Dietary intakes and diet quality according to levels of organic food consumption by French adults: cross-sectional findings from the NutriNet-Santé Cohort Study

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Abstract

Objective: We aimed to assess dietary profiles of adults from the NutriNet-Santé cohort according to different levels of organic food consumption using detailed self-reported data on organic food intakes.
Design: Food intakes were obtained using an organic food frequency questionnaire (Org-FFQ). The participants were ranked into five groups (quintiles, Q) according to the proportion of organic foods in their diet. To determine diet quality, two scores were computed reflecting adherence to food-based recommendations (mPNNS-GS) and the probability of adequate nutrient intake (PANDiet). Relationships between levels of organic food consumption and dietary characteristics were assessed using multivariable-adjusted ANCOVA models.
Setting: The NutriNet-Santé Study.
Subjects: French adults from the NutriNet-Santé Study (*n* 28 245).
Results: Intakes of foods of plant origin increased along with the contribution of organic foods to the diet while a reverse trend was identified for dairy products, cookies and soda (*P*-trend < 0·0001). The diet quality scores increased from Q1 (mPNNS-GS, 7·89 (SE 0·02); PANDiet: 63·04 (SE 0·11)) to Q5 (mPNNS-GS, 8·78 (SE 0·02); PANDiet, 69·37 (SE 0·10)). Overall, high organic food consumers exhibited better diet quality, although intermediate organic food consumers showed better adherence to specific nutritional recommendations related to animal products.
Conclusions: The study provides new insights into the understanding of organic food consumption as a part of a healthy diet and sheds some light on the dietary profiles of different categories of organic food consumers. These results underline strong dietary behaviour correlates associated with organic food consumption that should be controlled for in future aetiological studies on organic foods and health.

One of the key challenges of the current food systems is both to meet the nutritional requirements of a growing population and to adopt sustainable production practices[1]. In this context, organic agriculture, defined in 2015 by the International Federation of Organic Agriculture Movements as 'a production system that sustains the health of soils, ecosystems and people', is often seen as a spearhead for a transition towards more sustainable food production[2]. Notably, organic agriculture has been promoted by public policies in France since 1981 through an agriculture law that officially acknowledged the principles of organic agriculture and in Europe since 1991, through regulations establishing the legal framework for agricultural products and foodstuffs obtained organically.

In addition to this increased attention of governments, the expansion of demand for organic foods in France over the past decades[3,4] is also largely driven by consumers' beliefs of the health benefits of organic foods[5–9]. Consumers are becoming more and more demanding with regard to the quality and safety of foods, which they want to have high nutritional values and be pesticide free[10]. Organic foods are perceived as healthier because of the

absence of pesticide residues[11–14] and more nutritious based on growing evidence for some foodstuffs[12–16], while the studies on the direct health impacts of organic foods are scant and inconsistent[17–23].

As the organic industry continues to gain market share[3], it is therefore crucial from a public health point of view to describe and characterise organic food consumers. A detailed knowledge of organic food consumers' profiles and correlates is an important prerequisite to future aetiological studies on the health impact of organic foods.

Recent studies have described regular organic food consumers as exhibiting an overall healthier lifestyle than non-consumers, as well as having better food choice habits[24–30]. However, several of these studies have focused on specific population subgroups such as pregnant women[25,26], or were conducted on small samples[24,29]. Thus, comparisons of food habits between organic food consumers and non-consumers based on nutritional intakes of a large population sample of adults are sparse[28,30]. In addition, these studies often focused on few categories of organic food. It is essential to consider the intake of numerous food groups among a large sample of subjects in order to cover a wide range of dietary practices. In addition, for research investigating the impact of organic food consumption on health status, it is also crucial to discriminate dedicated organic food consumers from those whose intake is only occasional or accidental. Approaches focusing only on consumption frequency do not integrate the quantities of organic foods consumed, while potential health impacts of the type of production are likely to be dependent on the percentage of total foods consumed that is organic or conventional.

In this context, the aim of the present study was to assess dietary intakes and overall diet quality according to different levels of organic food consumption among a large sample of French adults using detailed self-reported data on organic food intake.

Materials and methods

Study population
Data were collected from the NutriNet-Santé Study, a large web-based prospective observational cohort of adult volunteers aged 18 years or older, launched in France in May 2009 with a scheduled follow-up of 10 years. The NutriNet-Santé Study has been described in detail elsewhere[31].

Data collection

Sociodemographic data
At baseline and at each year thereafter, participants filled out self-administered questionnaires using a dedicated website to collect data on sociodemographic and lifestyle characteristics, including sex, age, height, weight, smoking status, physical activity (as measured by the International Physical Activity Questionnaire[32]), educational level, household size, marital status, number of children living at home, place of residence and current practices of diet (vegan or vegetarian diets). The baseline questionnaires were pilot-tested and compared against traditional assessment methods[33,34]. Income per household unit was calculated using information about household income and composition using the official weighting system by the French National Institute of Statistics and Economics Studies (INSEE)[35].

