primary, with an occupational category not corresponding to self-employed, farmer, employee or manual worker, with a monthly household income higher than 1200 €, not living in alone, living in a city, with a BMI corresponding to WHO categories of “underweight”, “overweight” or “obesity”, declaring a weight-loss diet and with a moderate or high physical activity. Note that the choice of profile was made to optimize graphical representation and has no influence on the differences in trajectories estimated by the model. Data not shown for the group “Other”.

Table 2. Comparison of adjusted frequencies according to different types of motives related to meat reduction and stages of change towards meat reduction, NutriNet-Santé, n=16,661 ¹

	Contemplation (n = 916)	Preparation (n = 184)	Action (n = 5052)	Maintenance (n = 10,509)
	% ²	% ²	% ²	% ²
I don't like the taste of meat				
No motive	98.1	98.4	97	94
Motive, not change-inducing	0.4	0	0.3	0.5
Change-inducing motive	1.5	1.6	2.7	5.5
I don't like the sight or the handling of meat, especially raw meat				
No motive	86.6	91.9	88.1	84.6
Motive, not change-inducing	7.5	4.3	5.3	6.2
Change-inducing motive	5.8	3.8	6.6	9.2
I think it's good to vary my diet and my protein sources by eating something different than meat				
No motive	17.7	14	11.8	9.9
Motive, not change-inducing	33.9	19.9	16.7	18.4
Change-inducing motive	48.4	66	71.4	71.7
I think it's healthier not to eat too much meat				
No motive	23.5	21.3	15.2	12.7
Motive, not change-inducing	25.5	17.7	10.5	11.9
Change-inducing motive	51	61	74.3	75.3
I think it's healthier to avoid meat				
No motive	94.7	97.3	93.1	90.3
Motive, not change-inducing	2	0.9	0.5	1.4
Change-inducing motive	3.3	1.8	6.3	8.3
I care about animal welfare or the lives of animals				
No motive	34.3	34	34.7	29.3
Motive, not change-inducing	32.6	30	22.5	23.2
Change-inducing motive	33.1	36	42.8	47.4

I think it's better for the environment not to eat too much meat

No motive	25	22.9	21.5	17.9
Motive, not change-inducing	29.6	21.6	15.7	15.6
Change-inducing motive	45.4	55.5	62.8	66.5

The people I live with don't like or eat meat

No motive	95.5	95.5	90.7	87.9
Motive, not change-inducing	1.9	0.7	1.9	3.4
Change-inducing motive	2.6	3.8	7.4	8.8

My doctor advises me to reduce my meat consumption

No motive	96.2	96.9	94.4	94.8
Motive, not change-inducing	0	0	0	0
Change-inducing motive	3.8	3.1	5.6	5.2

I am cutting back on my budget by eating less meat

No motive	57.4	49.3	46.6	45.3
Motive, not change-inducing	21.3	22.2	18.3	18.6
Change-inducing motive	21.3	28.6	35.1	36.1

I have trouble finding meat that I consider to be of good quality

No motive	67.5	69.2	65.3	63.7
Motive, not change-inducing	15.5	12.7	9.4	8.3
Change-inducing motive	17	18.1	25.3	28

I have difficulty preserving the meat I buy

No motive	91.2	93.8	93.5	93.8
Motive, not change-inducing	3.6	2.9	2	1.7
Change-inducing motive	5.2	3.3	4.6	4.5

¹ This subsample includes participants who declared a meat reduction in contemplation, preparation, action and maintenance stages, which explains the variations in the total number of participants (data for the "Other" group not shown)

² Percentage adjusted for sex, age (continuous), educational level, monthly household income classes, occupational category, household composition, size of urban residence unit, BMI categories, last weight-loss diet and level of physical activity.

Table 3. Comparison of adjusted frequencies according to different types of motives hindering meat reduction and stages of change toward meat reduction, NutriNet-Santé ($n = 3659$)¹

	Precontemplation ($n = 3,141$)	Contemplation ($n = 518$)
	% ²	% ²
I enjoy eating meat		
No motive	12.3	20.3
Motive, not change-hindering	13.8	12.5
Change-hindering motive	73.9	67.1
I have trouble changing my meat-eating habits		
No motive	55.4	39.3
Motive, not change-hindering	8.3	9.2
Change-hindering motive	36.3	51.5
I think meat is good for my health		
No motive	22.1	43.6
Motive, not change-hindering	14.4	12.5
Change-hindering motive	63.6	43.9
I want to support farmers and meat producers		
No motive	39.8	51.8
Motive, not change-hindering	23.6	19.8
Change-hindering motive	36.6	28.3
I think eating meat allows me to reach satiety		
No motive	36.4	44.1
Motive, not change-hindering	20.1	20.3
Change-hindering motive	43.5	35.6
The people I live with like meat and want to eat it		
No motive	29.3	32.5
Motive, not change-hindering	29.6	22.9
Change-hindering motive	41.1	44.5

I don't know what to eat as a substitute of meat

No motive	79.2	65.3
Motive, not change-hindering	4.1	4.1
Change-hindering motive	16.7	30.6

Meat is part of my culture

No motive	21.4	22.6
Motive, not change-hindering	28.9	24.4
Change-hindering motive	49.7	53

I feel pressure from those around me to eat meat

No motive	99.2	97.8
Motive, not change-hindering	0.7	1.9
Change-hindering motive	0.1	0.3

I think meat is a good source of protein

No motive	10.7	17.7
Motive, not change-hindering	25.3	28.9
Change-hindering motive	64	53.4

I think meat gives me strength

No motive	49	57.7
Motive, not change-hindering	9.3	8.2
Change-hindering motive	41.8	34.1

¹ This sample includes participants who declared meat continuation in precontemplation and contemplation stages, which explains the variations in the total number of participants (data for the “Other” group not shown).

² Percentage adjusted for sex, age (continuous), educational level, monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI categories, last weight-loss diet and level of physical activity.

