High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults

Florent Vieux, Louis Georges Soler, Djilali Touazi, Nicole N. Darmon

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ABSTRACT

Background: Healthy diets are supposed to be more environmentally friendly because they rely mainly on plant-based foods, which have lower greenhouse gas emissions (GHGEs) per unit weight than do animal-based foods.

Objectives: The objectives were to estimate the GHGEs associated with the consumption of self-selected diets in France and to analyze their relation with the nutritional quality of diets.

Design: For each adult in the national dietary Individual and National Survey on Food Consumption (n = 1918), the GHGEs of his or her diet were estimated based on the GHGEs of 391 foods. Highest-nutritional-quality diets were defined as those having simultaneously *1*) an energy density below the median, *2*) a mean adequacy ratio (MAR) above the median, and *3*) a mean excess ratio (MER, percentage of maximum recommended values for nutrients for which intake should be limited) below the median.

Results: MAR was positively correlated and MER was negatively correlated with diet-related GHGEs. High-nutritional-quality diets contained more plant-based foods, notably fruit and vegetables, and fewer sweets and salted snacks than did low-quality diets. After adjustment for age, sex, and energy intake, the consumption of sweets and salted snacks was negatively correlated with diet-related GHGEs, whereas the consumption of animal products and of fruit and vegetables was positively associated with them. After adjustment for energy intake, high-nutritional-quality diets had significantly higher GHGEs (+9% and +22% for men and women, respectively) than did low-nutritional-quality diets.

Conclusion: Despite containing large amounts of plant-based foods, self-selected diets of the highest nutritional quality are currently not those with the lowest diet-related GHGEs. *Am J Clin Nutr* 2013;97:569–83.

INTRODUCTION

The food sector contributes ∼15–30% of total greenhouse gas emissions (GHGEs)[4] in developed countries (1–4). Food consumption is therefore considered an important driver of climate change and changing the diets as a way of reducing GHGEs. In particular, reducing meat consumption in high-income countries has been proposed as a good way to reduce food-related GHGEs while simultaneously improving health (5–7). Indeed, the production of animal products, particularly red meat from ruminants, uses more energy and generates more GHGEs than does that of plant-based products (3, 8). Moreover, red meat is suspected to have a causal influence on colorectal cancer (9) and other forms of cancers (10) and may be associated with cardiovascular diseases because of its high cholesterol and SFA contents (11). Thus, it is now widely accepted that a global shift toward plant-based diets would have a favorable effect on both the environment and health (12, 13). In addition, vegetarian meals and diets have consistently been shown to have less of an environmental impact than omnivorous ones (14–18). However, meat, fish, and dairy products are unique sources of specific and essential nutrients, and a reduction of their consumption raises many nutritional challenges (19).

Sustainable diets have been defined by the FAO as "diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (20). Accordingly, the FAO recommends giving due consideration to sustainability when developing food-based dietary guidelines and policies and acknowledges the need for studies demonstrating the synergies between the different dimensions of sustainability (20). The aim of the current study was therefore to analyze in detail the relation between the nutritional quality of self-selected diets and their associated GHGEs. To account for the actual diversity of food-consumption patterns in France, data from the latest dietary survey conducted among a representative sample of the French adult population were used (21). The daily GHGEs of each diet were estimated on the basis of the GHGEs of several hundred foods consumed in this population (22). The estimated GHGEs of diets were correlated with the consumption of food groups and with indicators of nu-

[1] From the Unité Mixte de Recherche (UMR) "Nutrition, Obesity and Risk of Thrombosis," Institut National de la Recherche Agronomique 1260 (INRA), Institut National de la Santé et de la Recherche Médicale 1062 INSERM, Aix-Marseille Université, F-13385, Marseille, France (FV and ND), and the Institut National de Recherche Agronomique UR 1303, Ivry sur Seine, France (L-GS and DT).

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[3] Address correspondence to N Darmon, UMR 1062 INSERM/1260 INRA/Université d'Aix-Marseille, NORT: Nutrition Obésité et Risque Thrombotique, Faculté de Médecine de la Timone, 27 Boulevard Jean Moulin, 13385 Marseille Cedex 05, France. E-mail: nicole.darmon@univ-amu.fr.

[4] Abbreviations used: CO_2e, CO_2 equivalent; ED, energy density; GHGE, greenhouse gas emission; MAR, mean adequacy ratio; MER, mean excess ratio; MRV, maximum recommended value.

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tritional quality. Then, to avoid a priori assumptions about the food content of high and low-nutritional-quality diets, a way of classifying them that only relied on their energy density (ED) and their nutrient contents was specifically developed for this study. The daily GHGEs of diets of increasing nutritional quality according to this classification were compared.

SUBJECTS AND METHODS

Population sample and dietary data

The dietary data used in the current study were derived from the 7-d food records of a nationally representative random sample of adults (*n* = 2624; age > 18 y) participating in the Individual and National Survey on Food Consumption, a cross-sectional dietary survey conducted in 2006–2007 by the French Agency for Food, Environmental and Occupational Health Safety (21). The sampling method used was that of 3-stage stratified random sampling (23). To ensure the representativeness of the sample, a statistical adjustment was made for region, town size, age, sex, occupation of the household head, household size, and seasonal variables. After the exclusion of underreporters with the use of standard procedures, the current analysis was conducted on a final sample of 1918 adults (776 men and 1142 women). All of the foods declared as consumed by the participants during the survey (*n* = 1314 foods and beverages, including water) were listed in a survey-associated food database giving the nutritional composition of each food. The foods were aggregated into 10 main food groups (and 37 food families) as follows: starchy foods (refined grains and unrefined starches such as whole grains, potatoes, and legumes), fruit and vegetables (including fruit juices and nuts); dairy products (milk, fresh dairy products, and cheese); fats (animal and vegetable); fish (including shellfish); ruminant meat (such as beef and lamb); pork, poultry, and eggs (including pork meat and deli meat such as bacon or sausage); drinks (including water, alcohol, and hot and light drinks); a group containing (animal-based and plant-based) mixed dishes; and a group containing sweets and salted snacks (including sweet drinks).

Total diet weight, total energy intakes, and nutrient intakes were calculated on a daily basis for each participant, based on the list of foods and beverages that he or she recorded and the energy and nutrient contents of the foods consumed. The total intake of plant-based products was also calculated as the sum of the intakes of the fruit and vegetables food group, the starches food group, plus plant-based mixed dishes (within the mixed dishes food group) and vegetable fats (within the fats food group).

Three indicators of nutritional quality

The mean adequacy ratio (MAR), the mean excess ratio (MER), and the dietary ED were used as nutritional-quality indicators and were estimated without including nutrients from alcoholic beverages.

The MAR was used as an indicator of good nutritional quality, because it has been repeatedly shown to be positively associated with other indexes of dietary quality (24–30) and with health indicators (31, 32). In the current study, the MAR was calculated for the diet of each individual as the mean percentage of daily recommended intakes for 20 key nutrients (namely proteins, fiber, retinol equivalents, thiamine, riboflavin, niacin, vitamin B-6, folates, vitamin B-12, ascorbic acid, vitamin E, vitamin D, calcium, potassium, iron, magnesium, zinc, copper, iodine, and selenium) as follows:

$$MAR = \frac{1}{20} \times \sum_{bn=1}^{20} \frac{intake_{bn}}{RDA_{bn}} \times 100 \qquad (1)$$

where $\text{intake}_{\text{bn}}$ is the daily intake of each beneficial nutrient *bn*, and RDA_{bn} is the French Recommended Dietary Allowance (33) for that nutrient, taking into account the age and sex of the individual. As originally proposed (34, 35), each ratio ($100 \times \text{intake}_{\text{bn}}/\text{RDA}_{\text{bn}}$) was truncated at 100, so that a high intake of one nutrient could not compensate for the low intake of another.

We developed the MER by analogy with the MAR and used it as an indicator of bad nutritional quality. The MER was calculated for each diet as the mean daily percentage of maximum recommended values (MRVs) for 3 harmful nutrients (hn), namely SFAs, sodium, and free sugars, as follows:

$$MER = \left[\frac{1}{3} \times \left(\sum_{hn=1}^{3} \frac{intake_{hn}}{MRV_{hn}} \times 100\right)\right] - 100 \qquad (2)$$

The term *free sugars* refers to added sugars plus sugars naturally present in honey, syrups, and fruit juices (36). The MRVs for SFAs and free sugars corresponded to 10% of a standard energy intake of 2000 kcal, ie, 22.2 and 50 g, respectively. The MRV for sodium was 3153 mg and corresponded to a daily intake of 8 g NaCl. Each ratio ($100 \times \text{intake}_{hn}/\text{MRV}_{hn}$) <100 was set to 100, so that a low intake of one harmful nutrient could not compensate for the high intake of another.

Dietary ED was used as an indicator of bad nutritional quality because diets with a low ED have been shown to have a good overall nutritional quality (37, 38) and because decreasing the ED of the diet is recommended by several public health authorities to prevent obesity and obesity-associated disease conditions (39, 40). Diet weight (in g) and energy intake (in kcal) were calculated for each individual by summing the edible weight and the energy content of the foods consumed by that person. Dietary ED (in kcal/100 g diet) was then calculated by dividing energy intake by diet weight. As proposed by Ledikwe et al (41), only items typically consumed as foods, including soups, were included in the calculation of ED, whereas foods typically consumed as beverages, such as milk, juices, and other drinks, were excluded.