Organic food frequency questionnaire (Org-FFQ)
Overall food consumption and the relative share of organic foods in the diet were assessed using a web-based, semi-quantitative, 264-item organic food frequency questionnaire (Org-FFQ) based on a previously validated FFQ[36]. The Org-FFQ has been described elsewhere[37]. Participants were asked to report their frequency of consumption over the past year for 264 food and beverage items divided into food group categories. For most food items, to estimate food intake, standard portion sizes were applied in the questionnaire and participants were asked to report their consumption frequency on the basis of how many times they ate the standard portion size proposed (typical household measurements such as teaspoon). For eight of the main food group categories (cheese and vegan cheese; pâté and vegan pâté; fish; meat; butter used on bread; potatoes; starchy foods; vegetables) which are not usually eaten in a predetermined portion size, the questionnaire included sets of coloured validated photographs[38]. Participants were asked to choose among three photographs showing different portion sizes. The frequency of consumption referred to usual consumption over the past year on an increasing scale including yearly, monthly, weekly or daily units and participants were asked to provide only one answer. To estimate the intake of each food item in grams, standard portion sizes or portion sizes corresponding to the photographs were multiplied by the reported frequencies. Nutrient intakes were estimated using a food composition table developed for the 264 food items of the Org-FFQ based on the *ad hoc* NutriNet-Santé composition table that originally includes more than 2100 foods[39]. As a unique food composition database has been used for nutrient calculations, possible differences for contents in organic *v.* conventional foods reported in literature have not been taken into account (e.g. differences in contents of antioxidant compounds or *n*-3 fatty acids[14–16]). For mixed dishes, standard recipes were applied.

To determine the proportion of the intake that was from organic origin, for each food item except for water and sweetener products that do not exist in organic form, participants were asked to estimate how often the item came from organic source through a 5-point ordinal scale ranging from 'never' to 'always'. In order to estimate the organic intake of each food item, a weight of 0, 0·25, 0·50, 0·75 and 1 was respectively applied to the following

frequency categories: 'never', 'rarely', half the time', 'often' and 'always'.

Assessment of diet quality

To analyse the level of compliance with the French nutritional recommendations, two *a priori* dietary scores were computed reflecting the dietary components of adherence to French nutritional guidelines: (i) the modified Programme National Nutrition Santé Guidelines Score (mPNNS-GS)[40]; and (ii) the probability of adequate nutrient intake (PANDiet)[41] (Fig. 1).

The PNNS-GS has been described elsewhere[40]. Briefly, the original score includes thirteen components: eight refer to food serving recommendations (fruit and vegetables; starchy foods; wholegrain foods; dairy products; meat, poultry, seafood and eggs; seafood; vegetable fat; non-alcoholic beverages), four refer to moderation in

consumption (added fat; salt; sweetened foods; alcohol) and one refers to physical activity. Points are deducted for overconsumption of salt and sweets. Points are also deducted from the total when energy intake exceeds the necessary energy level by more than 5 %. In the present study, we computed a modified version of the PNNS-GS (mPNNS-GS) which did not integrate the physical activity component. Additionally, the percentages of participants with adequate intakes for the twelve individual dietary components of the mPNNS-GS were provided.