Stages of change toward meat reduction: Associations with motives and longitudinal dietary data on animal-based and plant-based food intakes in French adults. Reuzé al. 2023

Supplemental Table 1: Items for meat reduction (for contemplation, preparation, action and maintenance stages) and meat continuation (for precontemplation and contemplation stages)

Meat reduction	Meat continuation
I don't like the taste of meat	I enjoy eating meat
I don't like the sight or the handling of meat, especially raw meat	I have trouble changing my meat-eating habits
I think it's good to vary my diet and my protein sources by eating something different than meat	I think meat is good for my health
I think it's healthier not to eat too much meat	I have the will to support the farmers and the meat producers
I think it's healthier to avoid meat	I think eating meat allows me to reach satiety
I care about animal welfare or the lives of animals	The people I live with like meat and want to eat some
I think it's better for the environment not to eat too much meat	I don't know what to eat as a substitute of meat
The people I live with don't like or eat meat	Meat is part of my culture
My doctor advises me to reduce my meat consumption	I feel pressure from those around me to eat meat
I am cutting back on my budget by eating less meat	I think meat is a good source of protein
I have trouble finding meat that I consider to be of good quality: origin, traceability, hygiene, labeled meat, organic meat, or other quality criteria	I think meat gives me strength
I have difficulty preserving the meat I buy	

Supplemental Table 2: Food groups used to calculate PDI, healthy PDIs and unhealthy PDIs.

		PDI	hPDI	uPDI
Plant-based foods	Healthy	Positive score (1 to 5 based on consumption quintiles)	Positive score (1 to 5 based on consumption quintiles)	Reverse score (5 to 1 based on consumption quintiles)
	Whole grains Fruits Vegetables Nuts Legumes Vegetable oil Tea and coffee			
	Unhealthy		Reverse score (5 to 1 based on consumption quintiles)	Positive score (1 to 5 based on consumption quintiles)
	Refined grains Potatoes Sugar sweetened beverages ¹ Sweets and desserts Miscellaneous plant-based foods ²			
<i>Plant-based Range</i>		<i>12 to 60</i>		
Animal-based foods		Reverse score (5 to 1 based on consumption quintiles)	Reverse score (5 to 1 based on consumption quintiles)	Reverse score (5 to 1 based on consumption quintiles)
	Animal added fats Dairy foods Eggs Fish and seafood Meat Miscellaneous animal-based foods			
<i>Animal-based Range</i>		<i>6 to 30</i>		
Total Range		18 to 90		

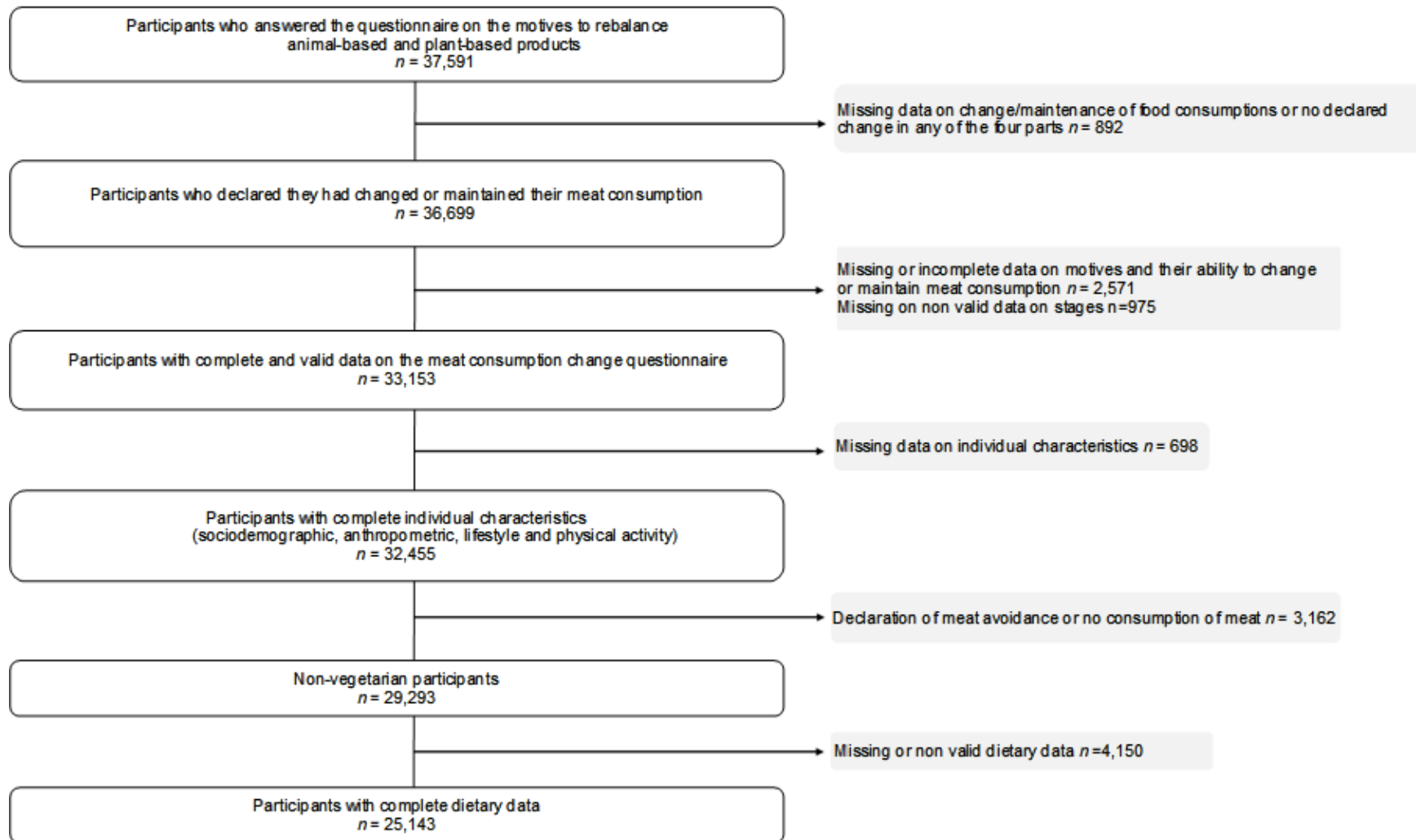
Abbreviations: PDI: Plant-based Diet Index

List of modifications from the original study Satija et al.