Four classes of nutritional quality

A method for classifying individuals based on the nutritional quality of their diets was specifically developed for this study. The 3 indicators of nutritional quality described above were calculated for each diet. Individuals were then ranked according to the values of the 3 indicators compared with their observed sex-specific median. A high-nutritional-quality diet was defined as a diet complying with the 3 following nutritional properties: MAR above the median, MER below the median, and dietary ED below the median. Diets complying with the 3 properties were allocated to the "High" nutritional quality class, whereas those complying with only 2, 1, or 0 of these properties were allocated to the "Intermediate +" (I+), the "Intermediate –" (I−), and the "Low" nutritional-quality classes, respectively. Therefore, each individual diet was classified into 1 of 4 possible sex-specific classes of nutritional quality.

Estimation of diet-related GHGEs

The estimation of diet-related GHGEs was based on a selection of foods. Within each food family, foods with the highest percentage of consumers were selected as representative of the food family, which resulted in a list of 391 widely consumed foods. Then, an environment consultancy—Greenext—assigned values for GHGEs to the 391 foods. Life cycle analysis as recommended by the International Organization for Standardization 14040-44 (42) norms and by the French regulation BP X 30–323 (43), ie, from cradle to grave, was used to assess the GHGE value for each selected food. The assessment included all the recommended steps, except for transportation by consumers from the retail centers to home, by using a range of life cycle inventory databases (eg, Ecoinvent data for primary agricultural goods). The final GHGEs value reflected the average food product as consumed on the French market and took into account the different geographic sources of the product. The Greenext method is presented in more detail on their website (http://www.greencode-info.fr/index.html). Data were expressed as grams of CO_2 equivalent per 100 g of edible part (g CO_2e/100 g) of the food, ie, once the changes in weight associated with the trimming or cooking processes had been taken into account with use of the appropriate conversion factors (44).

Although the 391 selected foods were highly consumed, they do not represent the totality of food intakes. We therefore developed a way of calculating diet-related GHGEs that took into account the restricted number of foods in the GHGE food database, to correct for the undercoverage of total food intake. For each individual, total diet-related GHGEs were estimated as shown in Equations *3–5*, where i is the individual, j is the food family, h is the representative food, $GHGE_i$ is the diet-related GHGE of individual i (in g CO_2e), Q_{ij} is the quantity consumed of food family j by individual i, $GHGE_{ij}$ is the individual (i) GHGE of food family j (in g CO_2e/g), N_{ij} is the number of representative foods consumed by individual i in food family j, W_{ih}^{j} is the weighting factor associated with a representative food h in a food family j for individual i, $GHGE_h$ is the GHGE of representative food h (per gram), Q_{ih} is the quantity consumed of representative food h by individual i, N_j is the number of representative foods in food family j, W_h^j is the weighting factor associated with a representative food h in a food family j, and Q_{nh} is the quantity consumed of representative food h by individual n in the population.

For each individual and each food family, the total quantity consumed was calculated and multiplied by an estimated food family–related GHGE (expressed in g CO_2e/g). There were 2 possible cases in the estimation of food family–related GHGEs: they were calculated individually if the individual consumed at least one representative food in the food family [first case (Equation *4*)], or they were based on the consumption of the representative foods in the population [second case (Equation *5*)]. In the first case, the individual weighting factor associated with

TABLE 1
Simple and partial Pearson correlations between diet-related GHGEs (in g CO_2e/d) and the 3 indicators of nutritional quality (MAR, MER, and ED) in adults (n = 1918) participating in INCA2[1]

	MAR	MER	ED	GHGEs
MAR				
Univariate		0.43[2]	−0.15[2]	0.62[2]
Age and sex adjusted		0.42[2]	−0.20[2]	0.60[2]
Age, sex, and energy adjusted		−0.27[2]	−0.55[2]	0.27[2]
MER				
Univariate			0.45[2]	0.53[2]
Age and sex adjusted			0.35[2]	0.46[2]
Age, sex, and energy adjusted			0.24[2]	−0.14[2]
ED				
Univariate				0.04
Age and sex adjusted				−0.06[3]
Age, sex, and energy adjusted				−0.33[2]

[1] Means (95% CIs): MAR: 82 (82, 83) %; MER: 35 (33, 37) %; ED: 167 (165, 168) kcal/100 g; GHGEs: 4092 (4029, 4155) g CO_2e/d. MAR (% adequacy/d) was defined as the mean daily percentage recommended intakes for 20 essential nutrients; MER (% excess/d) was defined as the mean daily percentage of maximum recommended values for nutrients for which the intake should be limited; ED (kcal/100 g) was calculated according to Ledikwe et al (41) as the ratio between total energy intake and the intake of food only (ie, excluding beverages). CO_2e, carbon dioxide equivalent; ED, energy density; GHGEs, greenhouse gas emissions; INCA2, Individual and National Survey on Food Consumption; MAR, mean adequacy ratio; MER, mean excess ratio.

[2] $P < 0.0001$.

[3] $P = 0.0147$.

$$GHGE_i = \sum_{j=1}^{37} Q_{ij} \times GHGE_{ij} \tag{3}$$

with

$$GHGE_{ij} = \begin{cases} \sum_{h=1}^{N_{ij}} W_{ih}^{j} \times GHGE_h \quad with \quad W_{ih}^{j} = \frac{Q_{ih}}{\sum_{h=1}^{N_{ij}} Q_{ih}} & \text{if } N_{ij} \geq 1 \quad (4) \\ \sum_{h=1}^{N_j} W_{h}^{j} \times GHGE_h \quad with \quad W_{h}^{j} = \frac{\sum_{n=1}^{1918} Q_{nh}}{\sum_{h=1}^{N_j}\sum_{n=1}^{1918} Q_{nh}} \times GHGE_h & \text{if } N_{ij} = 0 \quad (5) \end{cases}$$

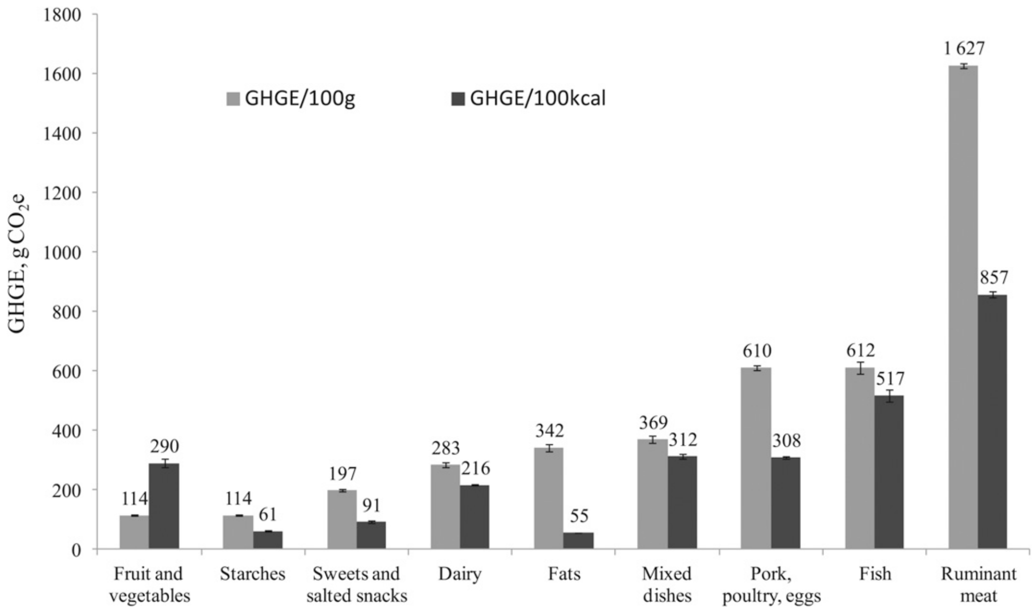

FIGURE 1. Mean GHGEs related to the consumption, of 100 g (gray bars) or of 100 kcal (black bars), of each food group by adults (n = 1918) participating in INCA2. Vertical lines represent 95% CIs. CO_2e, carbon dioxide equivalent; GHGEs, greenhouse gas emissions; INCA2, Individual and National Survey on Food Consumption.

each representative food consumed in a given food family (W_{ih}^{j}) was estimated as the ratio of the individual consumption of the representative food to the individual consumption of all representative foods within a food family. In the second case, the weighting factor (W_{h}^{j}) associated with a given representative food was estimated based on the entire population by the ratio between total consumption of this food and total consumption of all the representative foods included in a food family. This weighting factor was thus the same for all the individuals consuming a food family without consuming a representative food in this food family. The actual quantity consumed by each individual of each food family (ie, Q_{ij} in the equation) was used to calculate diet-related GHGEs, which enabled us to estimate the GHGEs associated with total food intake.

Statistical analysis

The relations between diet-related GHGEs and other dietary variables (energy, weight, MAR, MER, ED, and food group intakes) were tested by using both simple and partial (adjustment for age, sex, and energy intakes) Pearson correlation coefficients. The average nutrient intakes, the food group intakes, and the

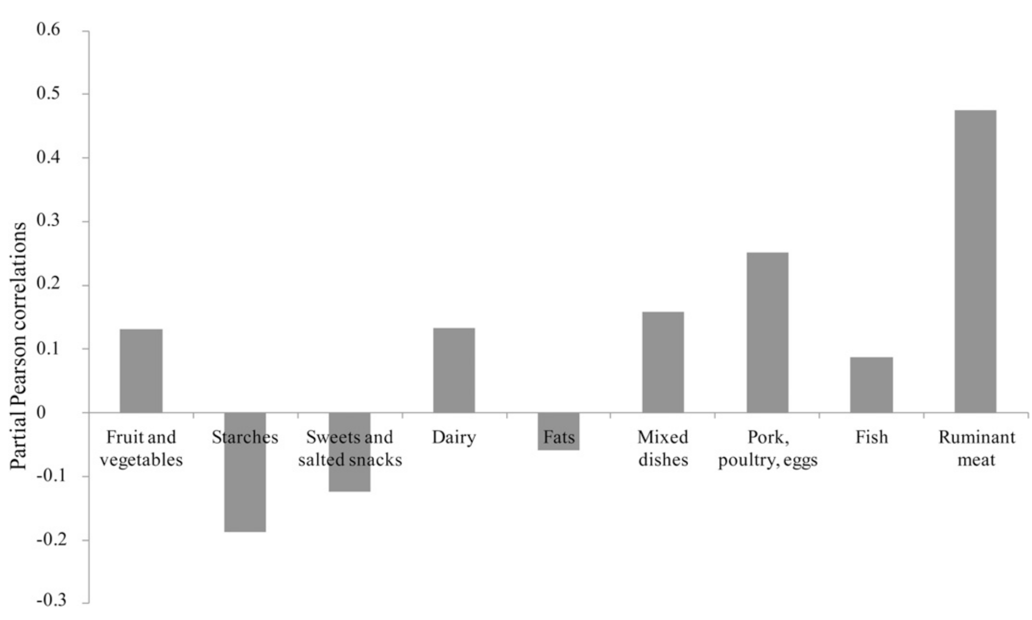

FIGURE 2. Partial (age-, sex-, and energy-adjusted) Pearson correlations between diet-related greenhouse gas emissions and the consumption of each food group by adults (n = 1918) participating in the Individual and National Survey on Food Consumption. All coefficients are significantly different from 0, $P < 0.001$.

