



HAL
open science

Self-declared attitudes and beliefs regarding protein sources are a good prediction of the degree of transition to a low-meat diet in France

Erwan de Gavelle, Olga Davidenko, H el ene Fouillet, Julien Delarue, Nicolas Darcel, Jean-Fran ois Huneau, Fran ois Mariotti

► To cite this version:

Erwan de Gavelle, Olga Davidenko, H el ene Fouillet, Julien Delarue, Nicolas Darcel, et al.. Self-declared attitudes and beliefs regarding protein sources are a good prediction of the degree of transition to a low-meat diet in France. *Appetite*, 2019, 142, pp.104345. 10.1016/j.appet.2019.104345 . hal-02179307

HAL Id: hal-02179307

<https://agroparistech.hal.science/hal-02179307v1>

Submitted on 3 Oct 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destin ee au d ep ot et  a la diffusion de documents scientifiques de niveau recherche, publi es ou non,  emanant des  tablissements d'enseignement et de recherche fran ais ou  trangers, des laboratoires publics ou priv es.

This is a “postprint” authors’ version of the following manuscript:

Erwan de Gavelle, Olga Davidenko, Helene Fouillet, Julien Delarue, Nicolas Darcel, et al.. Self-declared attitudes and beliefs regarding protein sources are a good prediction of the degree of transition to a low-meat diet in France. *Appetite*, Elsevier, 2019, 142, pp.104345. [10.1016/j.appet.2019.104345](https://doi.org/10.1016/j.appet.2019.104345). [hal-02179307](https://hal.archives-ouvertes.fr/hal-02179307)

1 **Self-declared attitudes and beliefs regarding protein sources are**
2 **a good prediction of the degree of transition to a low-meat diet**
3 **in France**^{1,2}

4 Erwan de Gavelle^a, Olga Davidenko^a, H el ene Fouillet^a, Julien Delarue^b, Nicolas Darcel^a, Jean-
5 Fran ois Huneau^a, Fran ois Mariotti^{a,*}

6 ^a UMR PNCA, AgroParisTech, INRA, Universit  Paris-Saclay, 75005, Paris, France

7 ^b UMR GENIAL Ing nierie Proc d s Aliments, AgroParisTech, INRA, Universit  Paris-Saclay,
8 91300, Massy, France

9 * corresponding author, francois.mariotti@agroparistech.fr, 16 rue Claude Bernard, 75005
10 Paris, France

11

¹ CFI, comparative fit index; INCA2, Second French national study on food consumption; PBC, Perceived behavioral control; RMSEA, Root-mean-square-error of approximation; SEM, Structural equation modelling; TLI, Tucker-Lewis index; TPB, Theory of Planned Behavior

² Declarations of interest: none

12 **Abstract**

13 Meat consumption in Western countries is declining and, while the proportion of strict
14 vegetarians remains low, intermediate diets such as flexitarianism have been developing in
15 recent years. Our objectives were to identify the different levels of transition towards low-meat
16 diets, characterize how these diets differ in terms of food intake, and identify whether attitudes
17 and beliefs can explain these degrees of transition. In a representative survey of the French
18 adult population conducted in 2018 (n=2,055), participants declared whether they followed a
19 particular diet and completed a food frequency questionnaire on 29 food sources of protein
20 and a questionnaire on their attitudes and beliefs regarding protein sources. We identified four
21 dietary types based on these declarative data: vegetarians, flexitarians, pro-flexitarians and
22 omnivores. The theory of planned behavior was used to predict meat intake and intentions to
23 reduce meat intake. The sample contained 2.5% vegetarians, 6.3% flexitarians, 18.2% pro-
24 flexitarians and 72.9% omnivores. The diet groups displayed specific dietary profiles and
25 attitudinal scores. Compared with omnivores, pro-flexitarians consumed less red meat, more
26 vegetables and legumes and were much more in agreement about the environmental impacts
27 of meat. Compared with pro-flexitarians, flexitarians consumed less red meat and processed
28 meat, and agreed much more about the health impacts of meat. Finally, versus flexitarians,
29 vegetarians consumed almost no meat but far more legumes, nuts and seeds, and were much
30 more sensitive to animal welfare issues. Attitudes, social norms and perceived behavioral
31 control (PBC) predicted intentions to reduce meat consumption but attitude was the most
32 important predictor. Intentions and PBC were both predictive of meat consumption. The dietary
33 type related to the level of meat intake could be predicted by self-declared attitudes and beliefs
34 regarding protein sources.

35

36 **Keywords**

37 Attitudes; dietary transition; protein sources; flexitarian; vegetarian;

38 Introduction

39 When compared to plant protein, an intake of animal protein, and particularly that of meat, has
40 been associated with sustainability issues (Godfray, et al., 2018) such as animal welfare,
41 higher risks of non-communicable diseases (colorectal cancer and cardiovascular diseases)
42 (Anses, 2016a; Norat, et al., 2005) and a more negative impact on the environment and climate
43 change (Cleveland & Gee, 2017; Gerber, et al., 2013). In parallel with increasing awareness
44 to sustainability issues in Western countries, there had been a decline in total per capita meat
45 consumption since the early 2000s in France (-9% between 2000 and 2015) (FranceAgriMer,
46 2015) and more generally in Southern Europe (-9% between 2000 and 2013), Western Europe
47 (-4%) and North America (-6%). This trend has involved a rearrangement of meat intake,
48 consisting in a lower consumption of pork and beef and a higher consumption of poultry meat
49 (FAO, 2018).

50 The motivations, levers and barriers attached to reducing meat intake, as well as attitudes and
51 beliefs related to meat, have been widely studied in the recent literature. The principal
52 motivations behind a lower meat intake are related to attitudes and beliefs regarding its impact
53 on health, animal welfare and, to a lesser extent, the environment (Clonan, Wilson, Swift,
54 Leibovici, & Holdsworth, 2015; De Backer & Hudders, 2015; Latvala, et al., 2012; Zur & A.
55 Klöckner, 2014). It appears that the motivations behind reducing meat are age-dependent,
56 inasmuch as young adults tend to lower their consumption for animal welfare and
57 environmental reasons, whereas health-related reasons prevail among older generations
58 (Pribis, Pencak, & Grajales, 2010). Furthermore, motivations also differ depending on the level
59 of meat intake: it has been reported that individuals who reduce their meat intake for health
60 reasons do not exclude meat altogether, while those concerned by animal welfare tend to stop
61 eating meat abruptly and are more likely to become vegans (de Boer, Schösler, & Aiking, 2017;
62 Petti, Palmieri, Vadalà, & Laurino, 2017). The main barriers identified in the literature are food
63 habits and a lack of skills to prepare meatless dishes (Pohjolainen, Vinnari, & Jokinen, 2015;
64 Schösler, de Boer, & Boersema, 2012), an attachment to meat (Graça, Oliveira, & Calheiros,
65 2015), or social norms (Amiot, El Hajj Boutros, Sukhanova, & Karelis, 2018). Psychological
66 theories such as the Theory of Planned Behavior (TPB) have been used to predict health-
67 related behaviors and notably meat intake, and have been shown to partially predict a transition
68 to plant-based diets (Wyker & Davison, 2010) or lower levels of meat intake (Zur & A. Klöckner,
69 2014) in non-representative populations in the USA and Norway.

70 Important gaps remain in our understanding of the individual determinants that underpin
71 changes to meat intake in Western populations, for three reasons. First, the literature has failed
72 to reveal the complexity of the relationship between attitudes and beliefs regarding particular

73 foods and the type of diet type adopted, whether this is actual or intended. Second, dietary
74 transitions during the past few years appear to have been characterized by the emergence of
75 moderate and low-meat diets which can constitute different degrees of a transition from high-
76 meat to vegetarian diets (Latvala, et al., 2012), although data on this transition are scarce.
77 Lastly, most of the aforementioned studies were conducted in Northern Europe or the UK,
78 which have much higher numbers of vegetarians and are characterized by dietary habits that
79 contrast with those in other Western countries such as France (Halkjaer, et al., 2009). The
80 proportion of vegetarians remains low among the French (around 2%) (Anses, 2017) who
81 declare more negative attitudes towards vegetarianism compared to other countries, which
82 could be explained because gastronomy is deeply rooted in French identity and culture, and
83 vegetarians could be seen as a threat to this identity (Ruby, et al., 2016). However, a recent
84 survey reported that intermediate profiles of transition towards a lower meat intake have grown
85 very rapidly in the recent years in France (the proportion of households with at least one person
86 who is “neither vegetarian nor vegan, but tends to reduce or limit their animal protein intake”
87 rose from 24% in 2015 to 34% in 2017) (Kantar WorldPanel, 2017). It therefore seems
88 important to study the transition towards low-meat diets in France as an example of a country
89 with a relatively weak acceptance of vegetarian diets but which has evolved very rapidly during
90 the past few years.

