Which functional unit to identify sustainable foods?

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Abstract

Objective: In life-cycle assessment, the functional unit defines the unit for
calculation of environmental indicators. The objective of the present study was to
assess the influence of two functional units, 100 g and 100 kcal (420 kJ), on the
associations between three dimensions for identifying sustainable foods, namely
environmental impact (via greenhouse gas emissions (GHGE)), nutritional quality
(using two distinct nutrient profiling systems) and price.
Design: GHGE and price data were collected for individual foods, and were each
expressed per 100 g and per 100 kcal. Two nutrient profiling models, SAIN,LIM and
UK Ofcom, were used to assess foods' nutritional quality. Spearman correlations
were used to assess associations between variables. Sustainable foods were
identified as those having more favourable values for all three dimensions.
Setting: The French Individual and National Dietary Survey (INCA2), 2006–2007.
Subjects: Three hundred and seventy-three foods highly consumed in INCA2,
covering 65 % of total energy intake of adult participants.
Results: When GHGE and price were expressed per 100 g, low-GHGE foods had a
lower price and higher SAIN,LIM and Ofcom scores ($r = 0.59$, -0.34 and -0.43,
respectively), suggesting a compatibility between the three dimensions; 101 and
100 sustainable foods were identified with SAIN,LIM and Ofcom, respectively.
When GHGE and price were expressed per 100 kcal, low-GHGE foods had a
lower price but also lower SAIN,LIM and Ofcom scores ($r = 0.67$, 0.51 and 0.47,
respectively), suggesting that more environment-friendly foods were less
expensive but also less healthy; thirty-four sustainable foods were identified with
both SAIN,LIM and Ofcom.
Conclusions: The choice of functional unit strongly influenced the compatibility
between the sustainability dimensions and the identification of sustainable foods.

Greenhouse gas emissions (GHGE) arising from human
activities are agreed as the main cause for climate
change[1]. Countries that ratified the Kyoto Protocol had
set legally binding targets for such reduction[2]. In the EU,
national targets have been further issued, with objectives
of reducing GHGE by 20–30 % by 2020 and by 70–80 % by
2050, compared with the 1990 reference[3,4]. Agricultural
production and food consumption represent 20–30 % of
total EU GHGE[5]. Improving the efficiency of the food
supply chain might help to reduce diet-related GHGE[6],
but reaching the long-term 2050 GHGE mitigation objec-
tive without major dietary changes may prove challen-
ging[7]. Above environmental consequences, food
supplies need to ensure the health and well-being of
individuals, be culturally acceptable and be accessible to
most[8]. As a result, and to integrate the different dimen-
sions of food-related sustainability, the FAO introduced in
2010 a definition of sustainable diets that includes criteria

related to environmental impact, nutritional adequacy,
cultural acceptance, affordability and economic develop-
ment[9]. While the concept has been defined, it needs to
be put into practice, for example by deriving practical
examples of sustainable dietary choices or sustainable diet
recommendations.

Among the public health nutrition community, most focus
has been put on the relationship between diets' environ-
mental impact, and more specifically diet-related GHGE,
and their nutritive value or health effects. Foods of animal
origin emit more GHGE than plant-based foods on a weight
basis and existing public health guidelines recommend a
lowering of red meat intake and an increased consumption
of fruit, vegetables and starchy foods[10–13]. As a result,
several studies using diet modelling or scenarios have sug-
gested a natural compatibility between low-GHGE and
healthy diets[14–16]. However, the nutritional assessment was
rarely complete and the suggested compatibility was not

observed in a study based on self-selected diets[17]. With regard to diet cost, theoretical vegetarian and vegan diets were shown to be less expensive than the higher-GHGE observed UK diet[18]; and French self-selected diets with both low GHGE and higher nutritive value were cheaper than the average diet of the French population[19]. But Macdiarmid *et al.* observed no price difference between theoretical diets with reduced GHGE and the observed UK diet[20]. To further explore the practical pathways towards sustainable diets, data at the food level are needed.