¹ Clustering of “Fruit juices” and “Sugar-sweetened beverages” groups

² Creation of the “Miscellaneous plant-based foods” group, including plant-based sugary or salty snacks, nuts and peanut butter, and plant-based meat and dairy substitutes. including all plant products used as substitutes for animal and all processed vegetarian products (protein substitutes, plant-based processed meats, dairy substitutes, plant-based salty snacks and fast food)

Supplemental Figure 1: Flowchart of the study.



Supplemental Table 3: Sociodemographic, anthropometric and lifestyle characteristics of participants according to stages of change, NutriNet-Santé, 2009-2018, n=25,143

	Precontemplation (n=3,141)		Contemplation (n=1,454)		Preparation (n=184)		Action (n=5,052)		Maintenance (n=10,509)		Others ¹ (n=4,803)		P ²
	n	%	n	%	n	%	n	%	n	%	n	%	
Sex													< 0.0001
Men	1232	39.2	436	30.0	47	25.5	985	19.5	2657	25.3	969	20.2	
Women	1909	60.8	1018	70.0	137	74.5	4067	80.5	7852	74.7	3834	79.8	
Age (y)	57.6 (14.4)		54.1 (14.6)		55.0 (14.2)		54.3 (14.0)		57.2 (13.2)		56.7 (13.9)		< 0.0001
Age (y, category)													< 0.0001
[18-30[	84	2.7	55	3.8	7	3.8	196	3.9	211	2.0	130	2.7	
[30-50[	885	28.2	525	36.1	55	29.9	1642	32.5	2677	25.5	1343	28.0	
[50-65[	908	28.9	425	29.2	69	37.5	1816	36.0	3920	37.3	1605	33.4	
[65+[	1264	40.2	449	30.9	53	28.8	1398	27.7	3701	35.2	1725	35.9	
Monthly household income class (per c.u.)													< 0.0001
< 1200 €	452	14.4	239	16.4	25	13.6	702	13.9	1172	11.2	703	14.6	
1200 - 1800 €	706	22.5	346	23.8	46	25.0	1093	21.6	1876	17.9	977	20.3	
1800 - 2700 €	763	24.3	354	24.4	40	21.7	1132	22.4	2546	24.2	1131	23.6	
> 2700 €	894	28.5	380	26.1	52	28.3	1648	32.6	4020	38.3	1484	30.9	
Refused to declare	326	10.4	135	9.3	21	11.4	477	9.4	895	8.5	508	10.6	
Occupational category													< 0.0001
Self-employed, farmer, employee, manual worker	963	30.7	401	27.6	52	28.3	1346	26.6	2371	22.6	1377	28.7	
Intermediate profession	738	23.5	380	26.1	47	25.5	1246	24.7	2626	25.0	1217	25.3	
Managerial staff, intellectual profession	1215	38.7	571	39.3	60	32.6	2049	40.6	4683	44.6	1810	37.7	
Unemployed	203	6.5	91	6.3	20	10.9	376	7.4	776	7.4	364	7.6	
No occupation	22	0.7	11	0.8	5	2.7	35	0.7	53	0.5	35	0.7	
Educational level													< 0.0001
None or Primary	85	2.7	27	1.9	3	1.6	88	1.7	135	1.3	90	1.9	
Secondary	1099	35.0	408	28.1	57	31.0	1264	25.0	2491	23.7	1377	28.7	
Undergraduate and others	927	29.5	487	33.5	51	27.7	1682	33.3	3377	32.1	1520	31.7	
Post graduate	1030	32.8	532	36.6	73	39.7	2018	39.9	4506	42.9	1816	37.8	
Household composition													< 0.0001
Alone without children	569	18.1	185	12.7	18	9.8	863	17.1	1970	18.8	1007	21.0	
Alone with at least one child	194	6.2	80	5.5	10	5.4	335	6.6	690	6.6	312	6.5	
Two adults living as a couple without children	1394	44.4	619	42.6	82	44.6	2041	40.4	4605	43.8	2059	42.9	
Two adults living as a couple with at least one child	945	30.1	549	37.8	69	37.5	1732	34.3	3075	29.3	1344	28.0	
Two or more adult without children	39	1.2	21	1.4	5	2.7	81	1.6	169	1.6	81	1.7	

Size of the urban residence unit													< 0.0001
Rural	814	25.9	351	24.1	34	18.5	1168	23.1	2198	20.9	1037	21.6	
< 20.000 inhabitants	514	16.4	231	15.9	31	16.9	815	16.1	1576	15.0	710	14.8	
20.000 - 200.000 inhabitants	591	18.8	278	19.1	38	20.7	900	17.8	1935	18.4	965	20.1	
> 200.000 inhabitants	1222	38.9	594	40.9	81	44.0	2169	42.9	4800	45.7	2091	43.5	
Last weight-loss diet followed													< 0.0001
Not declaring a weight-loss diet	1213	38.6	505	34.7	58	31.5	1634	32.3	4133	39.3	2072	43.1	
< 5 years	189	6.0	106	7.3	9	4.9	370	7.3	741	7.1	285	5.9	
> 5 years	1739	55.4	843	58.0	117	63.6	3048	60.3	5635	53.6	2446	50.9	
BMI													< 0.0001
Underweight	95	3.0	43	3.0	6	3.3	179	3.5	448	4.3	269	5.6	
Normal	1577	50.2	821	56.5	94	51.1	3017	59.7	6800	64.7	3117	64.9	
Overweight	1003	31.9	413	28.4	50	27.2	1315	26.0	2421	23.0	1027	21.4	
Obesity	466	14.8	177	12.2	34	18.5	541	10.7	840	8.0	390	8.1	
Physical activity													< 0.0001
Low physical activity	625	19.9	337	23.2	44	23.9	938	18.6	1610	15.3	757	15.8	
Moderate physical activity	1129	35.9	596	41.0	67	36.4	2121	42.0	4093	39.0	1834	38.2	
High physical activity	1387	44.2	521	35.8	73	39.7	1993	39.5	4806	45.7	2212	46.1	

¹ Other: participants who answered “No, it’s for another reason” and “No, because I was already eating little meat.” to the question “*In recent years, have you reduced your meat consumption?*”.