The PANDiet has also been described elsewhere[41]. Briefly, the PANDiet is composed of adequacy probabilities for nutrients grouped into two sub-scores (an adequacy sub-score and a moderation sub-score) using French national nutritional recommendations. In the present study, the following nutrients were selected for computation of the PANDiet: protein, total carbohydrate, total fat, added simple carbohydrates, SFA, PUFA, *n*-3 fatty
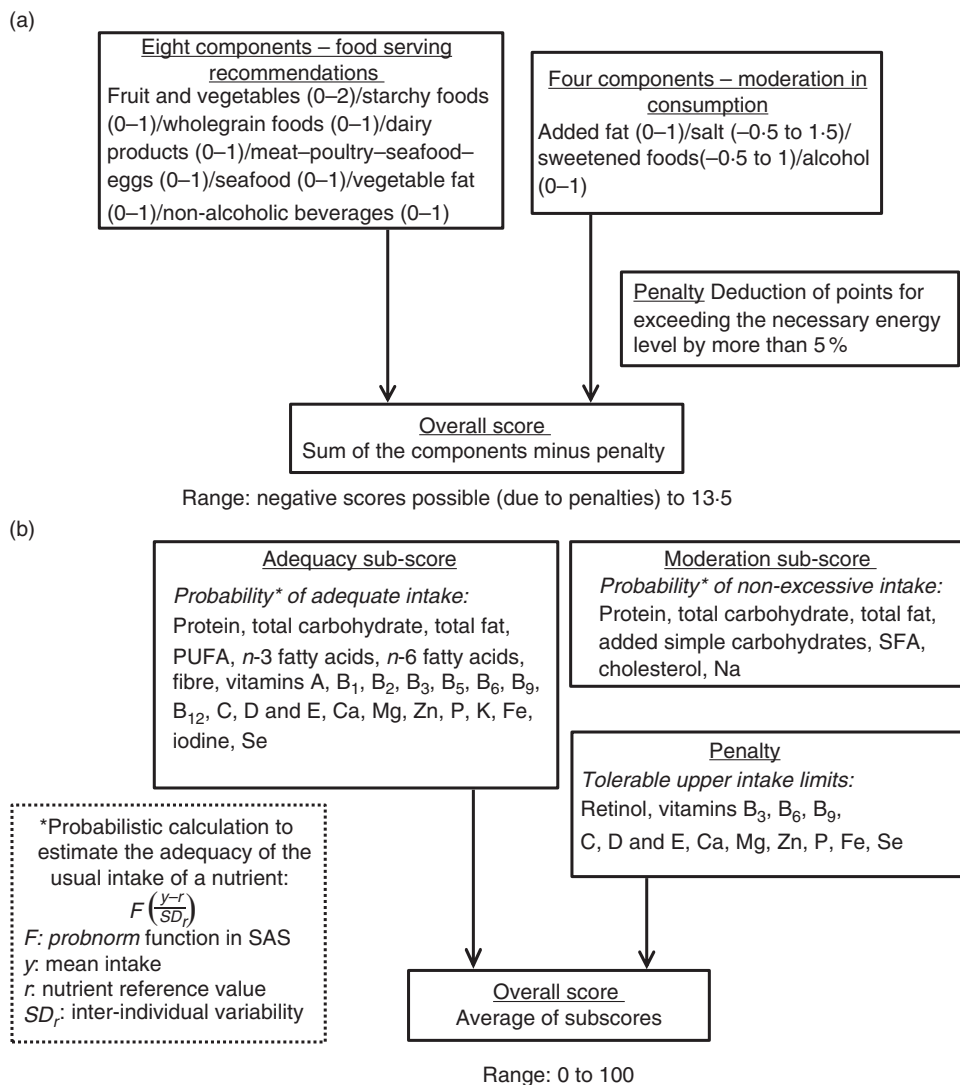

Fig. 1 Computation of diet quality scores: (a) modified Programme National Nutrition Santé Guidelines Score (mPNNS-GS), reflecting adherence to the French nutritional guidelines[40]; (b) PANDiet, reflecting the probability of adequate nutrient intake[41]

acids, *n*-6 fatty acids, cholesterol, fibre, vitamins A, B$_1$ (thiamin), B$_2$ (riboflavin), B$_3$ (niacin), B$_5$ (pantothenic acid), B$_6$, B$_9$ (folic acid), B$_{12}$, C, D and E, Ca, Mg, Zn, P, K, Fe, iodine, Se and Na.

Statistical analysis

The Org-FFQ was administered from June to October 2014. Among the 33 384 participants who had completed the questionnaire, we excluded those who were under-reporting or over-reporting (*n* 2097), who had missing socio-demographic or socio-economic data (*n* 2320) and who resided in overseas territories (*n* 722), therefore leaving 28 245 participants (20 980 women and 7265 men).

For each sex, a weighting was calculated according to the 2009 national census on age, occupational categories, area of residence, whether or not the household included at least one child (<18 years), marital status and educational level, using the iterative proportional fitting procedure, in order to adjust the percentage of individuals in each stratum to the actual percentage in the French population[42]. To identify under-reporting or over-reporting participants, we estimated BMR by the Schofield equations[43] according to sex, age, weight and height collected at enrolment in the study. Energy requirement, accounting for physical activity level and BMR, was compared with energy intake. The ratio of energy intake to energy requirement was calculated and individuals with ratios below or above cut-offs (0·35 and 1·93) were excluded.

The level of organic food consumption, defined as the proportion of organic foods in the overall diet, was computed by dividing the total organic food intake (g/d) by the total food intake excluding water (g/d). Then, weighted quintiles (Q) of the contribution of organic foods to the diet were estimated and the participants were classified according to the level of organic foods in their diet. Quintiles allowed defining no, occasional, medium, high and very high levels of organic food consumption. Daily consumption of thirty-four food groups and forty-two nutrients was calculated.

We compared the characteristics of respondents to the Org-FFQ and non-respondents using the χ^2 test and Student's *t* test. Overall, participants who completed the Org-FFQ (before weighting) were significantly older (53·20 (sd 14·07) *v.* 44·62 (sd 14·20) years) and more often men (79 *v.* 74 %) than those who did not complete the questionnaire (data not shown).

Descriptive characteristics of the sample are presented as means and standard deviations or as numbers and percentages, as appropriate, across quintiles. *P* values refer to the linear contrast test for continuous variables or the trend χ^2 test for categorical variables.