91 Our objectives were therefore to identify different dietary types which might constitute degrees
92 of transition to low-meat diets, to characterize how these diets differ in terms of protein source
93 intakes, and determine whether attitudes and beliefs might explain these dietary types.

94 **Population and methods**

95 *Population and food intake*

96 The data were collected between 9 April and 24 May 2018 using an online questionnaire sent
97 to members of an online panel (n=450,000) operated by a generalist market research company
98 (Creatests, Lille, France). The quota sampling method was used to obtain a representative
99 sample of French adults aged 18 to 65 years, compared to the 2017 French population, as
100 estimated by the French National Institute of Statistics and Economic Studies. A total of 2,692
101 individuals (1,408 women and 1,284 men) completed the entire questionnaire.

102 The questionnaire contained questions on food habits related to the dietary sources of protein
103 consumed by the individuals (including if they followed a vegetarian or vegan diet) (*Food*
104 *intakes*), their attitudes and beliefs relative to meat, their intentions to reduce meat
105 consumption (*Attitudes and beliefs related to protein sources*) and their socio-demographic
106 background (*Sociodemographic and lifestyle factors*). Three questions rating from 1 (“Not at
107 all”) to 7 (“Extremely”) on hunger (“How hungry are you?”), fullness (“How full are you?”) and
108 prospective consumption (“How much do you think you could eat right now?”) of participants
109 were asked, as recommended by Blundell et al. (Blundell, et al., 2010), and aggregated into
110 an appetite score.

111 *Food intakes*

112 To limit the time required to answer the questionnaire, it only included 29 food groups. They
113 were selected to cover 84% of the total protein intake of the French population in 2006-2007,
114 as described in a previous study (de Gavelle, Huneau, Fouillet, & Mariotti, 2019). Participants
115 were asked to declare their “overall meat” consumption (which included red meat, processed
116 meat or poultry), and then their consumption of specific meats and other food groups as
117 sources of protein. The food groups are described in **Supplemental Table 1**. Intake
118 frequencies were rated on a 9-item scale ranging from “never” to “>3 times/day”. In the second
119 part of the questionnaire, the individuals were asked to state their usual portion size on a 7-
120 item scale using standard pictures from the SU-VI-MAX picture booklet (Le Moullec, et al.,
121 1996). In a previous modelling study, de Gavelle et al. identified which modifications of portion
122 sizes of which protein food groups increased overall nutrient adequacy the most (de Gavelle,
123 et al., 2019). The 29 food groups of the present study were sorted from the ones whose
124 modifications of portion sizes increased nutrient adequacy the most, to the ones whose
125 modifications increased nutrient adequacy the least. To limit the time required to answer, each
126 participant was asked about his/her usual portion sizes of the first 20 food groups in the list
127 that he/she declared consuming. Thus each individual did not report portions for all food
128 groups, and the mean portion size (for men and women, separately) of the food group was

129 imputed to the food portions that were not reported. For each participant, daily mean intakes
130 (in grams) were then calculated per food group by multiplying the consumption frequency by
131 the portion size. Finally, an estimate of individual protein intake was made. The protein
132 contents of different food groups were estimated as means of protein content of the foods
133 included in each food group, weighted by the mean intake of each food, as reported in the
134 second French national study on food consumption (INCA2) (Dubuisson, et al., 2010). These
135 protein contents were then multiplied by the daily mean intakes of each group to calculate an
136 estimate of protein intake for each participant. These estimates were partial as the intakes of
137 only 29 food groups were reported, and should not be interpreted as estimates of total
138 individual protein intakes.

139 We identified misreports using a 3-step method. Consistency was verified by asking four
140 questions on portion size twice in different parts of the questionnaire. A participant was
141 excluded if he/she declared different portion sizes of the same food more than once (n=195).
142 The plausibility of the declared frequencies was then tested. If the sum of the declared intake
143 frequencies was <once/day or >20 times/day (2.5th and 97.5th percentiles of intake frequency
144 of the protein foods in the INCA2 population (as estimated from the dataset), respectively), the
145 participant was excluded (n=61). Finally, the plausibility of intakes was tested using the mean
146 intakes reported in the French 2014-2015 INCA3 study (Anses, 2017). Given that intakes
147 followed a lognormal distribution, if the logarithm of the sum of intakes declared (/kg body
148 weight) was not between mean + 2 SD and mean – 2 SD, or if the intake of one food group
149 was higher than the mean intake + 3 SD of this food group in, the participant was excluded.
150 However, an exception was applied for self-declared vegetarians or vegans, who had no upper
151 limit for their intake of legumes, nuts and seeds. Some vegetarians declared eating some meat,
152 which has been reported in other studies (Rothgerber, 2017), as the representation of
153 vegetarianism is not the same for all individuals. Participants that declared being vegetarians
154 and consuming more than the mean meat intake in INCA2 (64g/d for men and 41 g/d for
155 women) were considered to have obviously misreported that they were vegetarians and were
156 excluded. After excluding all the misreports (n=381), we obtained a final sample of 2,055
157 individuals (905 men and 1,055 women). The flowchart is detailed in **Supplemental Figure 1**.

158 *Attitudes and beliefs relative to protein sources*

159 Participants completed a 15-item questionnaire concerning their assumptions about meat or
160 plant protein. The choice of items was based on publications on the same topic (Clonan, et al.,
161 2015; Graça, Calheiros, & Oliveira, 2015; Jallinoja, Niva, & Latvala, 2016; Pohjolainen, et al.,
162 2015; Zur & A. Klöckner, 2014) and covering the main themes identified (intention or perceived
163 behavioral control regarding reduced meat consumption, attitudes towards environmental,

164 health or animal welfare issues, social norms or attachment to meat) (**Table 1**). Participants
 165 were asked to rate their agreement with each item on a 7-point Likert scale, ranging from “do
 166 not agree at all” to “fully agree”. We chose to reverse the rating of four questions (from 7 to 1),
 167 as these concerned positive attitudes towards meat, while all the others focused on negative
 168 attitudes. The reverse-coded questions were marked with “(-)”.

169 The Theory of Planned Behavior (TPB) (Ajzen, 1991) has been widely applied as a model for
 170 analyzing a wide variety of behaviors, and has often be applied to food choices analysis. The
 171 aim of the theory is to identify the causal mechanism underlying a behavioral intention. The
 172 TPB is based on the assumption that behavior is the result of a particular conscious behavioral
 173 intention. According to the TPB, intention is explained by attitude, subjective norms and
 174 perceived behavioral control (PBC), and behavior is explained by intention and PBC. This
 175 theory seems particularly adapted to predict meat intake because intentions to eat meat have
 176 been shown to predict actual consumption (Berndsen & van der Pligt, 2005) and the three TPB
 177 variables successfully predicted intentions to eat meat. Indeed, Arvola et al. have shown that
 178 attitudes and moral and subjective norms were good predictors of pro-environmental food
 179 choices (Arvola, et al., 2008). Likewise, Povey et al. found that attitudes, subjective norm and
 180 PBC were predictors of intentions to follow specific diets (meat eaters, meat avoiders,
 181 vegetarians or vegans) in the U.K. (Povey, Wellens, & Conner, 2001). The model was
 182 implemented by assigning the assumptions to four categories: intention, attitude, subjective
 183 norm and PBC. The score for each category was the mean score of the assumptions included
 184 in the category. The internal consistency of the constructs was assessed using Cronbach’s
 185 alpha (**Table 1**). We chose not to include items relative to the price of meat as this was not
 186 linked to any of the factors, and as it was not found significantly associated with meat intake
 187 or intention to reduce meat intake when added to the TPB models. Likewise, the item “I would
 188 be able to reduce my meat consumption if my doctor recommended it to me” (DOC) was
 189 considered separately, as had been the case in a previous TPB model on the adoption of plant-
 190 based diets (Wyker & Davison, 2010).

191 Table 1. Questionnaire items on attitudes and beliefs, classified as intentions or factors
 192 explaining intentions (variables), and internal consistency¹.

Assumption	Abbreviation	Variables	Cronbach's alpha
I intend to reduce my meat consumption in the coming months	INT	Intention	0.73
I am considering eating meat and fish only very rarely (no more than once a week)	FLEX		
I feel able to reduce my meat consumption in the coming months	ABLE	Perceived behavioral control	0.70
It is harder to prepare good vegetarian foods than meat ones (-)	HAB		
A full meal is a meal with meat (-)	HAB2		
I choose food which has been produced in a way that minimizes cruelty to animals	WELF	Attitude	0.73
I don't really think much about the animal when I buy meat (-)	WELF2		
To help reduce the impact of climate change, it is better to eat less animal foods (meat, dairy products and eggs)	ENV		
Substituting beans for meat slows down climate change	ENV2		
Meat is a nutritionally necessary component for humans (-)	HEAL		
Consuming high amounts of meat might cause serious health problems	HEAL2		

People around me often say that reducing your meat consumption is better for your health	NORM		
There are more and more people around me who are reducing their meat consumption	NORM2	Subjective norms	0.69
I would be able to reduce my meat consumption if my doctor recommended it to me	DOC	-	-
Eating meat at every meal is expensive	PRICE	-	-

193 ¹ Items were rated on a 7-item Likert scale, ranging from “do not agree at all” to “fully agree”. (-) indicates reverse-coded items.