² Chi2 tests or ANOVA

Supplemental Table 4: Percentage of consumers and adjusted mean daily consumption and dietary indices (mean and SEM), among consumers, at the inclusion in the cohort and at the latest available follow-up, according to stages of changes, NutriNet-Santé, n=25,143¹

	Precontemplation (n=3,141)						Contemplation (n=1,454)						Preparation (n=184)					
	Inclusion			Latest available follow-up			Inclusion			Latest available follow-up			Inclusion			Latest available follow-up		
	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM
Plant-based foods																		
Fruits (g/d)	89.9	200.3	2.8	89.0	191.9	2.8	92.2	203.1	4	89.8	193.2	4	93.5	203.3	11.1	92.9	198.5	11.1
Vegetables (g/d)	99.2	229.3	2.7	98.6	222.4	2.7	99.0	237.3	3.9	98.7	234.3	4	99.5	259.3	10.9	100.0	261	11
Legumes (g/d)	26.5	37.2	1.2	23.2	39.3	1.4	27.8	40.7	1.8	24.5	39.3	2	27.2	33.8	5.1	27.2	38.7	5.2
Potatoes and other tubers (g/d)	68.2	66	1.1	66.0	66.9	1.1	70.9	67.2	1.5	67.5	68.2	1.5	66.3	60.1	4.4	65.2	66.2	4.4
Whole grains (g/d)	48.7	52.1	1.3	48.2	57.5	1.3	57.3	54.2	1.8	55.8	55.2	1.8	63.0	60.2	4.6	56.0	59.4	4.9
Refined cereals and grains (g/d)	98.2	155	1.5	96.8	137	1.4	98.4	160.4	2.1	97.2	140.5	2	98.9	156.9	5.9	97.3	137.9	5.7
Sweet and desserts (g/d)	97.3	98.9	1.2	95.3	95.9	1.2	97.9	97.5	1.7	96.5	96.7	1.7	97.3	105.5	4.8	96.7	96.5	4.8
Nuts (g/d)	21.7	10.9	0.6	25.0	9.3	0.6	23.0	11.5	0.9	28.5	9.9	0.8	28.8	9.9	2.3	31.5	9	2
Vegetable oil (g/d)	75.2	9.4	0.2	72.2	8.4	0.2	79.8	9.7	0.3	73.8	8.5	0.3	81.5	9.8	0.7	72.3	7.9	0.7
Uncooked cereals and seeds (g/d)	2.1	12.9	1.6	2.3	15.7	1.6	2.1	11.1	2.3	3.7	10.2	1.9	3.8	9.6	4.8	7.1	15	3.8
Miscellaneous (g/d)	22.8	14.3	0.6	20.2	16.4	0.9	22.6	13.1	0.9	21.1	12.1	1.2	19.6	12.6	2.8	22.3	17	3.4
Dairy substitutes (g/d)	2.0	85.6	6.3	2.5	78.6	6.1	4.8	74.9	6	4.1	74.5	7.2	6.0	58.5	15.1	4.3	63.2	19.1
Meat substitutes (g/d)	0.4	38.3	5.8	0.5	43.3	6.9	0.6	39.9	6.4	1.6	48.1	6	0.5	30.6	19.3	1.1	30.7	20
Fermented and coagulated foods (g/d)	0.3	27.5	7.1	0.1	37.6	12.6	0.5	38.5	8.1	0.4	41.5	10.3	0.5	1	21.3	1.1	26.8	18
Animal-based foods																		
Meats (all types) (g/d)	98.9	123.2	1	98.4	117	1	98.6	119.3	1.5	98.8	111.1	1.4	98.9	113.1	4.1	99.5	107.4	4
Meat products ² (g/d)	96.5	98.9	0.9	95.8	92	0.9	96.1	93.8	1.3	95.1	88.2	1.3	95.7	88.1	3.7	96.2	82.6	3.6
Meat (g/d)	80.5	66.9	0.7	75.8	62.6	0.7	80.2	63.2	1.1	75.0	63.2	1.1	78.3	62	3.1	70.1	58.9	3.2
Offal (g/d)	13.0	41.8	1.2	79.9	42.8	1.3	12.9	41.2	1.7	10.5	39.3	2.1	12.0	40	5	12.5	35.8	5.3
Processed meat (g/d)	81.7	44.6	0.6	56.8	44.2	0.6	80.4	42.5	0.9	78.7	40.4	0.9	76.1	40.2	2.5	77.7	42.2	2.5
Poultry (g/d)	57.6	45.9	0.8	56.8	47.7	0.8	61.0	45.2	1.1	56.8	45	1.2	63.6	43.6	3	62.5	43.9	3.1
Eggs (g/d)	47.5	27.3	0.6	48.9	28.3	0.7	46.6	26.1	0.9	50.0	28	1	55.4	28.5	2.3	48.4	27.5	2.7