ANCOVA models were performed to identify the associations between dietary intakes, diet quality (mPNNS-GS and PANDiet) and level of organic food intake in the overall diet. Models were adjusted for sex, age and energy intake. Nutrient data were adjusted for total energy intake using the residual method. Data are presented as means with their standard errors for continuous variables. We used Bonferroni correction to adjust for multiple testing. We analysed trends across the five groups and report the *P* values from the linear contrast. The contributions of organic foods to each food group (ratios with their standard errors) are also provided and were adjusted for age and sex. For categorical variables, the *P* value refers to trend χ^2 tests.

In a supplementary analysis, we estimated the associations between the nutritional quality of the diet (reflected by the mPNNS-GS) and organic food consumption (using the proportion of organic foods in the diet as a continuous variable) stratified for several sociodemographic and lifestyle factors. The mPNNS-GS was used as the dependent variable and models were adjusted for sociodemographic and lifestyle variables. Parameter estimates and 95 % confidence intervals are provided.

Two-sided tests and *P* < 0·05 were used for statistical significance. Data management and statistical analyses were performed using the statistical software package SAS version 9.3.

Results

Individual characteristics

Before weighting, 74 % of the study sample was female, 63 % had post-secondary education and the mean age was 53 (sd 14) years.

Table 1 presents participant characteristics across quintiles of organic food consumption. Participants in Q1 consumed no or very little organic foods, while in Q5 organic foods made up, on average, 72 % of the diet. Q1 showed the highest proportion of males, while the proportion of young adults (18–25 years) was the highest in Q4 and Q5. A higher level of organic consumption was linked to a lower proportion of individuals with no high-school diploma and of current smokers. The highest proportion of individuals with a high household income was found in Q3 and the lowest was found in Q1. The highest percentage of individuals living in a population-dense urban unit (>200 000 inhabitants) was found in Q1, while the highest percentage living in a rural community was found in Q4. Individuals in Q5 were more often highly physically active than individuals in the other quintiles. Finally, a higher level of organic food consumption was linked to a higher proportion of vegetarians or vegans.

Food intakes and relative shares of organic foods by level of organic food consumption

Table 2 provides mean daily intakes of food groups across quintiles of organic food consumption. The intakes of plant-based foods including vegetables, soups, nuts, wholegrain

Table 1 Sociodemographic and lifestyle characteristics according to the level of organic food consumption by French adults (weighted sample), NutriNet-Santé Study, 2014 (n 28 245)*,†

	Q1 (0·00–0·01)		Q2 (0·01–0·09)		Q3 (0·09–0·25)		Q4 (0·25–0·49)		Q5 (0·49–1·00)		P-trend‡
n and %	3484	12·3	5099	18·1	6654	23·6	6244	22·1	6764	23·9	
Weighted n and %	5553·7	19·7	5742·8	20·3	5627·6	19·9	5670·7	20·1	5650·1	20·0	
Proportion of organic food consumption in the diet§	0·00	0·00	0·04	0·03	0·17	0·04	0·36	0·06	0·72	0·15	<0·0001
Sex											<0·0001
Female	41·56		53·34		55·56		55·16		55·97		
Male	58·44		46·66		44·44		44·84		44·03		
Age											<0·0001
18–25 years	7·52		8·02		8·04		17·01		15·61		
25–40 years	24·13		26·48		29·37		19·60		24·98		
40–55 years	34·38		29·33		24·38		24·25		19·98		
55–65 years	12·87		16·18		15·81		16·66		17·58		
≥65 years	21·10		19·99		22·40		22·48		21·85		
Educational level											<0·0001
<High-school diploma	70·98		63·09		56·10		55·02		53·72		
High-school diploma	13·81		16·12		14·91		14·59		17·30		
Post-secondary graduate	15·21		20·79		28·99		30·39		28·98		
Monthly income per household unit											<0·0001
Refuse to declare	15·71		13·29		12·27		14·42		16·36		
900–1200€	33·43		26·43		19·92		20·11		21·67		
1200–1800€	26·51		26·37		24·97		25·60		20·91		
1800–2700€	16·98		21·65		26·52		24·26		27·09		
>2700€	7·37		12·26		16·31		15·61		13·97		
Location											<0·0001
Rural community	23·04		24·85		25·00		28·23		26·05		
Urban unit with a population of <20 000 inhabitants	14·89		15·03		18·20		12·90		15·09		
Urban unit with a population of 20 000–200 000 inhabitants	15·79		19·17		15·33		17·30		15·06		
Urban unit with a population of >200 000 inhabitants	46·28		40·95		41·47		41·57		43·80		
Physical activity‖											<0·0001
Missing	23·91		17·57		11·58		11·23		9·45		
Low	21·57		23·30		23·15		14·49		12·34		
Medium	27·24		27·66		35·69		37·22		30·81		
High	27·28		31·47		29·58		37·06		47·40		
Vegetarian or vegan diet (yes)	0·26		0·37		2·11		5·72		18·18		<0·0001
Tobacco status											<0·0001
Never smoker	46·80		46·82		44·44		46·49		52·31		
Former smoker	34·04		35·90		42·41		40·46		37·87		
Current smoker	19·16		17·28		13·15		13·05		9·82		