194 *Identification and characterization of dietary types*

195 We separated our sample into four groups according to the diet followed by the participants.
 196 Several criteria were applied to assign dietary types: first, they were identified using self-
 197 declaration. Participants were asked “Do you follow a specific diet?”, and could answer
 198 “vegan”, “vegetarian” and/or “flexitarian (limiting meat consumption to a minimum)”.
 199 Participants who declared they were “vegetarians” and/or “vegans” were considered as
 200 “vegetarians” (because only nine participants were vegan). Those who stated they were
 201 “flexitarians (limiting meat consumption to a minimum)” and had not already been classified as
 202 vegetarians were considered to be “flexitarians”. Those who rated the question “I am
 203 considering eating meat and fish only very rarely (no more than once a week)” at ≥ 5 and were
 204 not flexitarians or vegetarians were considered to be “pro-flexitarians”. All other participants in
 205 the sample were considered to be regular meat/fish eaters and were referred to as
 206 “omnivores”.

207 *Socio-demographic and lifestyle factors*

208 The participants were asked about their sex, age, level of education, socio-professional
 209 category, household composition, height and weight, income, place of residence zip code and
 210 whether they were responsible for grocery shopping in the household. Body Mass Index (BMI)
 211 (in kg/m²) was computed as the ratio of weight to squared height and classified according to
 212 WHO guidelines (WHO, 2000). The categories used for monthly income were as follows:
 213 <€1,500, €1,500–2,500, €2,500–3,400 and >€3,400 per household. The zip codes reported
 214 provided information on the size of the local community: <2,000 inhabitants, 2,000-20,000
 215 inhabitants, 20,000-100,000 inhabitants and Paris conurbation.

216 *Statistical analyses*

217 An overall α level of 5% was used for statistical tests. Sample weightings were applied to
 218 ensure the representativeness of the sample with respect to sex, age, socio-professional
 219 category and geographic area of living, using the *Icarus* R package. All means were thus
 220 weighted in this way. ANCOVA adjusted for age, sex and appetite score was used to test for
 221 differences depending on the overall type of diet, and post-hoc tests with Tukey correction for
 222 differences between the diets. Multivariate logistic regression models were implemented to
 223 assess the association between sociodemographic factors and the type of diet, using
 224 omnivores as the reference.

225 Structural equation modelling (SEM) with the *lavaan* R package was used to test the TPB
226 model, which was evaluated by examining the comparative fit index (CFI), the Tucker-Lewis
227 index (TLI), the root-mean-square-error of approximation (RMSEA) and χ^2 divided by degrees
228 of freedom (χ^2/df). A good model fit was indicated by a high CFI or TLI (>0.90), a low RMSEA
229 (<0.10) and χ^2/df between 1 and 3 (Kline, 2015). When not stated otherwise, all analyses were
230 performed using SAS 9.1.3 (SAS Institute Inc., Cary, NC, USA).

231

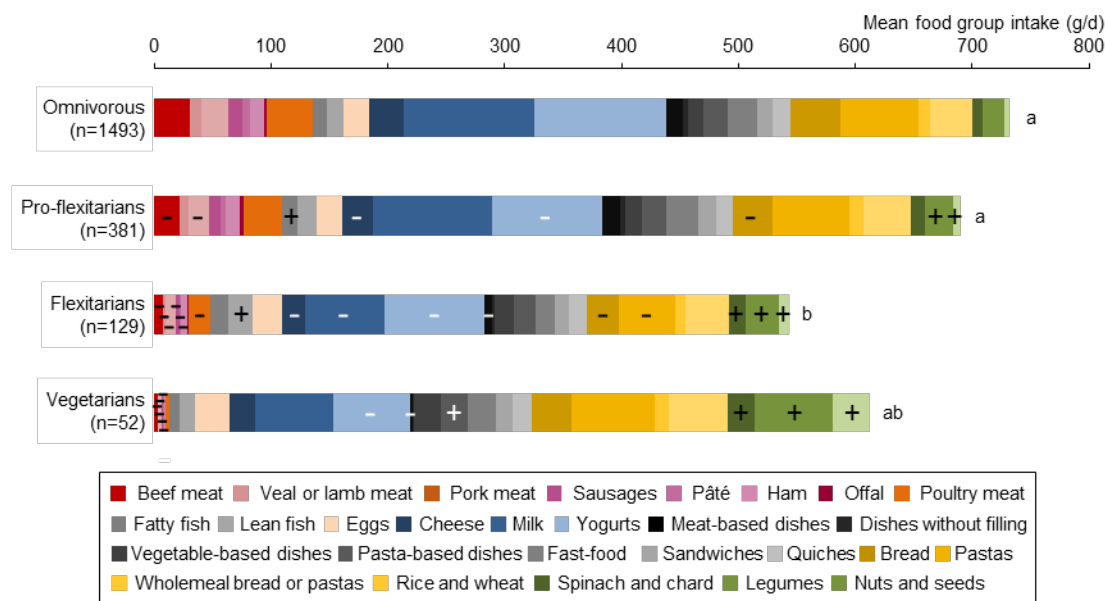
232 Results

233 After the misreports had been excluded, the study sample (n=2,055) contained 52 self-
234 declared vegetarians (2.5%, considering the survey weightings), 129 self-declared flexitarians
235 (6.3%), 381 pro-flexitarians (18.2%) and 1,493 omnivores (72.9%). In the overall population,
236 the mean meat intake (as declared for "overall meat") was 83.4 (± 85.9) g/d, the mean partial
237 food intake was 708.9 (± 343.1)g/d and the mean partial protein intake was 74.2 (± 38.5) g/d.

238 *Intakes of different protein food groups*

239 The mean partial food intake was 732.1 (± 335.1) g/d for omnivores, 689.8 (± 371.5) for pro-
240 flexitarians, 543.8 (± 282.3) for flexitarians and 612.6 (± 347.3) g/d for vegetarians (**Figure 1**).
241 The declared mean overall meat intake was 98.6 (± 91.7) g/d for omnivores, 54.5 (± 51.4) for
242 pro-flexitarians, 26.5 (± 32.3) for flexitarians and 6.2 (± 6.6) for vegetarians. Meat intake differed
243 ($P < 0.01$) between each dietary type except between flexitarians and vegetarians. The mean
244 partial protein intake was 77.7 (± 37.5) g/d for omnivores, 70.7 (± 41.3) g/d for pro-flexitarians,
245 51.1 (± 29.0) g/d for flexitarians and 51.1 (± 30.7) g/d for vegetarians. The mean partial protein
246 intake differed between each dietary type ($P < 0.01$), except between flexitarians and
247 vegetarians.

248 Omnivores and pro-flexitarians differed the most ($>20\%$) regarding their intakes of beef (-28%,
249 i.e. 28% lower among the latter than the former; $P < 0.0001$), pork (-26%, $P < 0.001$), bread (-
250 22%, $P < 0.01$), spinach and chard (+38%, $P < 0.05$) and legumes (+30%, $P < 0.01$). Pro-
251 flexitarians and flexitarians differed in terms of their intakes of pâté (-70%, $P < 0.05$), beef (-
252 67%, $P < 0.0001$), veal and lamb (-66%, $P < 0.01$), sausages (-59%, $P < 0.05$) and ham (-58%,
253 $P < 0.0001$). Finally, flexitarians and vegetarians had different intakes of poultry (-86%, $P < 0.05$),
254 nuts and seeds (+226%, $P < 0.0001$), legumes (+143%, $P < 0.0001$) and pasta (+46%, $P < 0.05$).



255

256 Figure 1. Mean intakes of different food groups in each dietary type determined in the
 257 questionnaire sample (2018, $n=2,055$). +/-: mean intake significantly higher or lower than
 258 omnivores, as tested using post-hoc pairwise comparisons with Tukey corrections. Labeled
 259 means without a common letter indicate a significant difference in total food group intake
 260 between the diet groups, as tested using post-hoc pairwise comparisons with Tukey
 261 corrections.

262 Differences in mean intakes between the diets were mostly explained by differences in the
 263 frequency of consumption. Indeed, the portion sizes declared were similar between the
 264 different dietary type, except for beef, which was consumed in larger portions by omnivores
 265 versus pro-flexitarians ($P < 0.01$) and flexitarians ($P < 0.0001$), and in larger portions by pro-
 266 flexitarians compared to flexitarians ($P < 0.05$), and poultry and pasta, which were consumed
 267 in larger portions by omnivores compared to flexitarians ($P < 0.05$).