Dairy foods (g/d)	98.6	249.8	2.9	97.9	227	2.6	98.7	234.9	4.2	97.6	206.2	3.9	98.4	252.9	11.7	97.8	212.1	10.7
Animal added fats (g/d)	67.5	10.4	0.2	63.3	11.8	0.2	72.1	10.5	0.3	67.4	12	0.3	67.9	9.9	0.7	61.4	11.4	0.8
Fish and other seafood (g/d)	73.1	58.3	0.9	68.0	54.4	0.9	74.8	58.6	1.4	67.2	57.8	1.4	79.9	54.8	3.7	77.2	53.3	3.6
Miscellaneous (g/d)	51.8	63	1.2	50.6	73	1.4	52.8	61.8	1.8	52.8	70.6	2.1	47.8	62.6	5.1	52.2	65.2	5.8
Beverages																		
Sugar-sweetened drinks (mL/d)	61.6	160.6	2.8	50.6	155.8	3	62.3	155.1	4.1	51.7	131.9	4.4	62.0	159.3	11.5	50.0	145	12.5
Tea and coffee (mL/d)	88.9	391.1	6.6	89.0	393	6.4	89.7	392.2	9.6	89.9	397	9.3	89.1	452.8	26.8	91.3	441.9	25.7
Plant-based drinks (mL/d)	2.3	137.3	12.7	3.0	155.1	11.3	3.4	129.4	15.4	5.0	128.4	12.8	7.1	81.6	30	8.2	91.1	27.7
Indices																		
Contribution of meat products ² (% of TEI)	97.7	10.9	0.1	97.3	10.9	0.1	97.9	10.4	0.2	96.6	10.6	0.2	97.3	9.6	0.4	98.9	10	0.4
Contribution of meat (% of TEI)	85.2	6.6	0.1	82.2	6.5	0.1	86.3	6.2	0.1	81.6	6.8	0.1	82.1	6.1	0.3	79.3	5.8	0.4
Contribution of processed meat (% of TEI)	85.8	5.1	0.1	84.0	5.4	0.1	86.0	4.8	0.1	82.7	4.9	0.1	82.1	4.4	0.3	84.2	5.4	0.3
PDI	100.0	48.1	0.1	100.0	47.5	0.1	100.0	49	0.2	100.0	48.2	0.2	100.0	49.4	0.4	100.0	49	0.4
healthyPDI	100.0	52.7	0.1	100.0	53.7	0.1	100.0	53.6	0.2	100.0	54.5	0.2	100.0	54.2	0.5	100.0	55	0.5
unhealthyPDI	100.0	58.4	0.1	100.0	58.3	0.1	100.0	57.6	0.2	100.0	57.7	0.2	100.0	56.5	0.5	100.0	57.1	0.5

Abbreviations: TEI, total energy intake

¹ Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age.

² Including meat, offal and processed meat.

Supplemental Table 4 (continued): Percentage of consumers and adjusted mean daily consumption and dietary indices (mean and SEM), among consumers, at the inclusion in the cohort and at the latest available follow-up, according to stages of changes, NutriNet-Santé, n=25,143¹

	Action (n=5,052)						Maintenance (n=10,509)						Other (n=4,803)					
	Inclusion			Latest available follow-up			Inclusion			Latest available follow-up			Inclusion			Latest available follow-up		
	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM
Plant-based foods																		
Fruits (g/d)	93.3	204.3	2.3	92.3	208.6	2.2	95.6	223	1.6	94.3	220.4	1.6	95.1	224.1	2.3	92.9	220.5	2.3
Vegetables (g/d)	99.6	248.5	2.2	99.4	254.2	2.2	99.7	268.8	1.6	99.6	268.1	1.6	99.6	263	2.2	99.6	257.1	2.3
Legumes (g/d)	28.1	37.2	1	26.8	41.9	1.1	28.6	40.5	0.7	28.8	45.3	0.7	27.9	42	1	25.9	44.4	1.1
Potatoes and other tubers (g/d)	66.4	64.1	0.9	62.5	63.2	0.9	64.1	65.2	0.6	60.1	64.6	0.6	64.1	65.6	0.9	59.8	63.2	0.9
Whole grains (g/d)	61.3	56.1	1	64.4	60.5	0.9	67.4	63	0.7	68.6	66.1	0.7	65.9	63	0.9	64.8	63.6	1
Refined cereals and grains (g/d)	98.0	155.8	1.2	96.7	137.2	1.1	97.7	154.9	0.9	95.8	134.8	0.8	97.6	154.9	1.2	95.7	137.7	1.2
Sweet and desserts (g/d)	98.0	103.4	1	96.5	96.6	1	97.9	104.4	0.7	96.9	96.9	0.7	98.0	106.9	1	96.9	101.1	1
Nuts (g/d)	26.5	11.1	0.5	35.9	11.5	0.4	33.1	13	0.3	44.2	13.1	0.3	31.6	13.1	0.5	39.6	12.9	0.4
Vegetable oil (g/d)	79.7	9.9	0.1	75.0	9.1	0.1	81.5	10.4	0.1	76.1	9.5	0.1	79.3	10.2	0.1	74.2	9.3	0.1
Uncooked cereals and seeds (g/d)	5.1	11.6	0.9	6.7	11.8	0.8	6.1	11.2	0.6	9.5	11.3	0.5	6.1	9.9	0.8	7.8	11.7	0.8
Miscellaneous (g/d)	23.1	13.8	0.5	21.6	17.4	0.7	21.3	14.1	0.4	21.7	17.2	0.5	19.8	13.6	0.6	20.0	17.5	0.7
Dairy substitutes (g/d)	5.1	70.1	3.3	6.0	77.9	3.4	7.6	75.2	2	8.1	79.8	2.2	6.7	76.4	3	7.3	81.1	3.1
Meat substitutes (g/d)	1.0	41.7	2.8	3.2	42.5	2.4	1.6	40.9	1.7	3.7	39.9	1.6	1.7	39.8	2.3	2.9	40.8	2.6
Fermented and coagulated foods (g/d)	0.6	33.4	4.1	1.0	31.8	4	1.4	32.9	2.2	1.6	36.1	2.5	1.2	31.8	3.1	1.1	29	3.7
Animal-based foods																		
Meats (all types) (g/d)	98.5	112.7	0.8	96.6	99.6	0.8	96.9	97.5	0.6	93.9	87.5	0.6	96.0	94.2	0.9	94.6	88.2	0.8
Meat products ² (g/d)	95.8	88.4	0.7	91.4	78.3	0.7	92.3	76.6	0.5	87.6	68.4	0.5	90.8	73.8	0.8	88.5	68.9	0.8
Meat (g/d)	77.7	61.9	0.6	67.5	56.6	0.6	70.0	55.9	0.5	60.2	50.9	0.5	66.4	54.2	0.7	60.9	50.9	0.7
Offal (g/d)	11.6	41.5	1	10.3	41.3	1.1	10.5	41.3	0.7	10.2	40.5	0.8	10.4	40.9	1.1	9.9	41.2	1.2
Processed meat (g/d)	77.6	40.4	0.5	73.2	38.6	0.5	74.5	36.2	0.4	69.8	35.4	0.4	73.0	35.8	0.5	69.9	36	0.6
Poultry (g/d)	59.2	44.5	0.6	54.8	44.4	0.7	56.0	42.2	0.5	51.6	42.8	0.5	55.1	41.6	0.7	52.1	42.7	0.7
Eggs (g/d)	49.3	26.8	0.5	49.7	28.7	0.5	49.3	26.3	0.4	51.0	28.8	0.4	49.7	26.7	0.5	49.8	28.2	0.5