TABLE 2
Classification of individuals participating in INCA2 in 4 classes of increasing nutritional quality class (High, I+, I−, and Low) and selected characteristics of their diets[1]

	Men				Women			
	High (n = 98)	I+ (n = 297)	I− (n = 275)	Low (n = 106)	High (n = 172)	I+ (n = 395)	I− (n = 386)	Low (n = 189)
Age (y)	58.4 ± 12.9	53.2 ± 16.9	45.7 ± 17.8	37.0 ± 13.9	49.7 ± 15.0	52.0 ± 13.8	40.0 ± 14.1	37.4 ± 12.9
Total energy intake (kcal/d)[2]	2365.7 ± 299.0	2384.3 ± 606.8	2674.6 ± 694.1	2494.8 ± 326.5	1757.6 ± 248.9	1742.1 ± 466.1	1979.6 ± 483.6	1924.2 ± 225.8
Total weight of diet (g/d)	3230.8 ± 724.4	2964.1 ± 885.1	2893.9 ± 857.1	2595.1 ± 624.8	2975.6 ± 706.0	2635.2 ± 718.7	2430.0 ± 723.3	2390.1 ± 640.8
Solid weight (g/d)	1526.5 ± 292.1	1385.0 ± 391.3	1212.7 ± 336.3	1054.0 ± 195.2	1291.7 ± 222.3	1186.6 ± 326.9	1016.5 ± 262.6	895.9 ± 151.4
Weight of plant-based products (% solid weight)[3]	63.9 ± 10.6	57.3 ± 11.7	49.4 ± 12.4	39.2 ± 13.2	60.1 ± 9.7	58.9 ± 9.1	49.9 ± 9.7	45.2 ± 10.4
Energy from plant-based products (% of total energy)[3]	46.9 ± 11.5	40.3 ± 11.5	35.3 ± 13.0	27.2 ± 10.4	44.6 ± 10.0	42.8 ± 10.0	35.4 ± 8.6	31.0 ± 9.1
MAR (% adequacy/d)	90.7 ± 3.4	84.7 ± 9.8	84.2 ± 11.5	80.1 ± 5.6	87.6 ± 4.3	79.7 ± 11.6	79.5 ± 12.1	74.9 ± 6.4
MER (% excess/d)	22.5 ± 11.5	36.9 ± 32.6	58.5 ± 45.4	63.7 ± 24.7	8.7 ± 5.7	17.2 ± 16.9	32.2 ± 24.5	38.9 ± 24.9
ED (kcal/100 g)[4]	141.3 ± 22.8	154.6 ± 19.2	193.1 ± 22.6	209.6 ± 25.7	127.2 ± 18.6	138.4 ± 18.9	180.6 ± 20.9	195.8 ± 25.2

[1] All values are means ± SDs. A high-nutritional-quality diet was defined as compliance with 3 properties: MAR (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; MER (mean daily percentage of the maximum recommended values for nutrients for which the intake should be limited) below the median; and ED below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. For each sex separately, all P values of the linear regression analysis used to compare (crude) means between the 4 classes and all tests for linear trend are significant, $P < 0.0001$. ED, energy density; I, intermediate; INCA2, Individual and National Survey on Food Consumption; MAR, mean adequacy ratio; MER, mean excess ratio.

[2] Total energy intake, including energy from alcoholic drinks.

[3] Plant-based products included fruit, vegetables, fruit juices, refined starchy food, unrefined starchy food, plant-based mixed dishes, vegetable fats, and nuts.

[4] ED was calculated according to Ledikwe et al (41) as the ratio between total energy intake and the intake of food only (ie, excluding beverages).

TABLE 3
Nutrient intakes of adults participating in the INCA2 survey, according to the nutritional quality of their diets[1]

	Men						Women					
	High (n = 98)	I+ (n = 297)	I− (n = 275)	Low (n = 106)	P^2	T^3	High (n = 172)	I+ (n = 395)	I− (n = 386)	Low (n = 189)	P^2	T^3
Fat (% of energy)[4]	34.1 ± 5.5	35.8 ± 5.6	36.2 ± 5.9	38.5 ± 5.5	<0.0001	<0.0001	37.0 ± 5.2	38.3 ± 4.9	39.4 ± 5.1	39.1 ± 5.4	0.0019	0.0009
SFA (% of energy)	12.7 ± 2.9	14.4 ± 3.0	15.1 ± 3.3	16.9 ± 2.9	<0.0001	<0.0001	13.6 ± 2.6	15.1 ± 2.7	16.3 ± 2.6	16.8 ± 2.8	<0.0001	<0.0001
Cholesterol (mg/d)	351.9 ± 111.5	377.2 ± 128.7	411.9 ± 148.9	397.2 ± 107.1	0.0028	0.0012	282.4 ± 86.7	286.4 ± 107.3	320.4 ± 101.8	301.1 ± 66.1	0.0002	0.0014
Carbohydrates (% of energy)	43.0 ± 7.2	41.2 ± 8.0	41.9 ± 7.5	41.4 ± 7.9	0.2813	—	42.4 ± 5.7	42.3 ± 6.1	42.8 ± 5.9	43.8 ± 6.8	0.1347	
Free sugars (% of energy)[5]	6.7 ± 3.5	7.5 ± 4.5	9.8 ± 5.9	13.2 ± 6.9	<0.0001	<0.0001	8.2 ± 3.3	8.5 ± 3.8	11.1 ± 4.0	14.6 ± 7.3	<0.0001	<0.0001
Alcohol (g/d)	20.4 ± 22.7	21.2 ± 21.2	22.8 ± 24.3	16.3 ± 19.7	0.1146	—	5.6 ± 6.9	5.1 ± 8.2	6.1 ± 8.2	6.1 ± 9.1	0.4578	
Sodium (mg/d)	3328.8 ± 656.1	3381.0 ± 1160.3	3651.5 ± 1263.7	3206.4 ± 799.7	0.0009	0.7778	2447.3 ± 522.4	2452.6 ± 787.9	2636.5 ± 798.9	2573.4 ± 901.7	0.0062	0.0923
Proteins (g/d)	99.1 ± 15.8	97.6 ± 26.1	104.2 ± 30.0	96.7 ± 19.6	0.0165	0.9591	77.8 ± 13.3	72.5 ± 18.8	75.9 ± 18.7	70.6 ± 12.5	<0.0001	0.0011
Fiber (g/d)	23.0 ± 5.9	20.0 ± 7.8	18.5 ± 6.6	15.1 ± 4.1	<0.0001	<0.0001	19.0 ± 4.7	16.8 ± 5.7	15.2 ± 4.7	12.8 ± 3.1	<0.0001	<0.0001
Retinol equivalent (μg/d)	1536.4 ± 947.6	1440.2 ± 1146.7	1297.4 ± 1033.8	937.5 ± 569.3	<0.0001	<0.0001	1298.4 ± 730.0	1343.8 ± 880.2	1127.1 ± 786.5	898.4 ± 482.7	<0.0001	<0.0001
Thiamine (mg/d)	1.4 ± 0.3	1.3 ± 0.5	1.4 ± 0.5	1.3 ± 0.3	0.0198	0.0377	1.2 ± 0.4	1.1 ± 0.5	1.1 ± 0.4	1.0 ± 0.2	<0.0001	< 0.0001
Riboflavin (mg/d)	2.1 ± 0.5	2.0 ± 0.7	2.1 ± 0.7	1.9 ± 0.5	0.0111	0.0062	1.9 ± 0.4	1.7 ± 0.6	1.7 ± 0.5	1.5 ± 0.4	0.0003	<0.0001
Niacin (mg/d)	22.0 ± 5.1	21.2 ± 7.5	21.8 ± 7.6	19.7 ± 5.0	0.0047	0.0037	18.5 ± 7.9	16.5 ± 5.9	16.0 ± 4.9	14.5 ± 3.0	<0.0001	<0.0001
Vitamin B-6 (mg/d)	2.1 ± 0.5	2.0 ± 0.7	1.9 ± 0.6	1.7 ± 0.4	<0.0001	<0.0001	1.8 ± 0.5	1.6 ± 0.6	1.5 ± 0.5	1.3 ± 0.3	<0.0001	<0.0001
Folates (μg/d)	352.6 ± 81.1	319.2 ± 106.5	301.9 ± 104.1	242.7 ± 56.4	<0.0001	<0.0001	323.9 ± 73.8	281.2 ± 96.8	258.2 ± 81.2	206.1 ± 42.8	<0.0001	<0.0001
Vitamin B-12 (μg/d)	6.7 ± 4.6	6.6 ± 5.2	6.8 ± 4.9	5.6 ± 2.7	0.0170	0.0814	5.2 ± 4.2	5.4 ± 4.1	5.2 ± 3.4	4.3 ± 2.5	0.0080	0.0169
Ascorbic acid (mg/d)	119.4 ± 49.6	100.6 ± 56.6	84.4 ± 55.3	56.8 ± 27.2	<0.0001	<0.0001	124.5 ± 57.1	103.5 ± 48.1	84.7 ± 42.9	65.1 ± 30.3	<0.0001	<0.0001
Vitamin E (mg/d)	14.2 ± 7.3	11.9 ± 6.1	11.7 ± 5.4	10.5 ± 5.4	0.0037	0.0004	12.2 ± 4.0	11.0 ± 4.9	11.5 ± 5.2	9.5 ± 3.5	<0.0001	<0.0001
Vitamin D (μg/d)	3.2 ± 1.7	2.7 ± 2.5	2.8 ± 2.5	2.3 ± 1.3	0.0007	0.0003	2.7 ± 1.5	2.6 ± 3.5	2.5 ± 1.5	1.9 ± 0.9	<0.0001	<0.0001
Calcium (mg/d)	1033.9 ± 325.5	945.5 ± 338.9	1031.1 ± 439.1	916.5 ± 265.6	0.0021	0.0218	948.5 ± 203.1	850.5 ± 296.5	838.5 ± 285.7	770.1 ± 223.0	<0.0001	<0.0001
Potassium (mg/d)	3760.7 ± 654.7	3401.2 ± 922.3	3190.8 ± 835.1	2767.4 ± 479.8	<0.0001	<0.0001	3202.9 ± 638.6	2765.5 ± 742.5	2536.6 ± 626.4	2270.4 ± 384.1	<0.0001	<0.0001
Iron (mg/d)	14.9 ± 3.3	14.9 ± 5.5	15.3 ± 6.6	14.0 ± 4.4	0.2376	—	12.6 ± 4.0	11.2 ± 4.2	11.8 ± 3.8	10.4 ± 2.3	<0.0001	<0.0001
Magnesium (mg/d)	360.8 ± 89.2	321.2 ± 98.2	330.7 ± 106.6	284.7 ± 55.2	<0.0001	<0.0001	304.9 ± 130.7	260.6 ± 75.7	254.2 ± 69.4	233.3 ± 42.9	<0.0001	<0.0001
Zinc (mg/d)	12.0 ± 2.8	11.9 ± 3.3	13.2 ± 4.2	12.3 ± 3.1	0.0147	0.1821	9.4 ± 1.9	8.8 ± 2.6	9.4 ± 2.7	8.8 ± 1.8	0.0034	0.0534
Copper (mg/d)	1.7 ± 0.7	1.7 ± 0.9	1.6 ± 0.8	1.3 ± 0.3	<0.0001	<0.0001	1.5 ± 0.7	1.4 ± 0.7	1.3 ± 0.6	1.1 ± 0.2	<0.0001	<0.0001
Iodine (mg/d)	142.2 ± 40.2	130.9 ± 53.1	142.2 ± 55.9	126.8 ± 45.4	0.0183	0.0694	131.5 ± 40.9	119.9 ± 48.0	115.3 ± 41.4	98.7 ± 23.3	<0.0001	<0.0001
Selenium (μg/d)	64.1 ± 14.4	58.3 ± 19.4	59.9 ± 19.8	52.4 ± 13.9	<0.0001	<0.0001	54.2 ± 11.4	48.3 ± 15.5	46.8 ± 12.9	41.7 ± 9.7	<0.0001	<0.0001