268 Sociodemographic characteristics

269 According to the results of logistic regression, pro-flexitarians were more likely to be women,
 270 older and to have a lower income than omnivores. Flexitarians were less likely to be overweight
 271 and more likely to belong to lower income groups than omnivores. Vegetarians were more
 272 likely to be women, less likely to be overweight or obese and more likely than omnivores to be
 273 single or in a couple without children (**Table 2**). Likewise, when the reference of the logistic
 274 regression was pro-flexitarians, flexitarians were more likely to be 25-34 years-old and single,
 275 and vegetarians were less likely to be obese and more likely to be single or in a couple without
 276 children. Finally, compared to flexitarians, vegetarians were more likely to be women and
 277 middle-income earners (€1501-3400), and less likely to be in a couple with children.

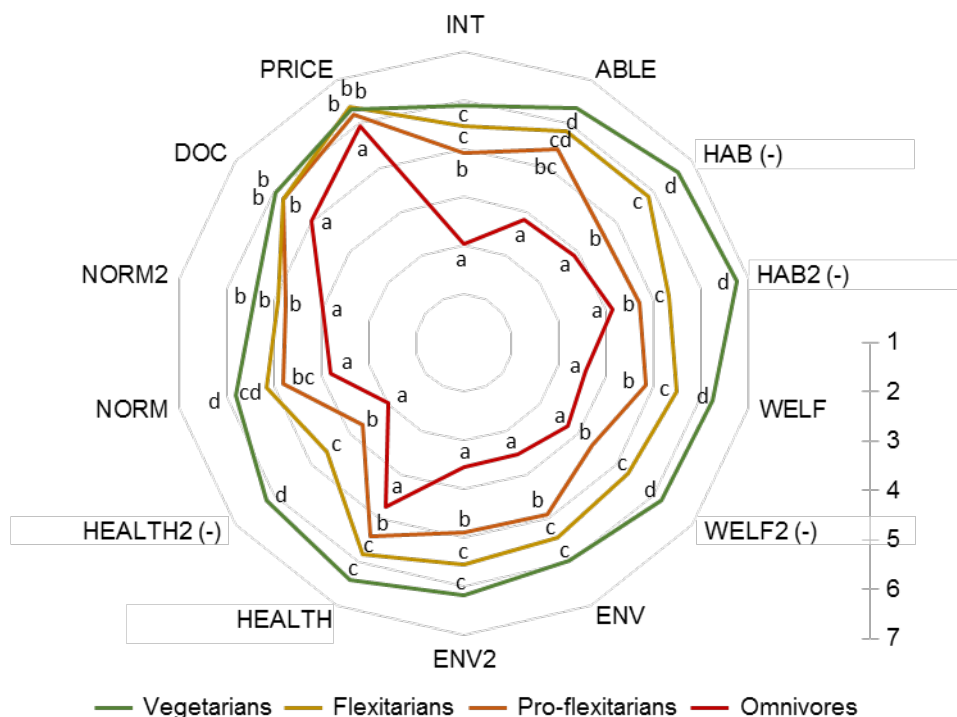
278 Table 2. Sociodemographic characteristics of the different dietary types compared to
 279 omnivores in the questionnaire sample (2018, $n=2,055$). Associations were tested using
 280 multivariate logistic regression models.

Variables	Omnivores ($n=1,493$)	Pro- flexitarians ($n=381$)	Flexitarians ($n=129$)	Vegetarians ($n=52$)	Pro- flexitarians vs Omnivores	Flexitarians vs Omnivores	Vegetarians vs Omnivores	P^1
	%	%	%	%	OR [95% CI]	OR [95% CI]	OR [95% CI]	
Sex								<.0001
Female	50.0	63.5	58.9	76.9	1.7 [1.34;2.17]	1.28 [0.87;1.88]	3.16 [1.61;6.22]	
Male	50.0	36.5	41.1	23.1	1	1	1	
Age (years)								0.021
18-24	12.6	12.6	14.7	26.9	0.61 [0.40;0.92]	0.73 [0.38;1.40]	1.41 [0.60;3.32]	
25-34	20.0	14.7	22.5	19.2	0.53 [0.36;0.76]	1.03 [0.59;1.81]	0.93 [0.38;2.27]	
35-44	22.0	17.3	20.9	11.5	0.61 [0.43;0.88]	1.04 [0.58;1.87]	0.79 [0.28;2.27]	
45-54	23.3	27.0	20.9	21.2	0.95 [0.68;1.32]	1.03 [0.58;1.84]	1.61 [0.66;3.97]	
55-65	22.1	28.4	20.9	21.2	1	1	1	
BMI (kg/m²)								0.036
< 18.5	4.2	5.3	7.75	3.9	1.11 [0.65;1.89]	1.31 [0.64;2.69]	0.48 [0.11;2.04]	
18.5-25	51.3	53.0	62.8	76.9	1	1	1	
25-30	30.7	28.6	20.9	17.3	0.92 [0.70;1.20]	0.60 [0.38;0.96]	0.45 [0.21;0.94]	
≥ 30	13.8	13.1	8.5	1.9	0.86 [0.60;1.22]	0.53 [0.27;1.02]	0.09 [0.01;0.70]	
Income (€/ month / household)								0.003
≤ 1500	18.3	25.7	33.3	26.9	1	1	1	
1501-2500	29.2	30.7	22.5	40.4	0.74 [0.54;1.03]	0.47 [0.28;0.79]	1.30 [0.62;2.73]	
2501-3400	26.5	21.8	17.8	11.5	0.56 [0.39;0.81]	0.46 [0.25;0.83]	0.44 [0.16;1.26]	
>3400	26.0	21.8	26.4	21.2	0.58 [0.39;0.85]	0.70 [0.40;1.24]	0.97 [0.39;2.44]	
Household composition								0.023
2 adults living as a couple with at least 1 child	44.3	42.5	31.8	17.3	1	1	1	
2 adults living as a couple without children	27.3	26.5	27.9	42.3	0.96 [0.71;1.30]	1.48 [0.9;2.44]	3.95 [1.68;9.28]	
Alone	28.5	31.0	40.3	40.4	0.89 [0.65;1.23]	1.64 [0.97;2.76]	2.54 [1.03;6.24]	

281 ¹ Odds ratios (95% CI) from the multivariate model included sex, age, BMI, household income and household composition. OR: Odds ratio; CI: Confidence
 282 interval

283 *Attitudes and beliefs relative to sources of protein*

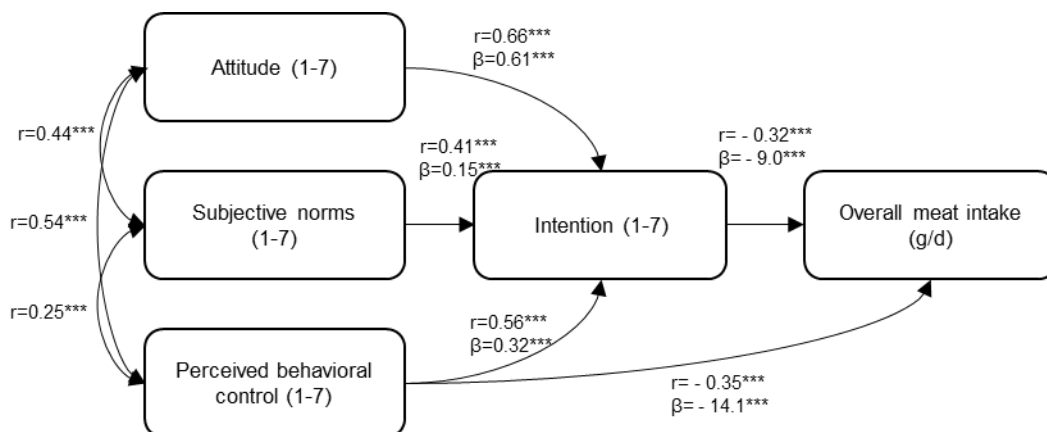
284 Attitudes and beliefs relative to protein sources were associated with different dietary types.
 285 Omnivores had lower mean scores than the three other dietary types for each assumption.
 286 Pro-flexitarians had lower scores than flexitarians and vegetarians for each assumption except
 287 for those concerning subjective norms (NORM and NORM2), an ability to reduce meat
 288 consumption if advised by a doctor (DOC) and price (PRICE), which did not differ between
 289 pro-flexitarians and flexitarians or vegetarians. The most marked differences (>30%) between
 290 pro-flexitarians and omnivores were the estimates of intent (INT +62%) and ability (ABLE
 291 +42%) to reduce meat intake, and concerns regarding the environment (ENV +39% and ENV2
 292 +38%) and animal welfare (WELF +36%). The most marked differences (>15%) between
 293 flexitarians and pro-flexitarians were habits of consuming meatless dishes (HAB +26%), beliefs
 294 about the link between meat and health (HEALTH2 + 25%) and concern for animal welfare
 295 (WELF2 +22%). The most marked differences between flexitarians and vegetarians concerned
 296 similar assumptions (HEALTH2 +35%, HAB2 +27% and WELF2 +17%) (**Figure 2**).