Dairy foods (g/d)	98.9	237.2	2.3	97.9	202.7	2.2	98.3	223.5	1.7	97.6	191.8	1.5	98.4	237.1	2.4	97.7	208.7	2.2
Animal added fats (g/d)	69.8	10.1	0.1	64.8	11.3	0.2	68.6	9.8	0.1	64.5	10.9	0.1	67.6	9.9	0.2	63.8	11.1	0.2
Fish and other seafood (g/d)	75.0	60.4	0.8	68.9	56.1	0.8	76.1	59	0.5	70.4	54.7	0.5	76.1	58.3	0.8	68.7	53.8	0.8
Miscellaneous (g/d)	53.0	61.6	1	51.2	70.1	1.2	49.4	60.1	0.7	47.5	69.4	0.9	49.3	61.3	1	47.3	69.8	1.3
Beverages																		
Sugar-sweetened drinks (mL/d)	62.2	146	2.3	49.9	132.1	2.5	60.7	143.8	1.7	49.6	128.8	1.8	60.1	145	2.4	48.6	134.8	2.6
Tea and coffee (mL/d)	90.9	425.2	5.4	91.9	433.2	5.2	93.1	478.4	3.8	93.5	481.1	3.7	91.7	467.7	5.4	92.9	471.5	5.2
Plant-based drinks (mL/d)	4.9	117.1	7.2	8.2	144.7	5.7	7.8	126.8	4.3	10.1	135	3.8	6.6	124.2	6.4	8.0	136.4	5.9
Indices																		
Contribution of meat products ² (% of TEI)	97.1	9.9	0.1	94.4	9.3	0.1	94.6	8.5	0.1	90.7	8.2	0.1	93.2	8.3	0.1	91.6	8.3	0.1
Contribution of meat (% of TEI)	83.8	6	0.1	75.4	5.9	0.1	76.7	5.4	0	67.8	5.2	0.1	73.2	5.3	0.1	68.2	5.3	0.1
Contribution of processed meat (% of TEI)	83.0	4.6	0.1	79.1	4.7	0.1	79.5	4.1	0	74.9	4.4	0.1	77.6	4.1	0.1	74.7	4.4	0.1
PDI	100.0	49.5	0.1	100.0	49.7	0.1	100.0	51.2	0.1	100.0	51.2	0.1	100.0	50.8	0.1	100.0	50.5	0.1
healthyPDI	100.0	54.1	0.1	100.0	56.2	0.1	100.0	56	0.1	100.0	57.8	0.1	100.0	55.6	0.1	100.0	57	0.1
unhealthyPDI	100.0	57.2	0.1	100.0	56.8	0.1	100.0	56.7	0.1	100.0	56.3	0.1	100.0	57	0.1	100.0	56.9	0.1

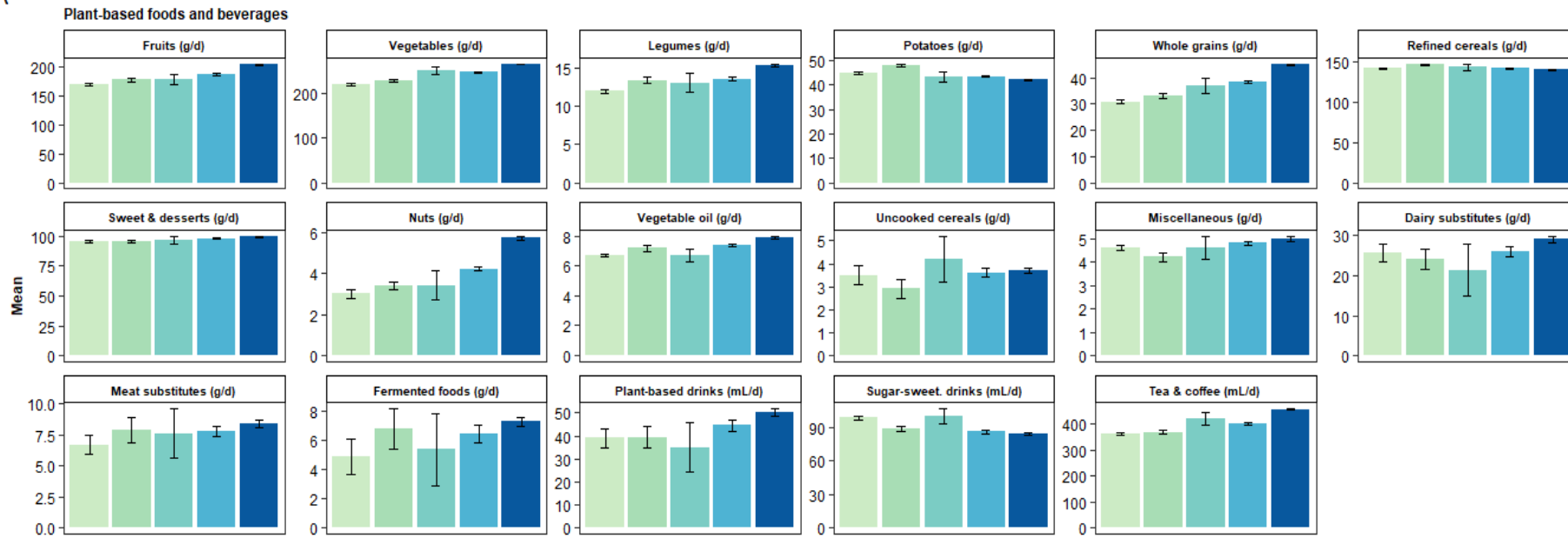
Abbreviations: TEI, total energy intake

¹ Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age.