*Q, quintile.
†Values presented are numbers and percentages, means and standard deviations, or percentages, as appropriate.
‡Values based on linear contrast test or trend χ^2 test.
§Contribution of organic foods to the diet: ratios computed by dividing the total organic food intake (g/d) by the total food intake excluding water (g/d).
‖As some questions were optional, data are missing.

products and grains increased across quintiles, while an inverse trend was observed for meat, dairy products, cookies and soda. Dairy and meat substitutes were only marginally consumed by individuals in Q1 while individuals in the other quintiles (notably in Q5) consumed substantial quantities of these products. Individuals in Q4 showed the highest intakes of seafood and eggs while those in Q3 showed the highest intakes of fast foods and alcohol. No linear relationship was found between the intake of sweets and organic food consumption. Supplemental Table 1 (see online supplementary material) provides the relative share of organic foods across quintiles of organic food consumption in the overall diet. The proportion of eggs and poultry that came from organic sources was relatively high even among individuals in Q2 and Q3. Supplemental Table 2 provides

detailed information on nutrient intakes across quintiles. Overall, individuals in Q5 showed higher intakes of proteins and lipids of plant origin and of most minerals and vitamins.

Diet quality by level of organic food consumption

Table 3 shows mean values of the two diet quality scores that reflect adequacy to French food-based and nutrient-based dietary recommendations across quintiles of organic food consumption. Both diet quality scores increased gradually across quintiles. Considering individual food-based recommendations (Table 4), the percentage of individuals meeting the guidelines on plant-based products (fruit and vegetables, bread, cereals, potatoes and legumes) and sweetened foods increased across quintiles while the

Table 2 Food group intakes by level of organic food consumption in the diet of French adults, NutriNet-Santé Study, 2014 (*n* 28 245)*

Food group (g/d)	Q1 (0·00–0·01) Total intake†		Q2 (0·01–0·09) Total intake†		Q3 (0·09–0·25) Total intake†		Q4 (0·25–0·49) Total intake†		Q5 (0·49–1·00) Total intake†		*P*-trend‡
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Vegetables	222·7	2·6	223·5	2·6	229·9	2·6	249·5	2·5	359·5	2·5	<0·0001
Soups	57·4	1·3	57·5	1·3	59·2	1·3	72·9	1·3	83·8	1·3	<0·0001
Fruit	244·0	3·9	274·3	3·9	212·8	3·9	251·4	3·8	330·2	3·8	<0·0001
Fruit juice	81·2	1·6	78·8	1·6	83·5	1·6	94·3	1·5	96·3	1·5	<0·0001
Nuts	1·2	0·1	1·6	0·1	2·1	0·1	3·2	0·1	5·7	0·1	<0·0001
Legumes	14·6	0·6	14·2	0·5	17·1	0·6	20·3	0·5	45·9	0·5	<0·0001
Seafood	32·0	0·6	41·0	0·6	40·4	0·6	45·1	0·6	36·3	0·6	<0·0001
Meat	98·1	1·0	64·8	1·0	69·0	1·0	56·6	1·0	37·7	1·0	<0·0001
Processed meat	37·0	0·4	34·6	0·4	35·3	0·4	32·4	0·4	20·4	0·4	<0·0001
Poultry	25·6	0·4	27·8	0·4	27·0	0·4	25·7	0·4	15·3	0·4	<0·0001
Eggs	11·1	0·3	12·9	0·3	11·6	0·3	18·5	0·3	10·5	0·3	0·0027
Milk	76·3	1·9	68·1	1·9	60·6	1·9	59·5	1·9	41·3	1·9	<0·0001
Dairy products	158·2	1·9	158·2	1·8	148·6	1·9	146·1	1·8	88·2	1·8	<0·0001
Cheese	34·8	0·6	41·9	0·6	38·9	0·6	36·3	0·6	30·7	0·6	<0·0001
Milky desserts	14·4	1·9	14·2	1·8	10·9	1·9	8·5	1·8	6·2	1·8	<0·0001
Potatoes	27·8	0·5	34·0	0·5	24·1	0·5	23·4	0·5	22·6	0·5	<0·0001
Bread§	82·7	0·9	92·4	0·9	89·2	0·9	99·7	0·9	86·0	0·9	<0·0001
Cereals‖	95·5	1·1	97·1	1·1	88·2	1·1	88·2	1·1	83·1	1·1	<0·0001
Wholegrain products¶	11·1	0·7	11·0	0·6	13·4	0·6	27·0	0·6	47·7	0·6	<0·0001
Vegetable oil	12·5	0·2	18·2	0·2	16·2	0·2	19·1	0·2	20·6	0·2	<0·0001
Butter/margarine	7·1	0·1	6·9	0·1	6·3	0·1	6·4	0·1	4·7	0·1	<0·0001
Other fats**	3·0	0·1	3·1	0·1	3·5	0·1	3·0	0·1	3·5	0·1	<0·0001
Dressing	8·1	0·1	7·0	0·1	6·8	0·1	6·5	0·1	6·4	0·1	<0·0001
Cookies	18·2	0·3	12·3	0·3	10·3	0·3	9·0	0·3	7·5	0·3	<0·0001
Sweets††	47·5	0·5	43·0	0·5	47·7	0·5	47·4	0·5	46·1	0·5	0·95
Fast foods	36·8	2·1	24·9	2·0	79·5	2·1	25·1	2·0	24·1	2·0	<0·0001
Snacks‡‡	9·4	0·2	7·9	0·2	9·8	0·2	8·3	0·2	13·2	0·2	<0·0001
Grains§§	0·8	0·1	1·5	0·1	2·1	0·1	2·9	0·1	6·5	0·1	<0·0001
Dairy substitutes‖‖	6·8	1·4	7·7	1·4	17·8	1·4	39·7	1·4	88·1	1·4	<0·0001
Meat substitutes	1·6	0·3	3·6	0·3	3·8	0·3	9·3	0·3	21·2	0·3	<0·0001
Non-alcoholic drinks¶¶	635·9	6·5	655·6	6·4	735·4	6·4	735·0	6·3	667·7	6·3	<0·0001
Alcohol	87·1	2·0	90·6	1·9	112·4	1·9	87·4	1·9	86·0	1·9	0·45
Soda	93·0	1·9	74·0	1·9	45·5	1·9	42·4	1·9	28·6	1·9	<0·0001
Water	908·8	9·3	939·6	9·1	991·3	9·2	982·6	9·0	927·9	9·0	<0·0001