[1] All values are means ± SDs. A high-nutritional-quality diet was defined as compliance with 3 properties: mean adequacy ratio (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; mean excess ratio (mean daily percentage of the maximum recommended values for nutrients for which the intake should be limited) below the median; and energy density below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. I, intermediate; INCA2, Individual and National Survey on Food Consumption.

[2] P values were derived from a linear regression analysis used to compare (crude) means between the 4 classes, for each sex separately.

[3] T values were derived from a test for linear trend (calculated only when the general P value was <0.05).

[4] The calculation of total energy and percentage energy intake included energy from alcohol.

[5] Defined as added sugars plus sugars naturally present in honey, syrups, and fruit juices (36).

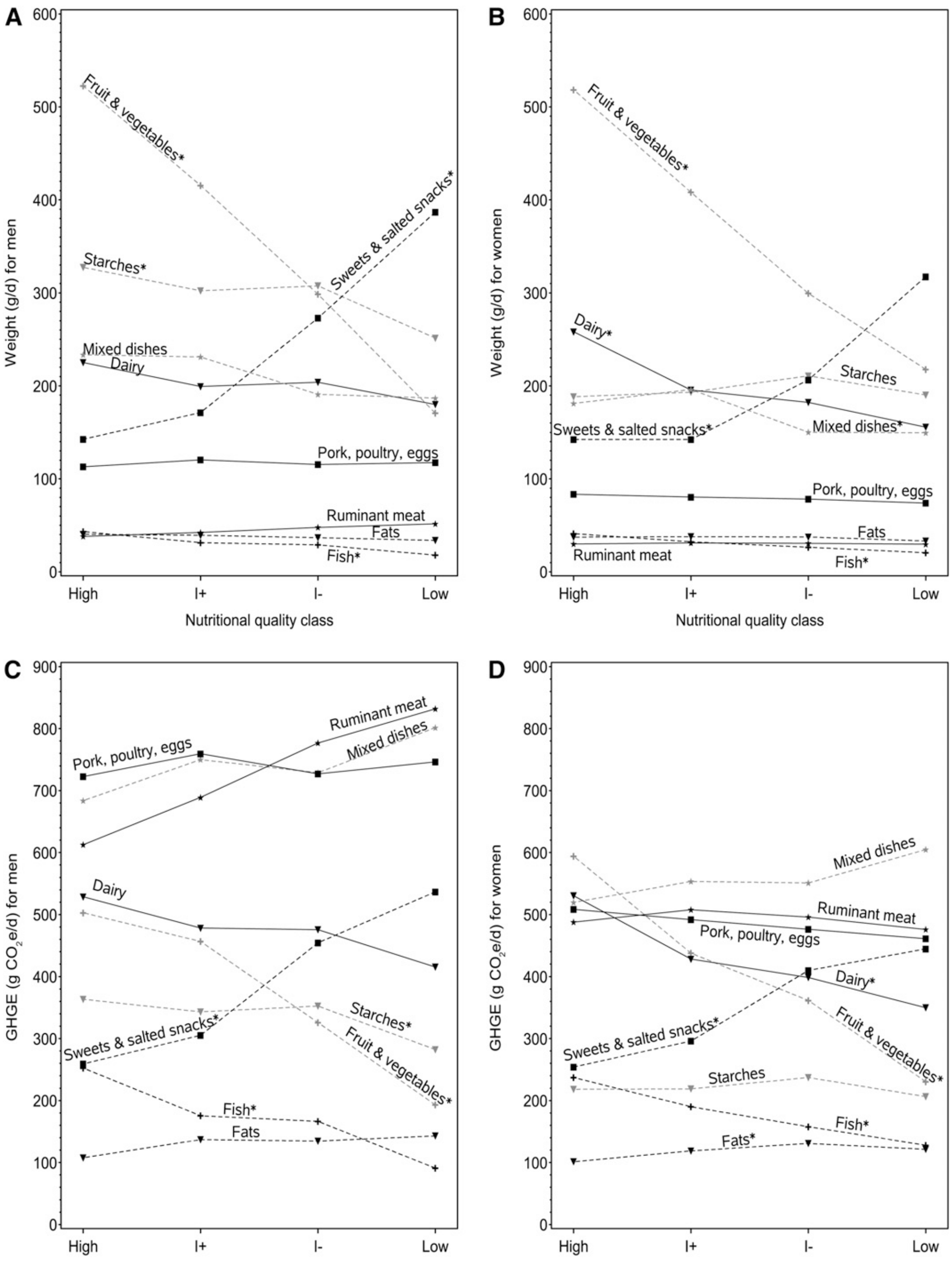

FIGURE 3. Weights and GHGEs of the food groups consumed by men (n = 776) and women (n = 1142) participating in the Individual and National Survey on Food Consumption, according to the nutritional quality of their diets. A: Weights of food groups consumed by men; B: weights of food groups consumed by women; C: GHGEs of food groups consumed by men; and D: GHGEs of food groups consumed by women. *Significant difference between nutritional-quality classes and a significant linear trend ($P < 0.01$). A high-nutritional-quality diet was defined as compliance with 3 properties: mean adequacy ratio (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; mean excess ratio (mean daily percentage of the maximum recommended values for nutrients for which the intake should be limited) below the median; and energy density below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. CO_2e, carbon dioxide equivalent; GHGE, greenhouse gas emission; I, intermediate.

diet-related GHGEs were estimated for the 4 sex-specific nutritional classes. Then, comparisons of means among the 4 classes and tests for linear trends were performed by using regression analysis for sample survey data for men and women separately. In additional analyses, diet-related GHGEs were adjusted for energy or total diet weight intakes with the SAS SURVEYREG procedure, which performs regression analysis for sample survey data, fits linear models, and computes regression coefficients. An α-level of 0.05 was used to determine statistical significance. Statistical analyses were performed by using SAS software version 9.2 (SAS Institute).

RESULTS

Representativeness of the foods selected for GHGE calculations

The consumption of the 391 representative foods accounted for, on average (±SD), 71 ± 15% of total food consumption and 66% ± 10% of total energy intake, and the level of coverage varied between food families (data not shown). However, our method of calculation allowed us to estimate the GHGEs associated with total food intake.