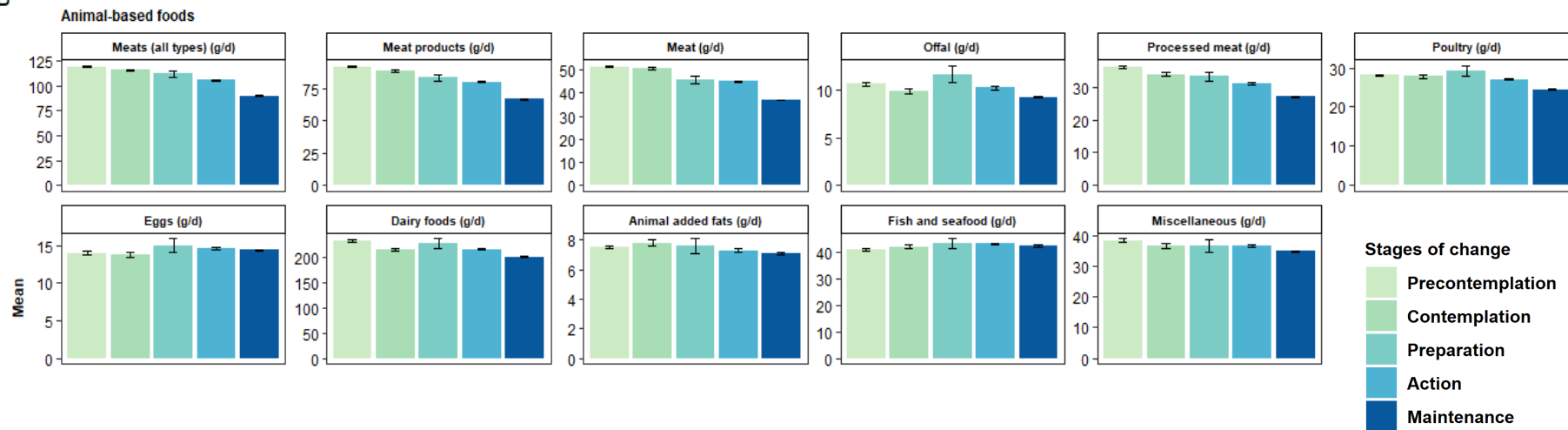
² Including meat, offal and processed meat.

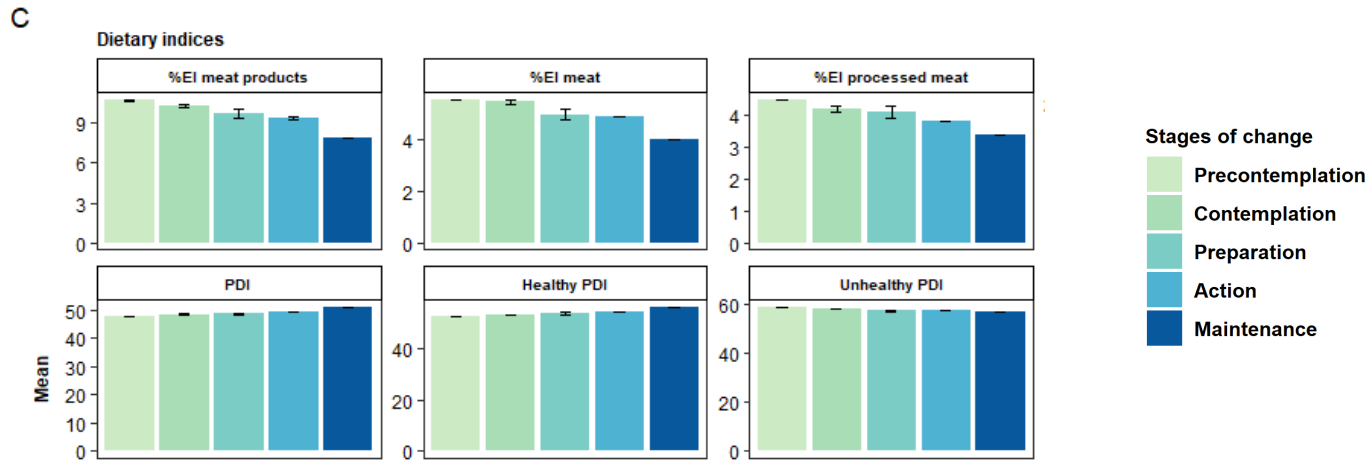
Supplemental Figure 2: Adjusted mean daily consumption and contribution of plant-based and animal-based foods groups among consumers over the 2009-2019 period, n=25,143¹

A



B





¹ Mean daily consumptions and indices have been calculated among consumers of the given food item. Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age.

Data not shown for the group “Other”

“Miscellaneous plant-based foods” group includes plant-based sugary or salty snacks, nuts and peanut butter, and plant-based meat and dairy substitutes. including all plant products used as substitutes for animal and all processed vegetarian products (protein substitutes, plant-based processed meats, dairy substitutes, plant-based salty snacks and fast food).

“Miscellaneous animal foods” group includes all dressings, sauces and animal-based salty snacks and fast foods.

“Fermented foods”: Fermented or coagulated foods (e.g. tempeh, tofu...)