297
 298 Figure 2. Mean scores (from 1 to 7) for items in the attitudes and beliefs questionnaire, for
 299 each dietary type in the sample (2018, $n=2,055$). When ANCOVA was adjusted for age, sex
 300 and appetite score and identified a significant effect of the type of diet, labeled means without
 301 a common letter indicate a significant difference between the dietary types, as tested by
 302 pairwise post hoc comparisons with Tukey corrections ($P < 0.05$). Scores were reverse-coded
 303 for the items marked (-). ABLE, I feel able to reduce my meat consumption in the coming
 304 months; DOC, I would be able to reduce my meat consumption if my doctor recommended it
 305 to me; ENV, To help reduce the impact of climate change, it is better to eat less animal foods
 306 (meat, dairy products and eggs); ENV2, Substituting beans for meat slows down climate
 307 change; HAB, It is harder to prepare good vegetarian foods than meat ones; HAB2, A full meal
 308 is a meal with meat; HEALTH, Consuming high amounts of meat might cause serious health
 309 problems; HEALTH2, Meat is a nutritionally necessary component for humans; INT, I intend to
 310 reduce my meat consumption in the coming months; NORM, People around me often say that
 311 reducing your meat consumption is better for your health; NORM2, There are more and more
 312 people around me who are reducing their meat consumption; PRICE, Eating meat at every
 313 meal is expensive; WELF, I choose food which has been produced in a way that minimizes
 314 cruelty to animals; WELF2, I don't really think much about the animal when I buy meat.

315 As for structural equation modelling, fit indices (CFI=0.999, TLI=0.997, RMSEA=0.021 and
 316 $\chi^2/df=1.89$) indicated that the TPB model procured a good fit to the data. Attitudes, subjective
 317 norms and PBC explained 51% of the variance of intention ($R^2=0.51$). Each variable was
 318 significantly associated with intention ($P < 0.0001$). The most important predictors of intention

319 were attitude ($\beta=0.61$, which meant that +1 point of attitude led to +0.61 points of intention),
 320 PBC ($\beta=0.32$) and subjective norms ($\beta=0.15$). Attitude and subjective norms were not
 321 associated with meat intake, and only intention and PBC explained individual meat intake (P
 322 <0.0001 for both). These variables explained 15% of the variance of meat intake ($R^2=0.15$).
 323 PBC was a better predictor ($\beta=-14.1$, which meant that +1 point of PBC led to -14.1 g/d of meat
 324 intake) than intention ($\beta=-9.0$) (**Figure 3**).



325

326 Figure 3. Measurement model for the Theory of Planned Behavior applied to the intention to
 327 reduce meat and meat intake in the questionnaire sample (2018, $n=2,055$). r , Pearson
 328 correlation coefficient; β , path coefficients; ***, $P < 0.0001$

329

330 Discussion

331 During this study on a large sample representative of the French adult population we were able
332 to classify participants in four types whose diets related to different degrees of transition from
333 a traditional Western diet towards a lower meat intake: omnivores, pro-flexitarians, flexitarians
334 and vegetarians. Among these dietary types, a gradual reduction of meat intake (particularly
335 beef and pork) was associated with a compensatory gradual increase in that of vegetables,
336 legumes, nuts and seeds. Differences in food intake were associated with differences in
337 attitudes, subjective norms, PBC and intention to reduce meat consumption. One major finding
338 of this study is that, beyond these dietary types, an intention to reduce meat could be predicted
339 from beliefs and attitude more than from other factors in the TPB model, and that meat intake
340 could be predicted from intention and PBC. The second important finding is that specific
341 attitudes regarding the impact of meat on the environment, human health and animal welfare
342 were strong determinants of these dietary types.

343 *Contrasts between dietary types*

344 There seemed to be a gradation of dietary types from omnivores to vegetarians, but this should
345 not be understood as a necessary transition that would ultimately lead to an all-vegetarian
346 population in the future. Rather, this gradation should be seen as a picture of the different
347 dietary types related to animal protein intake in France in 2018. Latvala et al. identified clusters
348 of consumers depending on whether they were undergoing a transition, had already lived a
349 transition or did not plan to change their behavior (Latvala, et al., 2012). The cluster of “past
350 change” still consumed meat, but at lower levels than initially, and there were four different
351 clusters of participants “ongoing a change”, depending on which food they intended to eat
352 more in the future (chicken, beef or vegetables), showing that there was not a single trajectory
353 of change that every individual followed. In our study, even though omnivores had lower scores
354 than pro-flexitarians and pro-flexitarians had lower scores than flexitarians for almost every
355 attitude, the magnitude of the contrasts between each stage was not the same. The main
356 dietary differences between omnivores and pro-flexitarians were lower beef and pork intakes,
357 but not processed meat and poultry, and higher vegetable and legume intakes. This could be
358 related to differences in symbolism between the different types of meats. Indeed, the word
359 “meat” is associated to red meat like beef and pork, but rarely with processed meat or poultry.
360 Red meat is associated with weight gain, health issues and disgust, more often than processed
361 meat or poultry (Kubberød, Ueland, Tronstad, & Risvik, 2002; Santos & Booth, 1996). Latvala
362 et al. also identified that most of the individuals who experiencing a transition towards less
363 meat intake were primarily reducing their beef and pork intakes, but not that of poultry (Latvala,
364 et al., 2012). The motivations of this transition were mainly related to healthiness and weight

365 management, and there were more women in the cluster undergoing a transition than in the
366 cluster not planning to change. This was also true in the present study as there were more
367 women in the pro-flexitarian group than in the omnivore group. This may be in line with the fact
368 that people valuing masculinity, people that do not see enjoying meat as a moral issue and
369 find dominance acceptable are more likely to consume animals (Loughnan, Bastian, & Haslam,
370 2014). The principal attitudinal differences between omnivores and pro-flexitarians were higher
371 scores on environment-related attitudes, and a higher evaluation of their ability to reduce meat
372 consumption, thus reflecting their intention (according to the TPB model). In view of the
373 literature and our results, we could therefore hypothesize that the first steps in the transition,
374 in addition to unconscious psychological parameters associated with sociodemographic
375 characteristics, are partly operated by a raising awareness to the environmental impacts of
376 meat consumption (because beef is the major contributor to food-related GHG emissions
377 (Gerber, et al., 2013)) among individuals with a higher self-declared ability to reduce meat
378 intake.

379 The principal differences between pro-flexitarians and flexitarians were a lower intake of beef
380 and processed meat, a more pronounced habit of consuming meatless dishes and higher
381 scores for health and animal welfare attitudes. The contrast between these two dietary types
382 therefore appeared to be partly explained, again in addition to unconscious psychological
383 parameters, by better habits to eat meatless dishes, animal welfare motivations and health-
384 related motivations, as high intakes of red and processed meats are recognized as increasing
385 the risk of colorectal cancer and cardiovascular diseases (Anses, 2016a; Boutron-Ruault,
386 Mesrine, & Pierre, 2017). Finally, the contrast between flexitarians and vegetarians was
387 marked by a lower poultry intake, and a higher intake of vegetables, legumes, nuts and seeds,
388 with higher health and animal welfare-related attitudes and better habits. The question on meat
389 being a necessary food for humans was the most discriminating, which may not appear
390 surprising given that most vegetarians evict meat. The differences between flexitarians and
391 vegetarians could be linked to the ethical vegetarians who focus on moral considerations
392 related to animal welfare, and tend to associate meat with disgust and emotional distress (Petti,
393 et al., 2017). The differences in reasons depending on the stage of transition were consistent
394 with findings from a few previous studies where omnivores tended to have lower scores for
395 attitudes related to animal welfare than flexitarians, who in turn had lower scores for attitudes
396 related to animal welfare than vegetarians (Clonan, et al., 2015; De Backer & Hudders, 2015).
397 Among young native Dutch adults, and as in our study, animal welfare was the main reason to
398 reduce meat consumption among vegetarians, while for low-meat eaters (who were similar to
399 the flexitarians in our study) it was health, and for medium meat-eaters (who were similar to
400 the pro-flexitarians in our study) it was the environment (de Boer, et al., 2017).

401 *Theory of Planned Behavior*

402 When TPB was applied to predict meat intake during two studies in the USA and Norway,
403 Wyker et al. found that attitudes, PBC and subjective norms could predict intentions to follow
404 a plant-based diet ($R^2=0.61$), and, as in our study, attitudes were the most important predictor
405 (Wyker & Davison, 2010). Zur et al. used a modified model based on TPB, norm activation
406 theory and the protection motivation theory, and showed that attitude was the most important
407 predictor of intention, but found no significant association between PBC and intention or meat
408 consumption. They showed that meat consumption was well predicted by intention (Zur & A.
409 Klöckner, 2014). Finally, Weibel et al. used the TPB in Switzerland to assess the associations
410 between attitudes, social norms and PBC and the stage model of behavioral change towards
411 a plant-based diet. They identified that attitudes (which they separated into “attitude” and
412 “awareness”), PBC, and social norms, among other factors, were associated with the stage of
413 behavioral change ($R^2=0.58$), and in particular with the shift from individuals who did not wish
414 to change to individuals who had the intention to change (Weibel, Ohnmacht, Schaffner, &
415 Kossmann, 2019). The TPB hypothesizes that attitudes and PBC predict intention which, in
416 turn, predicts behavior. However, other theories hypothesize a reverse causation: individuals
417 who are used to eating large amounts of meat cannot form attitudes and beliefs under which
418 meat is deleterious to health, the environment or animal welfare as this would constitute a
419 major dissonance with their behavior, so that they adapt their attitudes, PBC and intentions in
420 order to limit the gap with their behavior (Rothgerber, 2017). A majority of omnivores see their
421 behavior as the norm and do not look for or reject dissonant information regarding the impacts
422 of meat consumption (Piazza, et al., 2015).

