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

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Self-declared attitudes and beliefs regarding protein sources are a good prediction of the degree of transition to a low-meat diet in France[1,2]

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[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

Abstract

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

Keywords

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

Introduction

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

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

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

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

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

Population and methods

Population and food intake

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

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

Food intakes

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

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

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

Attitudes and beliefs relative to protein sources

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

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

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

Table 1. Questionnaire items on attitudes and beliefs, classified as intentions or factors explaining intentions (variables), and internal consistency[1].

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	Subjective norms	0.69
There are more and more people around me who are reducing their meat consumption	NORM2		
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	-	-

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

Identification and characterization of dietary types

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

Socio-demographic and lifestyle factors

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

Statistical analyses

An overall α level of 5% was used for statistical tests. Sample weightings were applied to ensure the representativeness of the sample with respect to sex, age, socio-professional category and geographic area of living, using the *Icarus* R package. All means were thus weighted in this way. ANCOVA adjusted for age, sex and appetite score was used to test for differences depending on the overall type of diet, and post-hoc tests with Tukey correction for differences between the diets. Multivariate logistic regression models were implemented to assess the association between sociodemographic factors and the type of diet, using 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 χ2 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).

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Results

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

Intakes of different protein food groups

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

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

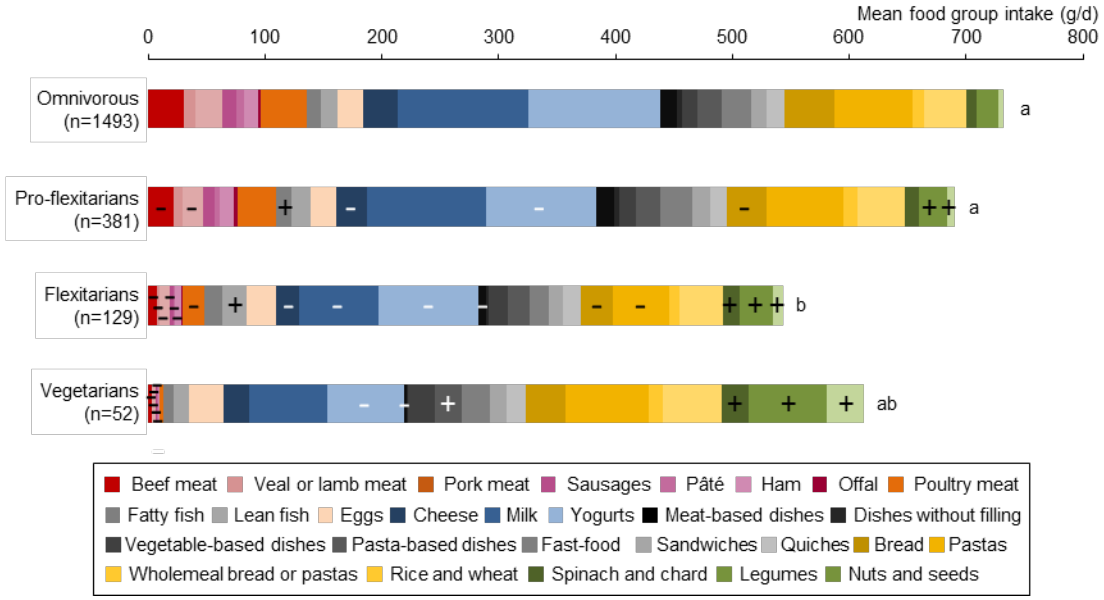

Figure 1. Mean intakes of different food groups in each dietary type determined in the questionnaire sample (2018, *n*=2,055). +/-: mean intake significantly higher or lower than omnivores, as tested using post-hoc pairwise comparisons with Tukey corrections. Labeled means without a common letter indicate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

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

Sociodemographic characteristics

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

Table 2. Sociodemographic characteristics of the different dietary types compared to omnivores in the questionnaire sample (2018, *n*=2,055). Associations were tested using 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]	