Correlation between diet-related GHGEs and nutritional-quality indicators

In simple regression analyses, MAR (R = 0.67, $P < 0.0001$), MER (R = 0.80, $P < 0.0001$), dietary ED (R = 0.34, $P < 0.0001$), and diet-related GHGEs (R = 0.75, $P < 0.0001$) were each positively and significantly correlated with energy intakes (data not shown). As expected, after age, sex, and energy adjustment, dietary MAR was negatively correlated with MER and ED; higher MER scores were associated with higher ED scores (**Table 1**). After age, sex, and energy adjustment, diet-related GHGEs were positively correlated with MAR and negatively with dietary MER and ED.

GHGEs of food groups and effect of their consumption on total diet-related GHGEs

The GHGEs related to the consumption of each food group are shown in **Figure 1**. Regardless of the basis of calculation (per 100 g or per 100 kcal food consumed), the highest GHGE value was recorded for the ruminant meat food group followed by the fish food group. The ranking of the other food groups varied depending on the calculation basis. In particular, the fruit and vegetables and the starches food groups had the lowest GHGEs on a weight basis: 114 g CO_2e/100 g each for fruit and vegetables (95% CI: 110, 117) and starches (95% CI: 113, 115). When expressed per 100 kcal, the GHGE of starches were still among the lowest, whereas that of fruit and vegetables (290 g CO_2e/d; 95% CI: 276, 304) increased in rank and was close to that of the mixed dishes (312 g CO_2e/d; 95% CI: 303, 320) and of the pork, poultry, eggs (308 g CO_2e/d; 95% CI: 303, 314) food groups and was higher than that of the dairy product food group (216 g CO_2e/d; 95% CI: 213, 218).

After adjustment for age, sex, and energy intake, a higher consumption of starches, sweets and salted snacks, and fats was associated with lower diet-related GHGEs (**Figure 2**). In contrast, an increased intake of the other food groups, including that of fruit and vegetables, increased diet-related GHGEs. The strongest positive association was seen for the ruminant meat group.

Food consumption, nutrient intakes, and GHGEs in the 4 classes of nutritional quality

The mean diet-related GHGE value was 4092 g CO_2e/d (95% CI: 4029, 4155; data not shown). Individuals in the high-nutritional-quality class were on average older than individuals in the low-nutritional-quality class. They had lower energy intakes and higher (total or solid) food intakes (**Table 2**). For both sexes, the contribution of all plant-based foods to total weight and energy intake increased significantly with increasing nutritional quality. By definition, high-nutritional-quality diets were those with the highest MAR, the lowest MER, and the lowest ED. Therefore, the daily intakes of fiber and of most vitamins and minerals increased with increasing nutritional-quality classes, whereas that of the harmful components—such as total fat, SFA, cholesterol and free sugars—generally decreased (**Table 3**).

For both sexes, high-nutritional-quality diets contained significantly more fruit and vegetables, more fish, and less sweets and salted snacks than did the low-quality diets (**Figure 3**). For men, high-nutritional-quality diets also contained more starches than did the low-quality diets, whereas for women they contained more dairy products (because of a significantly higher quantity of fresh dairy products; **Appendix A**). For both sexes, the quantities of the ruminant meat and of the pork, poultry, and eggs groups did not differ between nutritional-quality classes (Figure 3); but, within the pork, poultry, and eggs food group, high-nutritional-quality diets contained significantly less deli meat than did the low-nutritional-quality diets (Appendix A). For both sexes and all food groups, the patterns of the differences observed between the 4 nutritional classes for the food group–related GHGEs generally followed that of the daily amounts eaten in the corresponding food group. The only exceptions to this rule were observed in women's diets for mixed dishes and for fats: *1*) the total intake of mixed dishes increased with increasing nutritional quality but the GHGEs associated with their consumption did not differ (because of an increase in plant-based mixed dishes and a decrease in animal-based mixed dishes; **Appendix B**), and *2*) the total intake of fats did not differ between nutritional-quality classes, but their GHGEs decreased with increasing nutritional quality (because of an increased intake of vegetable fats and a decreased intake of animal fats; Appendix B).

The crude and adjusted values of daily diet-related GHGEs in the 4 classes of nutritional quality are shown in **Figure 4**. Without adjustment (panel A), daily diet-related GHGEs were not significantly different between the 4 classes for men (P = 0.0958) and were greater in the highest nutritional-quality class for women ($P < 0.0001$). After adjustment for total diet weight (panel B), diet-related GHGEs were not significantly different between nutritional-quality classes, for both sexes (P = 0.1796 for men and 0.0876 for women). In contrast, after adjustment for energy intakes (panel C), high-nutritional-quality diets were associated with higher GHGE values than were the low-nutritional-quality diets (+9% and +22% for men and women, respectively; $P < 0.0001$ for both sexes).

DISCUSSION

On the basis of food-consumption data from a representative sample of French adults and on the GHGEs of foods currently consumed in this population, the current study showed that, at a given level of energy intake, diet-related GHGEs tend to be positively associated with nutritional quality: *1*) the more nutrient-dense diets (high MAR) had a high level of GHGEs, whereas the diets with a high content of nutrients to be limited (high MER) and the more energy-dense diets (high ED) had a low level of GHGEs; *2*) the consumption of sweets and salted snacks was negatively associated with diet-related GHGEs, whereas the consumption of fruit and vegetables was positively associated with them; *3*) when diets were classified according to their overall nutritional quality, high-nutritional-quality diets tended

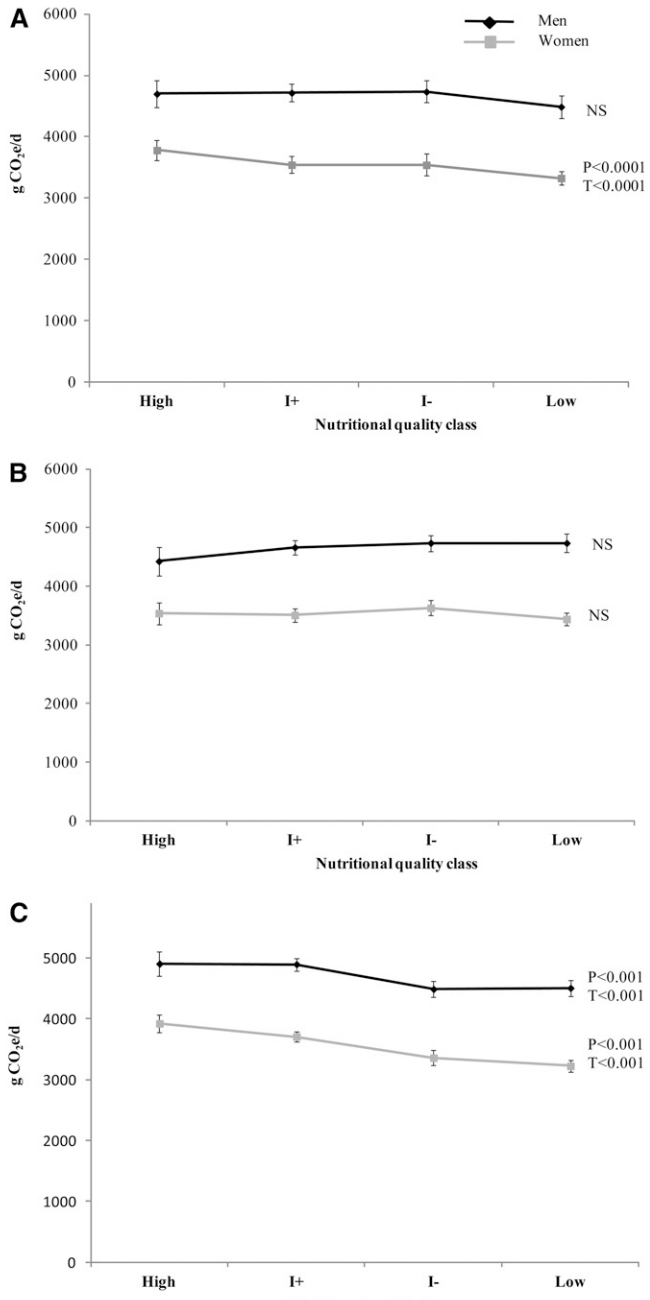

FIGURE 4. Mean greenhouse gas emissions associated with the diets of adults participating in the Individual and National Survey on Food Consumption (n = 1918), according to the nutritional quality of their diets. A: Crude values; B: values adjusted for total quantities consumed; and C: total energy intakes. Bars represent 95% CIs. A high-nutritional-quality diet was defined as compliance with 3 properties: mean adequacy ratio (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; mean excess ratio (mean daily percentage of the maximum recommended values for nutrients for which the intake should be limited) below the median; and energy density below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. CO_2e, carbon dioxide equivalent; I, intermediate; P, global P value; T, test for linear P-trend.

to a have high level of GHGEs, although they contained more plant-based products than did the low-nutritional-quality diets.

Compared with other international studies, our approach was original in 2 ways: *1*) we analyzed diets spontaneously consumed by individuals (we could therefore observe a wide and "natural" variety of realistic food choices), and *2*) nutritional quality was introduced into our analyses and was estimated by using nutrient-based indicators rather than preconceived views on the food composition of balanced diets. In contrast, previous studies on the environmental impact of food consumption were based either on stereotyped meals (18) and diets (6, 14, 17) or on a comparison between average and theoretical diets (15, 45–47). Moreover, most studies were focused on the share of animal compared with plant-based products (16). Only one of these (47) precisely controlled the nutrient content of designed theoretical diets, and the conclusion was that "it is possible to create a realistic and affordable diet that meets dietary requirements for health and a 25% reduction in GHGEs." However the "realism" of such a diet was doubtful because it was based on arbitrary decisions on the extent to which changes are culturally and socially acceptable by people, in particular as regards reducing the consumption of meat and dairy products. Other studies also found that vegetarian or vegan diets have a lower environmental impact than do omnivorous diets (6, 14, 18). However, little attention has been paid to the fact that quite radical changes in food consumption would be required to obtain only small differences on the environmental side. For instance, in the comparison between the observed average Finnish diet and various theoretical alternatives, only a fully vegan diet had lower GHGEs than the others (15). Likewise, only a small difference in GHGEs (5%) was found between the observed mean Swedish diet and a Mediterranean diet (45). Another study simulated the effect on GHGEs of reducing meat production but the emissions of the substituted foods were not included in the calculation (11). Recent work has shown that the effect on GHGEs depends very much on the substitutions made to limit environmental damage (48).