423 *Cultural specificities of the French population*

424 Some self-declared vegetarians did report meat consumption, and we chose not to exclude
425 them for as long as this was not high (83% of vegetarians declared no meat intake, and only
426 one vegetarian declared $\geq 10\text{g/d}$). This had also been the case in other studies (Allès, et al.,
427 2017; Rothgerber, 2017), and our study was designed to question subjective representations
428 by individuals of their diets, rather than their objective diets, and we saw that these
429 representations were strongly associated with food intakes, attitudes and beliefs. Among the
430 17% of vegetarians who also declared eating meat, 67% declared eating poultry only.
431 Therefore vegetarianism seems to represent meat avoidance for most of the French self-
432 declared vegetarians, and red and processed meat avoidance for a smaller part of French self-
433 declared vegetarians. This is consistent with a study conducted in the USA showing that
434 among the participants who declared being vegetarians, a significant part declared consuming
435 poultry (Dietz, Frisch, Kalof, Stern, & Guagnano, 1995). The proportion of vegetarians in our

436 study was consistent with the most recent French data (2% in 2014-2015) (Anses, 2017). The
437 same food intake trends were reported in France by the Nutrinet-Santé study and in the UK by
438 the Biobank cohort: vegetarians ate more vegetables, legumes and nuts, fewer dairy products
439 and virtually no meat, compared to meat eaters. However, in those studies, the vegetarians
440 ate more eggs and less fish than meat eaters, which was not the case in our study (Allès, et
441 al., 2017; Bradbury, Tong, & Key, 2017). Similarly when comparing our study to the UK
442 Biobank cohort, the main differences between regular meat eaters and low meat eaters were
443 primarily a lower intake of beef, processed meat (but not poultry) and bread, and a higher fish
444 intake. However, there were no/few differences with respect to legumes, nuts and seeds and
445 dairy products in the UK, whereas the difference was marked in our study. Likewise, the low
446 amounts of meat consumed by vegetarians were mainly poultry in the present study, and
447 mainly red meat in the UK. These differences were perhaps indicative of differences in
448 vegetarian diets in countries such as France that do not have a large number of vegetarians
449 and have negative attitudes towards vegetarianism, in line with the rooted cultural specificity
450 of gastronomy in France, unlike northern Europe and the UK. The sociodemographic
451 characteristics of vegetarians and meat eaters were similar to those seen in the Nutrinet-Santé
452 study, as in both cases vegetarians were more likely than meat-eaters to be women, have a
453 BMI within the 18.5-25 range and be single. Scores related to the belief that eating meat was
454 expensive were similar across pro-flexitarians, flexitarians and vegetarians, even though
455 incomes differed between these groups. Likewise, meat intake was not associated with income
456 among non-omnivores. Taken together, this may suggest that price was not a determinant of
457 a low-meat diet among groups other than the omnivores. Flexitarians reported a lower food
458 intake compared to omnivores and pro-flexitarians, but as the study focused on food sources
459 of protein, only partial intake was estimated, and no conclusions in terms of total volume or
460 energy intake could be drawn. However, we were able to estimate that protein intake that was
461 partial but expected to cover about 84% of total protein intake, was similar between vegetarians
462 and flexitarians, which was in line with the findings of other studies (Clarys, et al., 2014).

463 *Limitations and uncertainties*

464 Some limitations and uncertainties affecting this study need to be underlined. First, the
465 hypotheses on the dynamic transition from classic Western diets to a lower meat intake could
466 not be tested because the individuals did not report whether they had experienced a dietary
467 transition or not, or the reasons why they would have experienced such a transition. Our results
468 were nevertheless consistent, in terms of contrasts in food intake, with other studies that
469 explored past or undergoing transitions to low-meat diets. Moreover, the BMI and food intake
470 values were estimated from declared data only, which may have involved a desirability bias
471 and underestimation of the BMI and “unhealthy” food intakes (Gorber, Tremblay, Moher, &

472 Gorber, 2007). Food intakes were estimated using a partial food frequency questionnaire,
473 which had not been validated by another assessment such as 24h recalls. Therefore, these
474 data could not be used to assess nutrient intakes or adequacies, or to study differences in
475 energy intake between the diets. However, we were able to indirectly determine differences in
476 diet quality between the dietary types, as red and processed meat intakes were lower among
477 pro-flexitarians and flexitarians than in omnivores, while the intakes of vegetables, legumes,
478 nuts and seeds and fish were higher, which was in line with the latest dietary guidelines in
479 France (Anses, 2016b). The diets of flexitarians and pro-flexitarians were therefore likely to be
480 of better quality than those of omnivores, which may also partly explain the lower BMI seen
481 among flexitarians and vegetarians than in omnivores. Contrary to those on energy and
482 nutrient adequacy, the survey method was developed to adequately characterize profiles of
483 dietary protein intake. The mean intakes of the food groups reported were at least 20% higher
484 than those found in the 2014-2015 INCA3 study except for bread, milk and fast foods, whose
485 intakes were lower. This is common as food frequency questionnaires tend to overestimate
486 intakes when compared to 24h recalls (Deschamps, et al., 2007). However, the present study
487 focused on differences in intake between different dietary types and associations between
488 intakes and attitudes, and not on absolute intakes. Finally, only 52 vegetarians were identified
489 in our sample, which limited the statistical power of the analyses, and may explain why some
490 contrasts between vegetarians and other groups were not found to be significant. However, as
491 discussed before, our results were consistent with those of other studies involving a large
492 number of vegetarians.

493 *Conclusion and prospects*

494 During this study, we were able to identify diets corresponding to different levels of meat intake.
495 Pro-flexitarians appeared to be driven by environmental reasons, and these individuals had a
496 lower beef and pork consumption and ate more vegetables and legumes than omnivores.
497 Flexitarians appeared to be driven by health and animal welfare issues, were more used to
498 meatless dishes and had lower intakes of red and processed meats. Finally, vegetarians
499 considered that meat was not a necessary food for humans, and were concerned by animal
500 welfare. We were able to predict overall meat intake from the score of intention to consume
501 less meat and the PBC, and to predict intention from attitudes, social norms and PBC. Attitudes
502 were the most important predictor of intention. We can therefore conclude that raising
503 awareness to the impacts of high meat consumption on the environment, health and animal
504 welfare could be a critical lever to enable a transition to low meat consumption. Indeed, it has
505 been shown in some interventional studies that providing information on the impacts of meat
506 consumption on health, the environment or animal welfare was associated with a reduced
507 intention to consume and choose meat (Bianchi, Garnett, Dorsel, Aveyard, & Jebb, 2018).

508 Other strategies based on group dynamics have been shown to be more effective than
509 providing information to change dietary behavior, and, as a result, attitudes towards this
510 behavior (Lewin, 1943).

511

512 **Acknowledgments**

513 The authors would like to thank Dr. Serge Hercberg (EREN, Bobigny, France) for access to
514 the images of food portions.