*Q, quintile.
†Values presented are means with their standard errors adjusted for sex, age and total energy intake.
‡Values based on linear contrast test.
§Including bread and whole bread.
‖Including pasta, white rice, muesli, semolina and breakfast cereals.
¶Including wholegrain rice and wholegrain pasta.
**Including mayonnaise, fresh cream and vegetal fresh cream.
††Including jam, honey, sugar, sweeteners, confectionery, chocolate and chocolate spread bars, cakes, brownies, pancakes and ice cream.
‡‡Including chips, popcorns, salted cakes aperitif, peanuts, almonds and pistachio nuts.
§§Including sprouted seeds, bran and wheat germs.
‖‖Including soya yoghurt, vegetal-based cheese, vegan fresh cheese and soya milk.
¶¶Including coffee, tea, chicory and hot chocolate.

Table 3 Diet quality scores by level of organic food consumption in the diet of French adults, NutriNet-Santé Study, 2014 (*n* 28 245)*,†

	Q1 (0·00–0·01)		Q2 (0·01–0·09)		Q3 (0·09–0·25)		Q4 (0·25–0·49)		Q5 (0·49–1·00)		*P*-trend‡
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
mPNNS-GS	7·89	0·02	8·04	0·02	8·28	0·02	8·45	0·02	8·78	0·02	<0·0001
PANDiet	63·04	0·11	64·38	0·11	64·64	0·11	65·92	0·10	69·37	0·10	<0·0001

*Q, quintile; mPNNS-GS, modified Programme National Nutrition Santé Guidelines Score; PANDiet, probability of adequate nutrient intake.
†Values presented are means with their standard errors adjusted for sex, age and total energy intake.
‡Values based on linear contrast test.

proportion of individuals meeting the recommendation on 'added fat' gradually decreased.

This was not the case for added fat of vegetable origin: here, the highest proportion of individuals meeting the recommendation was found in Q5. Q5 also included the highest proportion of individuals complying with the guideline on wholegrain foods. Of note, the highest proportion of individuals meeting the recommendations

Table 4 Compliance with the individual components of the mPNNS-GS by level of organic food consumption in the diet of French adults, NutriNet-Santé Study, 2014 (*n* 28 245)*,†

Follow the recommendation (%)	Q1 (0·00–0·01)	Q2 (0·01–0·09)	Q3 (0·09–0·25)	Q4 (0·25–0·49)	Q5 (0·49–1·00)	P-trend‡
Fruit and vegetables	56·9	57·5	64·7	69·9	80·2	<0·0001
Starchy foods (bread, cereals, potatoes and legumes)	37·7	37·9	40·6	41·5	42·9	<0·0001
Wholegrain foods	8·5	13·7	12·3	16·2	22·2	<0·0001
Dairy products	20·9	26·7	30·8	25·1	17·6	<0·0001
Meat, poultry, seafood and eggs	43·0	46·5	47·1	46·8	37·2	<0·0001
Seafood	27·7	40·5	41·3	47·8	39·1	<0·0001
Added fat	82·1	74·7	74·3	71·7	68·4	<0·0001
Added fat of vegetable origin	91·2	89·8	90·6	90·2	95·1	<0·0001
Sweetened foods (sugar, sweets and cookies)	86·4	86·4	91·2	92·5	95·0	<0·0001
Non-alcoholic beverages	92·4	91·4	97·0	95·8	97·7	<0·0001
Alcohol	93·1	89·6	90·6	94·0	93·7	<0·0001
Salt	51·3	45·3	44·2	44·1	62·8	<0·0001

*Q, quintile; mPNNS-GS, modified Programme National Nutrition Santé Guidelines Score.
†Values presented are percentages of individuals with adequate intake.
‡Values based on trend χ^2 test.

on animal-based products (dairy products; meat, poultry, seafood and eggs; seafood) was found in the three intermediate quintiles. Concerning non-alcoholic beverages and salt, Q5 included the highest proportion of individuals meeting the recommendations. The lowest percentage of individuals following the recommendation on alcohol was found in Q2 and the highest in Q4.