The current results (Figure 1) confirm that animal-based products (ruminant meat, fish, dairy products, and pork, poultry, and eggs) have higher GHGEs than do plant-based products (fruit and vegetables and starchy food) on a weight basis (8). We also showed that, among the food groups, ruminant meat, mixed dishes (because of animal-based mixed dishes), and pork, poultry, and eggs were the main contributors to diet-related GHGEs (Figure 3) and were the most strongly and positively associated with them (Figure 2). However, despite the large amounts of plant-based products, diets in the highest-nutritional-quality class were not those with the lowest GHGEs. At a given level of energy intake, they were in fact those with the highest GHGEs. In addition, consumption of the least healthy food group (ie, sweets and salted snacks) was actually associated with a large decrease in energy-adjusted GHGEs. The latter finding may be explained by the high ED and by the relatively low GHGEs of these foods (the latter being putatively associated with their ease of transport and storage and a low risk of wastage). Moreover, our indicator of good nutritional quality (ie, MAR) was positively associated with diet-related GHGEs, and our 2 indicators of low nutritional quality (ie, dietary MER and ED) were negatively associated with them.

Altogether, our results therefore seem to contradict the widely accepted view that diets that are good for health are also good for the planet. This notion has progressively emerged, based on the fact that plant-based products have a lower environmental impact than do animal products and on the belief that vegetarian diets are necessarily healthy. However, the current results show that, when expressed per calorie, fruit and vegetables may have GHGEs similar to those of animal products (excluding ruminant meat). In addition, the good health status of vegetarians is mostly related to their general "health-consciousness" (which leads them to adopt healthier behavior regarding smoking, physical exercise, and overall dietary balance), rather than to the fact that they avoid meat consumption (49). Obviously, not all vegetarian diets are healthy (50) and not all healthy diets are vegetarian. Current dietary guidelines (51–53), including the recently updated Mediterranean diet pyramid (54), actually recommend the consumption of moderate amounts of a variety of animal products. Increased consumption of starches may deserve a specific focus because this food group had one of the lowest GHGEs values, regardless of the calculation basis (in g or kcal), and was negatively correlated with diet-related GHGEs.

This study had limitations. First, diet-related GHGE estimations were based on a limited number of foods. However, those foods were the most frequently consumed in the study population so that their consumption represented ~75% of total food and energy intakes. In addition, our estimate of the daily GHGEs was of a magnitude similar to those given in studies of other European populations (5, 20), which suggests that our way of calculating diet-related GHGEs was able to overcome the limitation of not having GHGE data for all the food consumed by the population. Second, we used GHGEs as the sole indicator of environmental impact because only GHGE data were available for a large set of foodstuffs. In future studies, other criteria, such as water and land use or biodiversity, must also be considered. Third, the transport from retail to home was not taken into account in food GHGE estimates, and we hypothesized that all the foods consumed came from a retail center (therefore excluding food produced at home or consumed out of home). In addition, the food GHGE data used in the current study reflected the average food products as consumed on the French market, ie, mainly conventional. In future studies, the effect of alternative production, processing, and distribution schemes must also be considered.

The method used to classify diets according to their nutritional quality was not previously published. Our aim was to classify existing diets based only on their nutrient contents and, to our knowledge, at the time we conducted our study, there was no published method allowing such classification. Note that our method identified diets rich in fruit and vegetables with moderate amounts of a variety of animal products and limited amounts of sweets and salted snacks as being of the highest nutritional quality, which agrees with all existing dietary guidelines (51, 52).

In the current study, the healthiness of diets, whether reflected by a high intake of fruit and vegetables, a low intake of sweets and salted snacks, a high nutrient density, a low ED, or a more comprehensive definition of nutritional quality (eg, belonging to a high-nutritional-quality class) was associated with slightly but significantly higher GHGEs. In contrast, increasing the energy provided by sweets and salted snacks, fats, and starches decreased diet-related GHGEs. Unlike modeling studies, which have shown that it is theoretically possible to meet nutrient-based recommendations while achieving major GHGE reduction (47), the current observational study showed that environmental and nutritional objectives do not necessarily concur. However, the relatively high variability of diet-related GHGEs within the high-nutritional-quality class suggests that some individuals have diets with both high nutritional quality and low GHGEs. More research is therefore needed to evaluate the feasibility of adopting sustainable dietary patterns in everyday life.

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The authors' responsibilities were as follows—ND, L-GS, and FV: designed and conducted the research and wrote the manuscript; FV and DT: analyzed the data; and ND: had primary responsibility for the final content. All authors read and approved the final manuscript. No conflicts of interest were reported.

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APPENDIX A

Consumption in each food family in adults participating in INCA2 according to the nutritional quality of their diets[1]