515

516

517 **References**

- 518 Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision*
519 *Processes*, 50, 179-211.
- 520 Allès, B., Baudry, J., Méjean, C., Touvier, M., Péneau, S., Hercberg, S., & Kesse-Guyot, E. (2017).
521 Comparison of Sociodemographic and Nutritional Characteristics between Self-Reported
522 Vegetarians, Vegans, and Meat-Eaters from the NutriNet-Santé Study. *Nutrients*, 9, 1023.
- 523 Amiot, C. E., El Hajj Boutros, G., Sukhanova, K., & Karelis, A. D. (2018). Testing a novel multicomponent
524 intervention to reduce meat consumption in young men. *PLoS One*, 13, e0204590.
- 525 Anses. (2016a). Actualisation des repères du PNNS : étude des relations entre consommation de
526 groupes d'aliments et risque de maladies chroniques non transmissibles
527 - www.anses.fr/en/system/files/NUT2012SA0103Ra-3.pdf. *Rapport d'expertise collective*.
- 528 Anses. (2016b). Updating of the PNNS guidelines: revision of the food-based dietary guidelines -
529 <https://www.anses.fr/en/system/files/NUT2012SA0103Ra-1EN.pdf>. *Anses opinion - Collective*
530 *expert report*.
- 531 Anses. (2017). Étude individuelle nationale des consommations alimentaires 3 (INCA 3) -
532 <https://www.anses.fr/fr/system/files/NUT2014SA0234Ra.pdf>. *Rapport d'expertise collective*.
- 533 Arvola, A., Vassallo, M., Dean, M., Lampila, P., Saba, A., Lähteenmäki, L., & Shepherd, R. (2008).
534 Predicting intentions to purchase organic food: The role of affective and moral attitudes in the
535 Theory of Planned Behaviour. *Appetite*, 50, 443-454.
- 536 Berndsen, M., & van der Pligt, J. (2005). Risks of meat: the relative impact of cognitive, affective and
537 moral concerns. *Appetite*, 44, 195-205.
- 538 Bianchi, F., Garnett, E., Dorsel, C., Aveyard, P., & Jebb, S. A. (2018). Restructuring physical micro-
539 environments to reduce the demand for meat: a systematic review and qualitative
540 comparative analysis. *The Lancet Planetary Health*, 2, e384-e397.
- 541 Blundell, J., de Graaf, C., Hulshof, T., Jebb, S., Livingstone, B., Lluich, A., Mela, D., Salah, S., Schuring, E.,
542 van der Knaap, H., & Westerterp, M. (2010). Appetite control: methodological aspects of the
543 evaluation of foods. *Obesity reviews : an official journal of the International Association for the*
544 *Study of Obesity*, 11, 251-270.
- 545 Boutron-Ruault, M.-C., Mesrine, S., & Pierre, F. (2017). 12 - Meat Consumption and Health Outcomes.
546 In F. Mariotti (Ed.), *Vegetarian and Plant-Based Diets in Health and Disease Prevention* (pp.
547 197-214): Academic Press.
- 548 Bradbury, E. K., Tong, Y. T., & Key, J. T. (2017). Dietary Intake of High-Protein Foods and Other Major
549 Foods in Meat-Eaters, Poultry-Eaters, Fish-Eaters, Vegetarians, and Vegans in UK Biobank.
550 *Nutrients*, 9.
- 551 Clarys, P., Deliens, T., Huybrechts, I., Deriemaeker, P., Vanaelst, B., De Keyser, W., Hebbelinck, M., &
552 Mullie, P. (2014). Comparison of Nutritional Quality of the Vegan, Vegetarian, Semi-
553 Vegetarian, Pesco-Vegetarian and Omnivorous Diet. *Nutrients*, 6, 1318.
- 554 Cleveland, D. A., & Gee, Q. (2017). 9 - Plant-Based Diets for Mitigating Climate Change. In F. Mariotti
555 (Ed.), *Vegetarian and Plant-Based Diets in Health and Disease Prevention* (pp. 135-156):
556 Academic Press.
- 557 Clonan, A., Wilson, P., Swift, J. A., Leibovici, D. G., & Holdsworth, M. (2015). Red and processed meat
558 consumption and purchasing behaviours and attitudes: impacts for human health, animal
559 welfare and environmental sustainability. *Public Health Nutrition*, 18, 2446-2456.
- 560 De Backer, C. J. S., & Hudders, L. (2015). Meat morals: relationship between meat consumption
561 consumer attitudes towards human and animal welfare and moral behavior. *Meat Science*, 99,
562 68-74.
- 563 de Boer, J., Schösler, H., & Aiking, H. (2017). Towards a reduced meat diet: Mindset and motivation of
564 young vegetarians, low, medium and high meat-eaters. *Appetite*, 113, 387-397.
- 565 de Gavelle, E., Huneau, J.-F., Fouillet, H., & Mariotti, F. (2019). The Initial Dietary Pattern Should Be
566 Considered when Changing Protein Food Portion Sizes to Increase Nutrient Adequacy in French
567 Adults. *The Journal of Nutrition*, 149, 488-496.

- 568 Deschamps, V., de Lauzon-Guillain, B., Lafay, L., Borys, J. M., Charles, M. A., & Romon, M. (2007).
 569 Reproducibility and relative validity of a food-frequency questionnaire among French adults
 570 and adolescents. *European Journal of Clinical Nutrition*, *63*, 282.
- 571 Dietz, T., Frisch, A. S., Kalof, L., Stern, P. C., & Guagnano, G. A. (1995). Values and Vegetarianism: An
 572 Exploratory Analysis. *Rural Sociology*, *60*, 533-542.
- 573 Dubuisson, C., Lioret, S., Touvier, M., Dufour, A., Calamassi-Tran, G., Volatier, J.-L., & Lafay, L. (2010).
 574 Trends in food and nutritional intakes of French adults from 1999 to 2007: results from the
 575 INCA surveys. *British Journal of Nutrition*, *103*, 1035-1048.
- 576 FAO. (2018). FAOSTAT - <http://www.fao.org/faostat/en/#data/CL>.
- 577 FranceAgriMer. (2015). Impact de la crise économique sur la consommation de viande et évolution des
 578 comportements alimentaires. *Les synthèses de FranceAgriMer*, *21*.
- 579 Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Faluccci, A., & Tempio, G.
 580 (2013). *Tackling climate change through livestock: a global assessment of emissions and*
 581 *mitigation opportunities*: Food and Agriculture Organization of the United Nations (FAO).
- 582 Godfray, H. C. J., Aveyard, P., Garnett, T., Hall, J. W., Key, T. J., Lorimer, J., Pierrehumbert, R. T.,
 583 Scarborough, P., Springmann, M., & Jebb, S. A. (2018). Meat consumption, health, and the
 584 environment. *Science*, *361*.
- 585 Gorber, S. C., Tremblay, M., Moher, D., & Gorber, B. (2007). A comparison of direct vs. self-report
 586 measures for assessing height, weight and body mass index: a systematic review. *Obesity*
 587 *Reviews*, *8*, 307-326.
- 588 Graça, J., Calheiros, M. M., & Oliveira, A. (2015). Attached to meat? (Un)Willingness and intentions to
 589 adopt a more plant-based diet. *Appetite*, *95*, 113-125.
- 590 Graça, J., Oliveira, A., & Calheiros, M. M. (2015). Meat, beyond the plate. Data-driven hypotheses for
 591 understanding consumer willingness to adopt a more plant-based diet. *Appetite*, *90*, 80-90.
- 592 Halkjaer, J., Olsen, A., Bjerregaard, L., Deharveng, G., Tjønneland, A., Welch, A., Crowe, F., Wirfält, E.,
 593 Hellstrom, V., & Niravong, M. (2009). Intake of total, animal and plant proteins, and their food
 594 sources in 10 countries in the European Prospective Investigation into Cancer and Nutrition.
 595 *European Journal of Clinical Nutrition*, *63*, S16-S36.
- 596 Jallinoja, P., Niva, M., & Latvala, T. (2016). Future of sustainable eating? Examining the potential for
 597 expanding bean eating in a meat-eating culture. *Futures*, *83*, 4-14.
- 598 Kantar WorldPanel. (2017). Le Flexitarisme: les Français et la consommation de produits d'origine
 599 animale - <http://www.lafranceagricole.fr/r/Publie/FA/p1/Infographies/Web/2017-12-01/KWP%20pour%20MeatLab%20Charal%20-%20Viande%20Les%20franc%CC%A7ais%20et%20les%20prote%CC%81ines%20animales%20%282%29.pdf> (accessed on on 18/12/2018).
- 600
 601
 602
- 603 Kline, R. B. (2015). *Principles and practice of structural equation modeling*: Guilford publications.
- 604 Kubberød, E., Ueland, Ø., Tronstad, Å., & Risvik, E. (2002). Attitudes towards meat and meat-eating
 605 among adolescents in Norway: a qualitative study. *Appetite*, *38*, 53-62.
- 606 Latvala, T., Niva, M., Mäkelä, J., Pouta, E., Heikkilä, J., Kotro, J., & Forsman-Hugg, S. (2012). Diversifying
 607 meat consumption patterns: Consumers' self-reported past behaviour and intentions for
 608 change. *Meat Science*, *92*, 71-77.
- 609 Le Moulllec, N., Deheeger, M., Preziosi, P., Monteiro, P., Valeix, P., Rolland-Cachera, M.-F., Potier de
 610 Courcy, G., Christides, J.-P., Cherouvrier, F., & Galan, P. (1996). Validation du manuel-photos
 611 utilisé pour l'enquête alimentaire de l'étude SU. VI. MAX. *Cahiers de Nutrition et de Diététique*,
 612 *31*, 158-164.
- 613 Lewin, K. (1943). Forces behind food habits and methods of change, from: Guthe, C. and Mead, M. The
 614 problem of changing food habits, Report of the Committee on Food Habits. *Bulletin of the*
 615 *National Research Council*.
- 616 Loughnan, S., Bastian, B., & Haslam, N. (2014). The Psychology of Eating Animals. *Current Directions in*
 617 *Psychological Science*, *23*, 104-108.
- 618 Norat, T., Bingham, S., Ferrari, P., Slimani, N., Jenab, M., Mazuir, M., Overvad, K., Olsen, A., Tjønneland,
 619 A., Clavel, F., Boutron-Ruault, M.-C., Kesse, E., Boeing, H., Bergmann, M. M., Nieters, A.,