Stratified analyses according to various sociodemographic and lifestyle factors are presented in Supplemental Fig. 1 (see online supplementary material). Overall, significant positive associations were found between the nutritional quality of the diet and organic food consumption in each subgroup. The strength of the association varied across subgroups (from $\beta_{\text{current smoker}} = 0\cdot53$; 95 % CI 0·25, 0·80 to $\beta_{\text{income 1800–2700€}} = 1\cdot40$; 95 % CI 1·26, 1·54).

Discussion

Our study evaluated the dietary intakes and diet quality across different levels of organic foods in the diet among a large population of French adults using detailed dietary data. A higher level of organic food consumption was related to overall healthier dietary patterns, although intermediate organic food consumers showed better adherence to nutritional recommendations related to animal product intakes.

Studies reporting sociodemographic and lifestyle differences between non-organic food consumers and frequent organic consumers are plentiful[6,25,30,44–49] and one was conducted in the NutriNet-Santé cohort[28]. Consistent with previous studies[25,45,47–49], we found herein that income seemed to be a weak determinant compared with education to explain differences in organic food consumption behaviours. However, whether high consumption of organic foods was not necessarily related to

high household income, low consumers exhibited elevated percentages of individuals with a low income in accordance with another work[49].

Few studies have explored the relationship between level of organic food consumption and intake of food groups and they focused only on the frequency of consumption of organic foods (frequent/regular/occasional *v.* non-consumption)[25,26,28,30]. We found herein that intakes of plant-based foods increased along with an increase in the share of organic foods in the diet while the reverse was observed for most animal-based foods. Furthermore, an inverse gradient was found between consumption of cookies and soda and the proportion of organic foods in the diet. The previous[25,26,28,30] and present convergent observations made from different surveys lead to state that a high level of organic food consumption is combined with a diet based on healthier foods. Nevertheless, as no clear linear trend was found between organic food consumption and the intake of sweet products, it can be assumed that individuals with a high consumption of organic foods did not exclude all unhealthy products. Similarly, in a German study, men consumed comparable amounts of sweets regardless of organic foods buying frequency, although women buying organic foods ate fewer sweets[30].

Another important finding of our study was that very high consumers of organic foods (Q5) exhibited particular dietary practices. Their intakes of nuts, legumes, wholegrain products, grains, and meat and dairy substitutes (including soya yoghurt, vegetal-based cheese, vegan fresh cheese and soya milk) were much higher than in the other groups. The consumption of dairy products in Q5 was almost half that in the other quintiles while the intake of dairy substitutes in Q5 was at least twice higher, suggesting a substitution of dairy products (animal-based foods) towards dairy substitutes (plant-based foods). This can be attributed, at least in part, to the high proportion of

vegetarians and vegans present in this group who have high intakes of whole grains and grains[50]. Previous works have also shown strong associations between regular organic food consumption and vegetarianism[25,26,44]. The underlying motives of organic food consumption and a vegetarian or vegan diet may also be convergent[51].

With regard to consumption of poultry, apart from Q5, the different categories of consumers seemed to have a comparable intake. Furthermore, across the five groups, individuals in Q4 had the highest intake of seafood and eggs. It seems that individuals in Q5 tended to avoid food products of animal origin including seafood or eggs, while individuals in Q4 tended to be less restrictive and might replace meat by a higher consumption of seafood and eggs. Thus, the diet of consumers in Q4 seemed to be close to a 'flexitarian diet' (i.e. an occasional consumption of meat). The underlying motives for consuming organic food products between the two groups may not be the same. This may have consequences in terms of the promotion of organic food consumption. A previous work thus showed that food choices of flexitarians were motivated by weight control or health while food choices of vegetarians were motivated by ethical concerns[52,53].

As underlined above, intakes of animal products were much lower in Q5 compared with Q4. This resulted in lower adequacy to the recommendations pertaining to animal-based foods. However, the animal foods consumed in Q5 were largely of organic origin. Recent meta-analyses have shown differences in fatty acid composition between organic and conventional animal foods, with higher total PUFA and n-3 PUFA concentrations in organic milk[15]. Concerning organic meat, the evidence base is weak[16] and studies on nutritional values of organic seafood are needed. Even though the difference at the food level is low, these 'organic' benefits may affect the nutritional status of Q5 participants at the diet level. However, composition data according to production method are lacking and thus PUFA intake has probably been underestimated in our study.