Food group and food family	Men: High (n = 98)	Men: I+ (n = 297)	Men: I− (n = 275)	Men: Low (n = 106)	Men: P^2	Men: T^3	Women: High (n = 172)	Women: I+ (n = 395)	Women: I− (n = 386)	Women: Low (n = 189)	Women: P^2	Women: T^3
	g/d						*g/d*					
Fruit and vegetables												
Fruit	278.7 ± 208.8	203.8 ± 177.3	103.4 ± 108.7	48.5 ± 66.2	<0.001	<0.001	254.5 ± 153.8	203.1 ± 137.7	112.3 ± 92.4	78.9 ± 64.4	<0.001	<0.001
Vegetables	195.1 ± 110.6	156.8 ± 96.5	118.3 ± 73.1	73.5 ± 61.1	<0.001	<0.001	197.6 ± 92.3	155.7 ± 73.6	119.8 ± 62.4	82.9 ± 51.4	<0.001	<0.001
Fruit juices	47.8 ± 77.2	53.4 ± 98.7	75.5 ± 132.9	47.8 ± 72.2	0.01	0.43	64.9 ± 81.7	48.6 ± 62.7	66.6 ± 86.2	55.4 ± 76.4	0.0151	0.7246
Nuts	1.0 ± 2.3	1.5 ± 4.8	1.4 ± 4.9	1.0 ± 3.5	0.1957	0.8767	1.5 ± 4.8	0.8 ± 2.9	0.8 ± 3.2	0.5 ± 2.7	0.0338	0.0079
Starches												
Refined starches	208.7 ± 113.5	209.2 ± 114.4	227.5 ± 128.5	175.0 ± 102.6	<0.001	0.0888	110.4 ± 58.2	121.8 ± 64.6	139.9 ± 67.9	129.5 ± 63.7	<0.001	0.0003
Unrefined starches	118.7 ± 86.9	93.1 ± 75.2	80.0 ± 59.2	76.4 ± 57.0	<0.001	<0.001	77.9 ± 56.9	71.4 ± 52.3	70.9 ± 45.0	60.7 ± 41.4	0.222	0.0434
Dairy products												
Cheese	37.0 ± 29.4	40.4 ± 32.4	44.2 ± 39.9	38.0 ± 36.5	0.4089	0.6975	24.8 ± 16.9	24.8 ± 19.7	28.6 ± 22.8	28.0 ± 24.7	0.1482	0.149
Milk	82.9 ± 131.9	76.1 ± 141.2	109.4 ± 224.5	83.4 ± 150.4	0.3209	0.5763	101.8 ± 139.5	67.9 ± 101.6	88.0 ± 113.7	76.1 ± 120.2	0.1001	0.3491
Fresh dairy products	105.2 ± 123.5	82.8 ± 100.9	50.3 ± 71.7	58.6 ± 72.2	<0.001	<0.001	131.5 ± 87.3	103.0 ± 68.3	65.5 ± 60.8	51.5 ± 50.2	<0.001	<0.001
Fats												
Animal fats	8.2 ± 9.6	14.8 ± 15.9	15.5 ± 16.2	17.7 ± 18.5	<0.001	<0.001	10.0 ± 11.0	12.7 ± 10.2	15.0 ± 12.0	15.0 ± 12.7	0.0019	0.0011
Vegetable fats	32.2 ± 22.3	24.6 ± 19.7	21.2 ± 17.1	16.1 ± 14.2	<0.001	<0.001	27.4 ± 15.6	25.1 ± 14.7	22.6 ± 13.9	18.2 ± 12.1	<0.001	<0.001
Sweets and salted snacks												
Sweet drinks	29.0 ± 69.9	38.8 ± 105.3	105.4 ± 208.7	211.3 ± 333.0	<0.001	<0.001	24.0 ± 53.8	14.0 ± 47.8	50.8 ± 98.3	160.5 ± 324.3	<0.001	<0.001
Sweets	27.3 ± 26.6	30.2 ± 33.2	40.8 ± 42.6	44.6 ± 43.6	<0.001	<0.001	21.0 ± 19.1	24.6 ± 21.4	38.7 ± 30.4	42.4 ± 28.3	<0.001	<0.001
Salted snacks	2.4 ± 4.5	2.5 ± 5.3	4.6 ± 10.3	4.0 ± 9.6	0.0122	0.0247	1.7 ± 4.1	1.9 ± 4.4	3.5 ± 7.3	4.1 ± 8.0	0.0044	0.0067
Desserts	51.8 ± 50.6	59.0 ± 57.1	76.2 ± 71.9	84.9 ± 76.9	<0.001	<0.001	50.0 ± 41.3	60.1 ± 49.6	70.8 ± 59.9	75.0 ± 51.5	<0.001	<0.001
Sauces and spices	18.2 ± 25.0	23.6 ± 45.5	16.4 ± 35.2	12.9 ± 15.4	0.0033	0.0078	28.8 ± 66.7	25.8 ± 73.4	14.4 ± 18.7	11.9 ± 13.1	0.0075	0.0051
Pastries	14.0 ± 23.7	17.2 ± 30.9	29.4 ± 40.5	29.1 ± 32.6	<0.001	<0.001	16.8 ± 21.0	15.9 ± 22.7	28.3 ± 28.6	23.3 ± 23.9	<0.001	0.0003
Mixed dishes												
Vegetables and starch	152.8 ± 171.0	116.4 ± 145.8	49.7 ± 71.1	33.2 ± 48.3	<0.001	<0.001	118.2 ± 132.5	130.0 ± 127.9	50.9 ± 62.2	42.6 ± 50.9	<0.001	<0.001
Dairy products and starch	5.6 ± 15.8	6.4 ± 19.2	10.9 ± 23.5	11.9 ± 19.8	0.0046	0.0012	5.7 ± 14.0	6.9 ± 14.5	8.3 ± 14.9	10.3 ± 16.7	0.2095	0.0559
Starch, vegetables, and meat	25.8 ± 54.6	34.8 ± 63.6	48.6 ± 68.2	49.2 ± 70.4	<0.001	0.0013	19.7 ± 34.6	18.3 ± 33.3	29.0 ± 40.2	30.3 ± 38.7	<0.001	0.0027
Meat and starch	23.8 ± 35.1	44.2 ± 79.9	50.5 ± 69.1	60.4 ± 63.3	<0.001	<0.001	19.2 ± 27.1	17.8 ± 28.8	36.4 ± 53.0	37.3 ± 37.4	<0.001	<0.001
Meat and vegetables	8.5 ± 20.7	11.3 ± 27.1	4.8 ± 13.7	6.4 ± 17.9	0.0051	0.1767	6.9 ± 15.5	7.8 ± 19.5	3.7 ± 10.3	6.9 ± 17.2	0.0031	0.6103
Fish	8.6 ± 21.3	7.6 ± 20.1	9.6 ± 26.6	4.7 ± 14.7	0.0721	0.2485	6.1 ± 12.2	7.7 ± 15.4	9.1 ± 16.5	5.6 ± 12.6	0.0825	0.9755
Meat and dairy products	8.4 ± 17.2	10.3 ± 24.0	16.9 ± 31.2	21.0 ± 29.7	<0.001	<0.001	5.2 ± 12.6	7.6 ± 13.4	12.8 ± 18.2	16.4 ± 23.3	<0.001	<0.001
Fish												
Nonfatty fish	17.0 ± 19.7	14.4 ± 22.6	13.1 ± 21.9	5.8 ± 12.9	<0.001	<0.001	19.8 ± 20.4	17.5 ± 18.7	10.9 ± 13.0	9.1 ± 14.2	<0.001	<0.001
Fatty fish	17.8 ± 22.3	11.2 ± 17.0	10.0 ± 17.0	6.2 ± 16.0	<0.001	<0.001	14.1 ± 16.5	8.8 ± 14.2	9.3 ± 12.9	7.5 ± 11.1	0.0007	0.0003
Shellfish	8.5 ± 15.1	5.7 ± 15.3	6.0 ± 15.4	5.9 ± 20.7	0.4299	0.32	7.2 ± 16.1	6.0 ± 14.7	6.2 ± 14.0	3.9 ± 8.2	0.0312	0.0122
Ruminant meat												
Ruminant meat	38.1 ± 35.0	42.3 ± 37.5	47.9 ± 41.1	51.7 ± 44.2	0.0984	0.0142	30.0 ± 24.9	31.0 ± 22.6	30.7 ± 23.8	29.7 ± 24.2	0.9245	0.8696
Pork, poultry, and eggs												
Pork	31.4 ± 28.9	33.9 ± 32.6	29.1 ± 31.5	27.5 ± 33.0	0.1231	0.2934	20.7 ± 17.1	22.7 ± 19.2	20.1 ± 18.3	22.6 ± 20.9	0.2829	0.6638
Poultry, game	40.1 ± 42.2	38.3 ± 46.3	36.5 ± 40.4	37.6 ± 42.2	0.8683	0.6918	29.0 ± 31.1	26.1 ± 27.8	22.9 ± 25.1	21.6 ± 19.1	0.2781	0.1142
Eggs	16.6 ± 20.0	16.9 ± 17.9	16.6 ± 21.5	12.8 ± 17.2	0.345	0.2085	18.3 ± 17.4	15.1 ± 15.5	14.3 ± 17.1	9.7 ± 10.5	0.003	0.0008
Deli meat	24.8 ± 25.5	31.4 ± 34.0	33.4 ± 33.6	39.7 ± 33.6	0.0025	<0.001	15.5 ± 15.5	16.6 ± 16.1	20.8 ± 19.6	20.1 ± 18.0	0.0039	0.003

(Continued)

APPENDIX A (*Continued*)

	Men						Women					
Food group and food family	High (n = 98)	I+ (n = 297)	I− (n = 275)	Low (n = 106)	P^2	T^3	High (n = 172)	I+ (n = 395)	I− (n = 386)	Low (n = 189)	P^2	T^3
Drinks												
Alcohol drinks	242.2 ± 263.0	259.3 ± 276.7	282.5 ± 325.0	187.5 ± 243.1	0.0415	0.2188	60.5 ± 75.8	57.0 ± 90.8	66.7 ± 90.0	71.5 ± 119.4	0.4868	0.2656
Unsugared hot drinks	401.4 ± 359.6	379.7 ± 311.8	323.7 ± 286.2	317.7 ± 304.3	0.074	0.0578	490.7 ± 454.9	405.1 ± 294.1	368.4 ± 310.9	412.8 ± 372.3	0.102	0.1039
Light drinks	9.0 ± 50.7	8.7 ± 39.6	14.5 ± 88.1	34.2 ± 116.7	0.2103	0.1134	9.9 ± 33.0	5.4 ± 21.0	15.1 ± 56.9	22.0 ± 88.0	0.0132	0.0756
Mineral water	593.4 ± 758.9	432.7 ± 571.6	347.8 ± 531.8	395.3 ± 536.7	0.0067	0.0076	556.6 ± 494.6	466.7 ± 468.8	412.9 ± 459.0	394.8 ± 432.1	0.0181	0.0017
Tap water	298.6 ± 431.0	330.5 ± 520.9	422.5 ± 515.3	263.8 ± 376.5	0.0041	0.9403	375.6 ± 608.1	384.0 ± 478.7	345.0 ± 446.6	301.0 ± 385.5	0.4867	0.2994

[1] All values are means ± SDs. A high-nutritional-quality diet was defined as compliance with 3 properties: mean adequacy ratio (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; mean excess ratio (mean daily percentage of the maximum recommended values nutrients for which the intake should be limited) below the median; and energy density below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. I, intermediate; INCA2, Individual and National Survey on Food Consumption.

[2] P values were derived from a linear regression analysis used to compare (crude) means between the 4 classes, for each sex separately.

[3] T values were derived from a test for linear trend (calculated only when the general P value was <0.05).

APPENDIX B

GHGEs in each food family in adults participating in INCA2 according to the nutritional quality of their diets[1]