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

Attitudes and beliefs relative to sources of protein

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

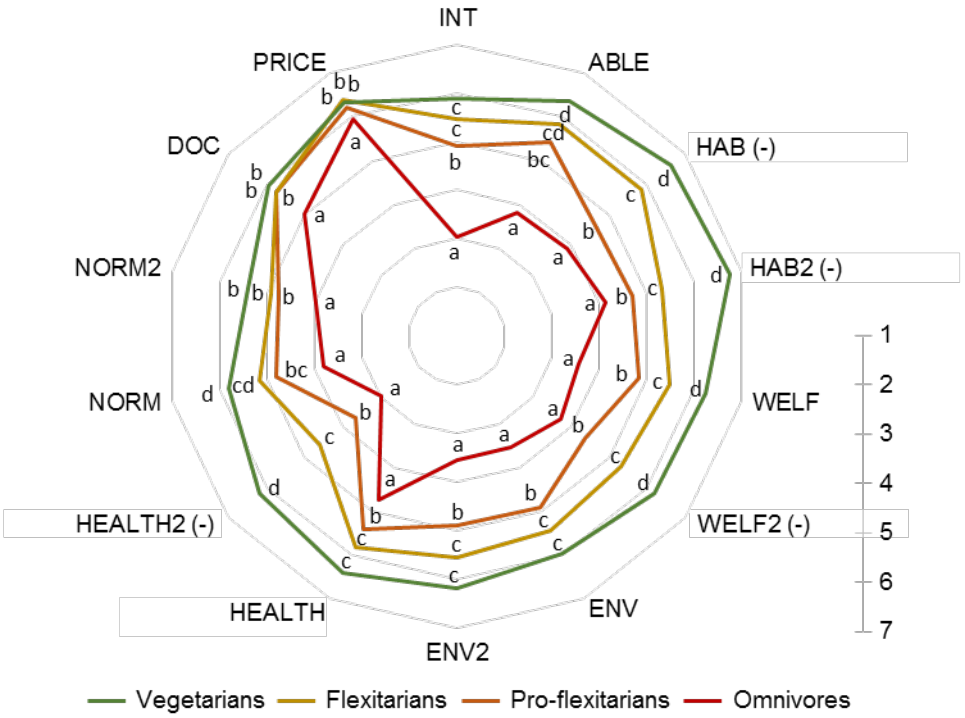

Figure 2. Mean scores (from 1 to 7) for items in the attitudes and beliefs questionnaire, for each dietary type in the sample (2018, *n*=2,055). When ANCOVA was adjusted for age, sex and appetite score and identified a significant effect of the type of diet, labeled means without a common letter indicate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

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

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

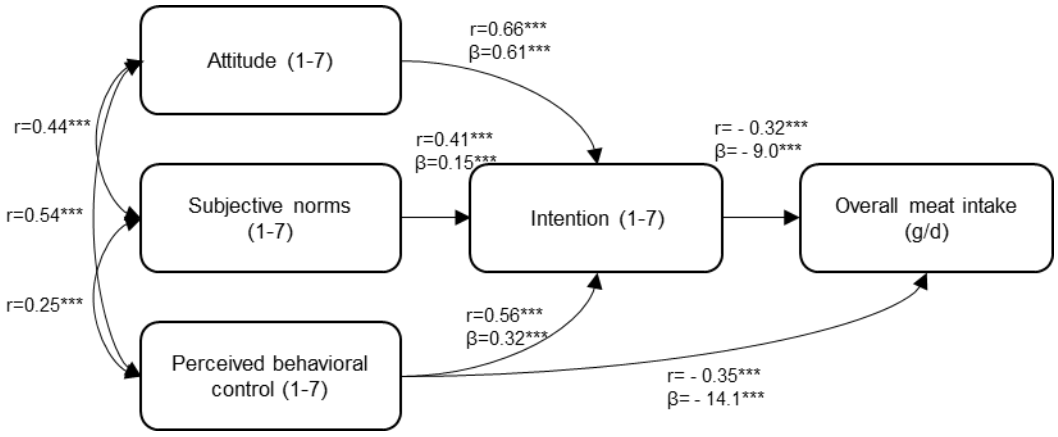

Figure 3. Measurement model for the Theory of Planned Behavior applied to the intention to reduce meat and meat intake in the questionnaire sample (2018, *n*=2,055). *r*, Pearson correlation coefficient; β, path coefficients; ***, *P* <0.0001

Discussion

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

Contrasts between dietary types

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

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

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

Theory of Planned Behavior

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

Cultural specificities of the French population

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

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

Limitations and uncertainties

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

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

Conclusion and prospects

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

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

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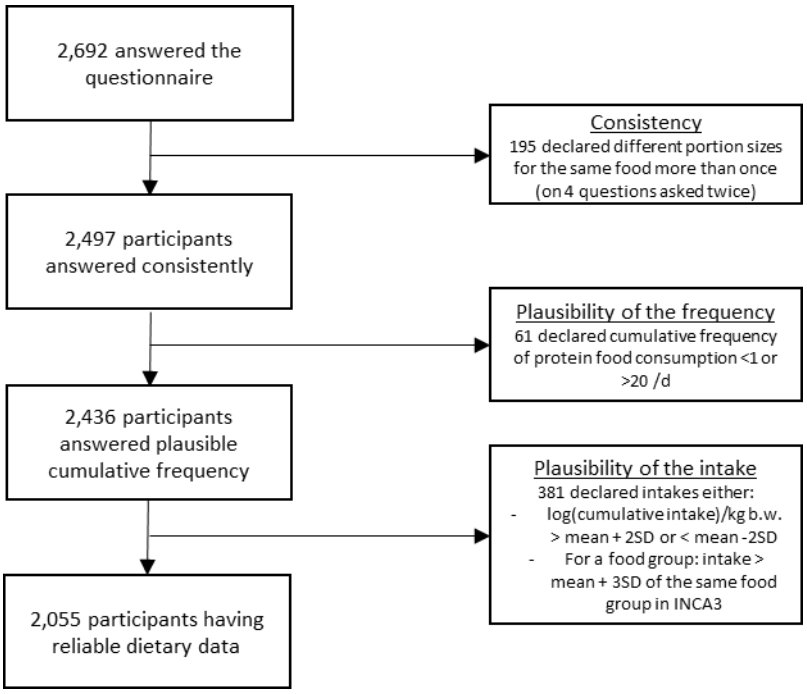
Supplemental table 1. Food groups whose frequency of intake were assessed in the questionnaire. Questions about portion sizes were asked for the 10 food groups whose intake increased the most and the 10 food groups that decreased the most in a previous modelling study (de Gavelle, Huneau, Fouillet, & 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)

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.