“Sugar-sweet. drinks”: Sugar-sweetened drinks

Supplemental Table 5: Multivariate linear mixed analysis for the associations between stages of change towards meat reduction and changes in percent energy intake provided by meat, processed meat and meat products (logarithm of the contribution of the given food to total energy intake) over the 2009-2019 period in French adults participating in the NutriNet-Santé cohort (n = 25,143)¹

	Contribution of meat to total energy intake (n=24,715) ²			Contribution of processed meat to total energy intake (n=24,820) ²			Contribution of meat products ³ to total energy intake (n=25,085) ²		
	β	95%IC	<i>p</i>	β	95%IC	<i>p</i>	β	95%IC	<i>p</i>
Intercept	0.29	[-0.07;0.65]	0.12	1.43	[1.06;1.8]	<0.0001	2.13	[1.91;2.36]	<0.0001
Time	-0.23	[-0.31;-0.15]	<0.0001	-0.13	[-0.21;-0.05]	0.001	-0.09	[-0.14;-0.04]	0.001
Contemplation	0.05	[-0.12;0.21]	0.57	-0.15	[-0.31;0.02]	0.08	-0.04	[-0.14;0.06]	0.45
Contemplation*time	0.00	[-0.03;0.04]	0.92	0.00	[-0.03;0.03]	0.98	0.00	[-0.02;0.03]	0.76
Preparation	-0.38	[-0.77;0.02]	0.06	-0.25	[-0.65;0.15]	0.22	-0.20	[-0.44;0.05]	0.11
Preparation*time	-0.01	[-0.09;0.08]	0.89	0.04	[-0.05;0.12]	0.39	0.01	[-0.04;0.07]	0.58
Action	-0.12	[-0.24;0]	0.05	-0.21	[-0.33;-0.08]	0.001	-0.07	[-0.15;0]	0.05
Action*time	-0.06	[-0.09;-0.04]	<0.0001	-0.04	[-0.07;-0.02]	0.001	-0.04	[-0.06;-0.03]	<0.0001
Maintenance	-0.77	[-0.88;-0.67]	<0.0001	-0.53	[-0.64;-0.43]	<0.0001	-0.46	[-0.52;-0.39]	<0.0001
Maintenance*time	-0.08	[-0.1;-0.06]	<0.0001	-0.05	[-0.07;-0.02]	<0.0001	-0.06	[-0.07;-0.04]	<0.0001

¹ Multivariate linear mixed models were performed on the total sample, including participants in precontemplation, contemplation, preparation, action and maintenance stages and the group “Other”. Non-consumers were excluded in each sample. Precontemplation stage was used as the category of reference. No significance over time for the group “Other”, data not shown.

² Coefficients β were computed using a linear multilevel mixed model expressing the relationship between stages of change and dietary indices (expressed by the mean) and time (in years). Logarithm of the contribution of meat, processed meat and meat products to the total energy intake was used to increase normality and model’s residual fitness. The coefficient for intercept represents the association of individuals in the precontemplation stage (reference) with baseline consumption and the coefficient for time represents the evolution of consumption over time for the precontemplation stage. The coefficient for stages of change represents the association of individuals in the stage of change with baseline consumption. The coefficient for the interaction term represents the association of individuals in stages of change with evolution of consumption over time, compared to the evolution of consumption of those in the precontemplation stage.

Models for sex, age (continuous), educational level, number of follow-up at which dietary data were recorded (continuous), monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI category, latest weight-loss diet and physical activity level.

³ Including meat, offal and processed meat.

Supplemental Table 6: Multivariate linear mixed analysis showing associations between stages of change towards meat reduction and changes in PDI, healthy PDI and unhealthy PDI over the 2009-2019 period in French adults participating in the NutriNet-Santé cohort (n = 25,143)¹

	PDI ²			healthyPDI ²			unhealthyPDI ²		
	β	95%CI	<i>p</i>	β	95%CI	<i>p</i>	β	95%CI	<i>p</i>
Intercept	41.43	[40.67;42.2]	<0.0001	44.91	[44;45.82]	<0.0001	71.62	[70.79;72.44]	<0.0001
Time	-0.04	[-0.17;0.08]	0.49	1.24	[1.09;1.38]	<0.0001	-0.07	[-0.21;0.07]	0.35
Contemplation	0.93	[0.62;1.25]	<0.0001	0.78	[0.41;1.15]	<0.0001	-0.63	[-0.97;-0.3]	0.00
Contemplation*time	-0.04	[-0.09;0.01]	0.16	-0.01	[-0.07;0.04]	0.67	0.02	[-0.04;0.07]	0.55
Preparation	1.35	[0.6;2.09]	0.00	1.16	[0.28;2.04]	0.01	-1.26	[-2.06;-0.46]	0.00
Preparation*time	0.00	[-0.12;0.12]	0.96	0.02	[-0.12;0.15]	0.83	0.00	[-0.14;0.13]	0.98
Action	1.13	[0.91;1.36]	<0.0001	1.11	[0.84;1.38]	<0.0001	-0.94	[-1.18;-0.7]	<0.0001
Action*time	0.13	[0.09;0.16]	<0.0001	0.16	[0.11;0.2]	<0.0001	-0.04	[-0.08;0]	0.05
Maintenance	2.63	[2.43;2.83]	<0.0001	2.91	[2.67;3.15]	<0.0001	-1.44	[-1.66;-1.22]	<0.0001
Maintenance*time	0.10	[0.07;0.13]	<0.0001	0.11	[0.07;0.14]	<0.0001	-0.02	[-0.06;0.01]	0.25

¹ Multivariate linear mixed models were performed on the total sample, including participants in precontemplation, contemplation, preparation, action and maintenance stages and the group “Other”.

Precontemplation stage was used as the category of reference. No significance over time for the group “Other”, data not shown.

² Coefficients β were computed using a linear multilevel mixed model expressing the relationship between stages of change and dietary indices (expressed the mean) and time (in days). The coefficient for intercept represents the association of individuals in the precontemplation stage (reference) with baseline consumption and the coefficient for time represents the evolution of consumption over time for the precontemplation stage. The coefficient for stages of change represents the association of individuals in stages of change with baseline consumption. The coefficient for the interaction term represents the association of individuals in stages of change with evolution of consumption over time, compared to the evolution of consumption those in the precontemplation stage.

Models were adjusted for sex, age (continuous), educational level, number of follow-up at which dietary data were recorded (continuous), monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI category, latest weight-loss diet, physical activity level and total energy intake.