- 620 Linseisen, J., Trichopoulou, A., Trichopoulos, D., Tountas, Y., Berrino, F., Palli, D., Panico, S.,
621 Tumino, R., Vineis, P., Bueno-de-Mesquita, H. B., Peeters, P. H. M., Engeset, D., Lund, E., Skeie,
622 G., Ardanaz, E., González, C., Navarro, C., Quirós, J. R., Sanchez, M.-J., Berglund, G., Mattisson,
623 I., Hallmans, G., Palmqvist, R., Day, N. E., Khaw, K.-T., Key, T. J., San Joaquin, M., Hémon, B.,
624 Saracci, R., Kaaks, R., & Riboli, E. (2005). Meat, Fish, and Colorectal Cancer Risk: The European
625 Prospective Investigation into Cancer and Nutrition. *JNCI: Journal of the National Cancer*
626 *Institute*, *97*, 906-916.
- 627 Petti, A., Palmieri, B., Vadalà, M., & Laurino, C. (2017). Vegetarianism and veganism: not only benefits
628 but also gaps. A review. *Progress in Nutrition*, *19*, 229-242.
- 629 Piazza, J., Ruby, M. B., Loughnan, S., Luong, M., Kulik, J., Watkins, H. M., & Seigerman, M. (2015).
630 Rationalizing meat consumption. The 4Ns. *Appetite*, *91*, 114-128.
- 631 Pohjolainen, P., Vinnari, M., & Jokinen, P. (2015). Consumers' perceived barriers to following a plant-
632 based diet. *British Food Journal*, *117*, 1150-1167.
- 633 Povey, R., Wellens, B., & Conner, M. (2001). Attitudes towards following meat, vegetarian and vegan
634 diets: an examination of the role of ambivalence. *Appetite*, *37*, 15-26.
- 635 Pribis, P., Pencak, R. C., & Grajales, T. (2010). Beliefs and Attitudes toward Vegetarian Lifestyle across
636 Generations. *Nutrients*, *2*.
- 637 Rothgerber, H. (2017). 2 - Attitudes Toward Meat and Plants in Vegetarians. In F. Mariotti (Ed.),
638 *Vegetarian and Plant-Based Diets in Health and Disease Prevention* (pp. 11-35): Academic
639 Press.
- 640 Ruby, M. B., Alvarenga, M. S., Rozin, P., Kirby, T. A., Richer, E., & Rutzstein, G. (2016). Attitudes toward
641 beef and vegetarians in Argentina, Brazil, France, and the USA. *Appetite*, *96*, 546-554.
- 642 Santos, M. L. S., & Booth, D. A. (1996). Influences on Meat Avoidance Among British Students. *Appetite*,
643 *27*, 197-205.
- 644 Schösler, H., de Boer, J., & Boersema, J. J. (2012). Can we cut out the meat of the dish? Constructing
645 consumer-oriented pathways towards meat substitution. *Appetite*, *58*, 39-47.
- 646 Weibel, C., Ohnmacht, T., Schaffner, D., & Kossmann, K. (2019). Reducing individual meat
647 consumption: the role of socio-psychological factors and the stage model of behavioral
648 change. *Food Quality and Preference*.
- 649 WHO. (2000). *Obesity: preventing and managing the global epidemic*: World Health Organization.
- 650 Wyker, B. A., & Davison, K. K. (2010). Behavioral Change Theories Can Inform the Prediction of Young
651 Adults' Adoption of a Plant-based Diet. *Journal of Nutrition Education and Behavior*, *42*, 168-
652 177.
- 653 Zur, I., & A. Klöckner, C. (2014). Individual motivations for limiting meat consumption. *British Food*
654 *Journal*, *116*, 629-642.
- 655
- 656

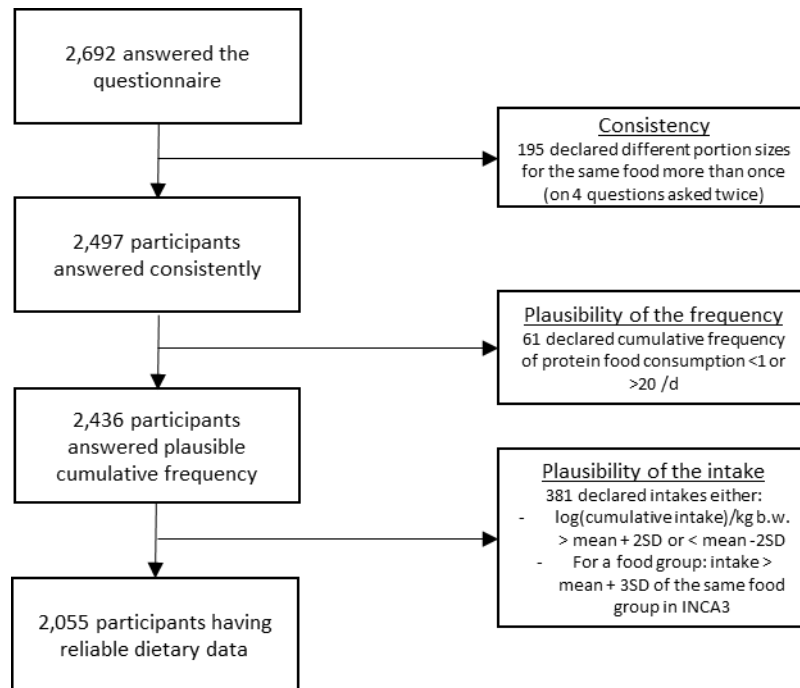
Supplementary data

Supplemental table 1. Food groups whose frequency of intake were assessed in the questionnaire. Questions about portion sizes were asked for the 10 food groups whose intake increased the most and the 10 food groups that decreased the most in a previous modelling study (de Gavelle, Huneau, Fouillet, & Mariotti, 2019), if consumed by individuals. If a food group whose intake increased frequently in the modelling study was not consumed, the portion size of another food group was asked.

Food group	Type of change in food intake that increased nutrient adequacy ¹	Question about portion size
Overall meat	-	Estimated equal to the portion of beef
Beef	Increase or decrease	If consumed
Veal or lamb	-	Estimated equal to the portion of beef
Pork (except ham and deli meat)	Decrease	If consumed
Sausages (Wieners, sausages, andouilles and puddings...)	Decrease	If consumed
Pâté, rillettes	Decrease	If consumed
Ham (cured or not, bacon)	Decrease	If consumed
Offal	Decrease	Estimated equal to the portion of beef
Poultry (chicken, turkey...)	Increase or decrease	If consumed
Fatty fish (salmon, sardines, mackerel...)	Increase	If consumed
Lean fish (tuna, cod, hake, sole...)	Increase	If consumed
Eggs and omelets	Decrease	If consumed
Cheese	Decrease	If consumed
Milk	-	Not asked (200g)
Yogurts and cottage cheese	Increase	Not asked (125g)
Meat-based dishes (cassoulet, beef bourguignon, couscous...)	Decrease	If consumed and 3 of the others were not
Dishes without filling (tripe, veal roulades, dumplings...)	Decrease	If consumed and 5 of the others were not
Prepared dishes based on vegetables (stuffed tomatoes, endive gratin, moussaka...)	Decrease	If consumed and 4 of the others were not
Dishes prepared with pasta or potatoes (ravioli, gratin dauphinois, Bolognese pasta...)	Decrease	If consumed and 1 of the other was not
Sandwiches	Decrease	If consumed and 6 of the others were not
Fast food (pizzas, kebabs, burgers...)	Decrease	If consumed and 7 of the others were not
Quiches and salty pies	Decrease	If consumed and 2 of the others were not
Pastas (excluding wholemeal pastas)	Increase or decrease	If consumed
Bread (excluding wholemeal bread)	Increase or decrease	If consumed
Whole grain rice, pastas or bread	Increase	Mean of rice, pastas and bread
Rice and wheat (semolina or cooked wheat)	Increase	If consumed
Spinach and chard	Increase	If consumed
Legumes (lentils, flageolets...)	Increase	If consumed
Nuts and seeds (almonds, hazelnuts, peanuts...)	Increase	If consumed

¹ The modelling study aimed at identifying which type of change in protein food intake was the most effective to increase overall nutrient adequacy in a French representative population. For some food groups, increasing or decreasing the intake could be effective to increase overall nutrient adequacy depending on the participant.

Supplementary data



Supplemental Figure 1. Flow chart of the selection of reliable dietary data in the population sample (2018, n=2,055)

Supplementary data

Supplemental references

de Gavelle, E., Huneau, J.-F., Fouillet, H., & Mariotti, F. (2019). The Initial Dietary Pattern Should Be Considered when Changing Protein Food Portion Sizes to Increase Nutrient Adequacy in French Adults. *The Journal of Nutrition*, *149*, 488-496.