Food group and food family	Men: High (n = 98)	Men: I+ (n = 297)	Men: I− (n = 275)	Men: Low (n = 106)	Men: P^2	Men: T^3	Women: High (n = 172)	Women: I+ (n = 395)	Women: I− (n = 386)	Women: Low (n = 189)	Women: P^2	Women: T^3
	g CO_2e/d						*g CO_2e/d*					
Fruit and vegetables												
Fruit	237.6 ± 215.2	204.8 ± 282.2	96.9 ± 134.9	49.7 ± 90.7	<0.001	<0.001	288.3 ± 277.3	196.5 ± 226.2	136.4 ± 181.1	75.1 ± 87.9	<0.001	<0.001
Vegetables	220.1 ± 134.6	198.4 ± 148.2	159.6 ± 125.0	98.2 ± 96.9	<0.001	<0.001	246.2 ± 146.3	194.4 ± 102.2	164.2 ± 103.9	104.8 ± 68.4	<0.001	<0.001
Fruit juices	43.5 ± 71.0	50.6 ± 94.0	67.1 ± 115.5	43.6 ± 67.0	0.011	0.5096	57.2 ± 69.7	45.6 ± 59.7	59.5 ± 76.1	49.8 ± 69.8	0.0561	0.7465
Nuts	1.7 ± 4.1	2.8 ± 10.1	2.4 ± 8.2	1.6 ± 6.0	0.1646	0.7228	2.4 ± 7.9	1.2 ± 3.9	1.4 ± 6.0	0.8 ± 4.7	0.0206	0.0088
Starches												
Refined starches	249.8 ± 136.1	243.8 ± 139.5	268.5 ± 158.0	196.4 ± 119.5	<0.001	0.0171	130.2 ± 75.1	145.0 ± 82.0	162.9 ± 83.5	144.9 ± 75.3	0.001	0.0287
Unrefined starches	113.5 ± 104.1	99.3 ± 99.5	84.0 ± 80.8	85.9 ± 68.1	0.0519	0.0097	88.0 ± 70.3	73.8 ± 58.6	74.3 ± 55.4	61.4 ± 45.3	0.0294	0.0048
Dairy products												
Cheese	197.9 ± 169.5	210.3 ± 169.0	232.3 ± 204.4	191.8 ± 169.2	0.2901	0.9662	127.3 ± 89.3	129.6 ± 108.1	148.6 ± 120.4	147.1 ± 119.5	0.1583	0.0973
Milk	114.3 ± 174.8	100.9 ± 185.2	143.7 ± 295.7	109.7 ± 198.1	0.3236	0.724	134.4 ± 181.2	88.8 ± 132.4	117.6 ± 149.5	99.9 ± 157.7	0.0739	0.3443
Fresh dairy products	216.4 ± 255.4	167.0 ± 205.4	99.6 ± 141.6	113.8 ± 140.1	<0.001	<0.001	268.8 ± 179.0	209.7 ± 138.7	132.4 ± 122.8	102.9 ± 100.9	<0.001	<0.001
Fats												
Animal fats	50.3 ± 62.3	92.3 ± 105.7	94.7 ± 101.3	113.4 ± 131.8	<0.001	<0.001	52.7 ± 52.1	75.4 ± 63.4	90.3 ± 76.6	86.8 ± 72.1	<0.001	<0.001
Vegetable fats	57.4 ± 41.1	44.7 ± 42.1	39.9 ± 37.4	29.6 ± 29.3	<0.001	<0.001	48.6 ± 33.3	43.4 ± 28.3	40.6 ± 27.6	34.6 ± 25.6	0.0016	0.0001
Sweets and salted snacks												
Sweet drinks	14.4 ± 34.9	19.5 ± 50.8	55.6 ± 109.1	113.1 ± 181.0	<0.001	<0.001	12.6 ± 30.0	7.7 ± 26.7	27.2 ± 48.1	77.1 ± 148.0	<0.001	<0.001
Sweets	47.7 ± 60.9	44.8 ± 57.5	72.8 ± 98.0	75.5 ± 87.9	<0.001	<0.001	36.8 ± 39.6	43.2 ± 45.2	72.2 ± 73.0	70.3 ± 54.1	<0.001	<0.001
Salted snacks	6.4 ± 12.4	6.5 ± 14.3	11.6 ± 24.4	9.7 ± 22.5	0.0251	0.05	4.7 ± 10.9	5.3 ± 11.9	8.7 ± 17.6	10.1 ± 18.1	0.0093	0.0067
Desserts	131.2 ± 124.8	159.7 ± 168.8	212.2 ± 207.2	236.3 ± 226.2	<0.001	<0.001	123.0 ± 107.1	156.9 ± 136.5	199.2 ± 169.2	205.8 ± 152.8	<0.001	<0.001
Sauces and spices	23.2 ± 36.3	30.1 ± 59.1	22.9 ± 31.8	23.9 ± 29.9	0.2739	0.7003	32.6 ± 66.0	41.0 ± 159.6	25.7 ± 47.7	19.1 ± 21.7	0.049	0.0277
Pastries	36.2 ± 60.0	44.6 ± 77.1	79.3 ± 109.6	78.2 ± 88.3	<0.001	<0.001	44.5 ± 56.1	41.9 ± 60.2	76.9 ± 79.2	62.4 ± 64.7	<0.001	<0.001
Mixed dishes												
Vegetables and starch	267.5 ± 297.5	202.4 ± 252.5	87.0 ± 123.2	58.9 ± 86.8	<0.001	<0.001	202.7 ± 230.4	223.5 ± 221.7	90.1 ± 110.2	74.3 ± 89.0	<0.001	<0.001
Dairy products and starch	20.4 ± 57.5	23.2 ± 65.7	39.3 ± 84.9	43.9 ± 72.0	0.0024	<0.001	20.3 ± 50.9	24.8 ± 53.0	31.0 ± 55.8	43.1 ± 78.0	0.1138	0.0341
Starch, vegetables, and meat	95.5 ± 206.2	124.0 ± 247.7	174.1 ± 253.5	163.6 ± 246.2	0.0043	0.0057	67.4 ± 122.7	62.0 ± 113.2	99.3 ± 142.3	103.2 ± 145.7	<0.001	0.0045
Meat and starch	108.0 ± 188.7	166.2 ± 281.7	223.7 ± 354.9	316.7 ± 362.4	<0.001	<0.001	87.7 ± 134.7	68.2 ± 115.8	164.5 ± 195.3	180.3 ± 200.0	<0.001	<0.001
Meat and vegetables	97.9 ± 239.8	130.9 ± 314.0	55.6 ± 158.7	74.0 ± 207.0	0.005	0.1768	79.4 ± 179.3	90.8 ± 226.0	42.4 ± 119.6	79.7 ± 198.7	0.0031	0.6106
Fish	54.4 ± 148.6	48.7 ± 139.3	57.5 ± 170.6	29.1 ± 100.5	0.1459	0.25	36.0 ± 76.7	47.9 ± 103.4	54.1 ± 105.7	34.8 ± 83.8	0.1068	0.9398
Meat and dairy products	40.0 ± 87.5	54.5 ± 131.8	91.6 ± 194.7	115.4 ± 170.8	<0.001	<0.001	26.1 ± 63.9	36.3 ± 65.1	69.6 ± 108.7	89.5 ± 135.9	<0.001	<0.001
Fish												
Nonfatty fish	112.8 ± 164.9	81.4 ± 139.5	76.3 ± 139.1	28.7 ± 63.0	<0.0001	<0.0001	113.1 ± 129.2	101.7 ± 116.5	63.4 ± 79.6	52.7 ± 87.4	<0.001	<0.001
Fatty fish	69.2 ± 98.7	47.0 ± 79.4	37.6 ± 69.8	27.9 ± 77.2	0.0017	<0.001	64.5 ± 81.3	39.3 ± 66.0	42.8 ± 61.5	33.4 ± 52.3	<0.001	<0.001
Shellfish	70.5 ± 133.7	47.1 ± 101.6	52.5 ± 120.0	34.4 ± 73.6	0.0446	0.0185	59.6 ± 97.1	49.1 ± 99.1	51.6 ± 97.7	42.0 ± 97.0	0.5637	0.1909
Ruminant meat												
Ruminant meat	612.6 ± 561.3	689.0 ± 613.0	776.8 ± 666.0	831.9 ± 703.4	0.0898	0.0117	487.8 ± 402.8	507.8 ± 373.6	496.0 ± 383.7	475.9 ± 386.2	0.8311	0.7266
Pork, poultry, and eggs												
Pork	179.4 ± 170.6	192.2 ± 188.3	166.3 ± 182.8	156.7 ± 193.1	0.1828	0.3055	114.2 ± 94.3	126.3 ± 110.8	111.6 ± 102.8	127.3 ± 120.9	0.2284	0.5546
Poultry and game	337.1 ± 371.8	327.2 ± 410.1	304.8 ± 347.4	322.4 ± 371.6	0.8048	0.734	240.0 ± 273.6	218.1 ± 246.2	191.7 ± 220.2	181.1 ± 162.6	0.3311	0.131
Eggs	60.8 ± 73.3	61.8 ± 65.6	60.8 ± 78.8	47.0 ± 63.0	0.346	0.2089	66.9 ± 63.9	55.2 ± 56.9	52.4 ± 62.6	35.7 ± 38.5	0.003	<0.001
Deli meat	145.5 ± 151.6	178.0 ± 200.8	195.0 ± 196.4	220.2 ± 181.6	0.0132	0.0016	87.2 ± 89.1	92.3 ± 88.2	120.6 ± 116.5	117.1 ± 107.5	0.0018	0.0014

(Continued)

APPENDIX B (*Continued*)

Food group and food family	Men: High (n = 98)	Men: I+ (n = 297)	Men: I− (n = 275)	Men: Low (n = 106)	P^2	T^3	Women: High (n = 172)	Women: I+ (n = 395)	Women: I− (n = 386)	Women: Low (n = 189)	P^2	T^3
Drinks												
Alcohol drinks	399.3 ± 438.9	430.0 ± 448.1	430.0 ± 489.2	282.1 ± 373.0	0.0067	0.0527	111.4 ± 144.2	96.4 ± 158.9	112.5 ± 157.3	115.7 ± 178.5	0.506	0.6497
Unsugared hot drinks	87.2 ± 267.3	61.8 ± 378.1	54.7 ± 129.3	37.7 ± 32.9	0.1564	0.1737	50.6 ± 56.9	64.0 ± 198.5	82.9 ± 440.1	64.0 ± 118.3	0.5479	0.3311
Light drinks	2.7 ± 15.2	2.6 ± 11.9	4.4 ± 26.4	10.3 ± 35.0	0.2099	0.1135	3.0 ± 9.9	1.6 ± 6.3	4.5 ± 17.1	6.6 ± 26.4	0.0133	0.0757
Mineral water	178.0 ± 227.7	129.8 ± 171.5	104.3 ± 159.5	118.6 ± 161.0	0.0066	0.0076	167.0 ± 148.4	140.0 ± 140.6	123.9 ± 137.7	118.5 ± 129.6	0.0183	0.0017
Tap water	0.1 ± 0.2	0.2 ± 0.3	0.2 ± 0.3	0.1 ± 0.2	0.0041	0.9403	0.2 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	0.2 ± 0.2	0.4865	0.2995

[1] All values are means ± SDs. A high-nutritional-quality diet was defined as compliance with 3 properties: mean adequacy ratio (mean daily percentage of recommended intakes for 20 essential nutrients) above the median; mean excess ratio (mean daily percentage of the maximum recommended values for nutrients for which the intake should be limited) below the median; and energy density below the median. Diets complying with 2, 1, or 0 properties were allocated to nutritional-quality categories of I+, I−, and Low, respectively. CO_2e, carbon dioxide equivalent; GHGEs, greenhouse gas emissions; I, intermediate; INCA2, Individual and National Survey on Food Consumption.

[2] *P* values were derived from a linear regression analysis used to compare (crude) means between the 4 classes, for each sex separately.

[3] *T* values were derived from a test for linear trend (calculated only when the general *P* value was <0.05).