Thus, not only may the consumption patterns of high organic food consumers be linked to lower risk of chronic diseases, but also their high consumption of organic products with some potentially better nutritional profiles may lead to better health status than their counterparts, although this still needs to be documented.

Strikingly, the two diet quality scores increased from Q1 to Q5 reflecting in the latter a better compliance with the nutritional guidelines and a better nutrient status. This is explained by the more important intakes of healthy foods such as fruit and vegetables, legumes, whole grains and nuts among high organic food consumers as described above. This seems consistent with previous studies[26–28,30] showing that frequent organic food consumers exhibit an overall better diet quality than non-organic food consumers.

Interestingly, when focusing on the individual dietary components of the mPNNS-GS, individuals with the highest proportion of organic foods in their diet (Q4 and Q5) tended to follow the nutritional recommendations pertaining to plant-based products but fewer followed animal-based products recommendations (inverted U-shaped relationships for dairy products and for meat, poultry, seafood and eggs). Thus, although the high organic food consumers had, overall, a healthier diet, the results regarding animal-based recommendations were more balanced: moderate organic food consumers seemed to include a larger variety of products of different origin in their diet. This resulted in a lower intake of vitamin B_{12} among Q5 participants. Nevertheless, the overall healthier dietary patterns reflected by higher dietary scores of high organic food consumers may translate into better health-related outcomes as observed in some studies[28,54,55].

We also observed a positive association between increased organic food consumption in the diet and the nutritional quality of the diet whatever the socio-demographic or lifestyle category. However, the magnitude of this association was variable depending on the subgroup considered (e.g. higher among males or among participants living in an urban unit with a population of >200 000 inhabitants). For these specific subgroups, even more than for the other groups, consumption of organic foods is probably part of an integrated approach of a global strategy towards a healthy diet.

Dietary patterns of high organic food consumers seem to fit those of sustainable diets[56]. The FAO has defined sustainable diets as those 'with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimising natural and human resources'[1]. High organic food consumers exhibited healthier dietary habits better for their own health. Besides the positive environmental impacts of organic production[57–59], they exhibited a plant-based diet with low consumption of meat, thereby reducing life-cycle greenhouse gas emissions[60]. Other studies have shown that high organic food consumers also favoured more direct links with producers[61]. The estimation of the sustainability of an 'organic diet' should therefore encompass all these factors including sources (organic or conventional), dietary patterns and practices.

Our study presents major strengths. One of the strengths lies in its large sample size that includes 28 245 French adults. It enables a large variation in dietary behaviours and in the practices about organic foods. A further strength of the current study is the use of a semi-quantitative FFQ that includes 264 items. It is also worthwhile mentioning that an innovative approach was used to assess organic food consumption using detailed data, allowing evaluation of the proportion of organic foods in the whole diet. However, the study has also several limitations. Given that the individuals enrolled were volunteers in a cohort

focusing on nutrition and health, they were certainly particularly interested in these topics. Furthermore, filling in the questionnaire was optional; therefore individuals included in the study were also more concerned with sustainable food issues than the general population and the other participants of the cohort. This may have led to recruitment biases and caution is therefore needed when generalising the results. The use of a 5-point ordinal scale has led to an overestimation of the actual organic food consumption as, for instance, a percentage of 25 % was allocated to the frequency 'rarely', not reflecting the very occasional consumers. However, in a sensitivity analysis[37], we attributed a percentage of 10 % to the frequency 'rarely' and the results were not substantially modified. FFQ have also been shown to misestimate overall food intake and in turn this must have been the case for organic food intake. Data collection was based on self-administered questionnaires which are prone to measurement errors. However, the Org-FFQ was based on a validated FFQ which had shown relative validity and reproducibility[36]. Finally, composition tables are based on average values and do not take into account the type of farming (conventional or organic). Recent meta-analyses[14,15] have reported higher antioxidant concentrations in organic crops as well as higher PUFA and n-3 PUFA, conjugated linoleic acid, α-tocopherol and Fe, but lower iodine and Se concentrations in organic milk. The potential differences between the observed intakes must be therefore interpreted in the light of this limitation. Development of updated food composition databases accounting for farming practices seems necessary to accurately estimate nutrient intakes of high organic food $v.$ non-organic consumers.

Conclusion

In conclusion, the present study provides new insights into the understanding of organic food consumption as an integral part of a healthy diet. These findings underline strong dietary behaviour correlates associated with organic food consumption that should be taken into account and controlled for in future aetiological studies on organic food consumption and health. Furthermore, an organic-based diet seemed to coincide with a plant-based diet and therefore might better fit the sustainable diet definition. In a framework of sustainable diet development, a better characterisation of organic food consumers including their motivations and trajectories in various contexts, as well as the sustainability of the 'organic diet', is needed.

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Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1368980016002718

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