Life-cycle analysis (LCA) is the most common tool to assess GHGE arising from individual products; it is defined as follows by the ISO 14040:2006 and ISO 14044:2006 international standards: the 'compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle'[21,22]. Thus, the GHGE estimates include the emissions associated with each stage of the production, transformation, distribution, use and end-of-life of food products. A key concept in LCA is the functional unit, i.e. the unit of product to express the environmental impact indicator, which is supposed to be linked to the function of the product. The functional unit for LCA of food products is usually a unit of mass or volume. With such a functional unit, the production of foods of animal origin, particularly ruminant meat, emits more greenhouse gas than the production of plant-based foods[5,23,24], which led to the suggestion of the potential compatibility between the environmental and public health requirements of sustainable diets. Nevertheless, some environmental scientists, arguing that the function of food is also to deliver nutritional quality, proposed that the functional unit accounts for the nutrient content of foods[25–27]. As an example, a 'quality-corrected functional unit'[28] is currently used in the dairy sector[29,30]. Further, it was shown that expressing GHGE on an energy basis modified the rankings of foods, with the difference between foods of animal and plant-based origin being considerably reduced[17,31]. Similarly, food prices can be very different depending on the basis for calculation (usually mass or energy)[32], which explains why healthy diets that provide sufficient energy and nutrients are often more expensive than unhealthy ones[33]. With regard to nutritional quality of foods, the debate on food nutrient profiling and the choice of the basis for deriving scores for individual foods[34,35] further highlights the influence of the functional unit when comparing between foods.

The objective of the present study was to assess the influence of the choice of functional unit on the identification of sustainable foods. Sustainable foods were defined as those meeting three criteria for a sustainable diet: (i) low environmental impact (via GHGE); (ii) high nutritional quality (using two distinct nutrient profiling systems); and (iii) affordable price. The three criteria were combined into a single sustainability score which was computed on either a mass or an energy basis.

Materials and methods

Data

Food selection

For the purpose of the present study, the foods that best represent the French diet were selected because assessing the GHGE of all foods and drinks would be a very costly process. To account for the diversity of French food consumption patterns, data from the Individual and National Dietary Survey (INCA2), a national cross-sectional dietary survey conducted in 2006–2007 on a three-stage stratified nationally representative sample of the French adult population, were used[36,37]. The INCA2 study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the French Data Protection Authority (Commission Nationale Informatique et Libertés). Dietary intakes were assessed using a 7 d diet record and after excluding the energy under-reporters using standard procedures[38], 1918 healthy adults (776 men and 1142 women) aged 18–79 years were retained. For each food reported to be consumed (1314 foods and beverages, including water), the percentage of individuals who consumed this item (i.e. the participants who reported consuming the food at least once in their 7 d diet record) was calculated. Then, within each of the thirty-six food subgroups of the food database, the food items were ranked in decreasing order based on the percentages of consumers and at least one food item was selected from among the most widely consumed items in each subgroup. This process resulted in 402 representative foods from the 1314 items initially listed in the food database. These 402 foods covered 65 % of the total energy intake of the INCA2 study population.

Greenhouse gas emission values

GHGE values expressed in units of grams of CO_2 equivalents (gCO_2eq) were assigned to the 402 foods by an environmental consulting firm, Greenext Service (Paris, France), using an in-house LCA software (GreenCode Saas)[39]. Briefly, using a top-down approach combining French trade and production data[40,41] and standard life-cycle inventory data (e.g. Ecoinvent[42]), the final values for GHGE reflected the average food product consumed in the French market[39]. GHGE estimates did not include emissions from indirect land-use change or from transport of consumers to and from retail stores. The values used for this analysis were updated with regard to the previous studies using Greenext data[17,19,31].

Food prices

Food prices were obtained from the 2006 Kantar Worldpanel purchase database[43], which gives the annual expenditures and the quantity purchased of each food item available on the market by a representative sample of

12 000 French households. The mean prices were calculated by dividing the annual expenditures by the quantities purchased.

Nutritional quality: SAIN,LIM and UK Ofcom nutrient profiling models

To assess the nutritional quality of each food, two nutrient profiling models were used: the French SAIN,LIM and the UK Ofcom, both precisely described elsewhere[44,45].

Briefly, the SAIN,LIM is based on two separate scores: the SAIN (score for the nutritional adequacy of individual foods) and the LIM (score for disqualifying nutrients). Both scores are calculated as average (nutrient content/recommendation) ratios, with the SAIN per 100 kcal (420 kJ) and the LIM per 100 g. The SAIN uses five basic nutrients (protein, fibre, calcium, vitamin C, iron) and the LIM includes three nutrients (SFA, added sugars, sodium). Vitamin D is used as an optional nutrient for calculating the SAIN; it replaces one of the five basic nutrients if the content/recommendation ratio for vitamin D is greater than one of the ratios for basic nutrients. The SAIN and LIM algorithms were applied to each food in the same manner, with the exception of two food categories[44]: (i) for sweet drinks, the LIM was multiplied by 2·5, assuming a regular portion size of 250 ml; and (ii) for nuts and foods deriving more than 97 % of their energy content from fat (e.g. oils, margarine, butter), vitamin E, MUFA and α-linoleic acid were used as optional nutrients in the SAIN algorithm to account for the quality of lipids. To integrate the nutritional quality of foods into one dimension, the SAIN/LIM ratio was used with the LIM set to one when lower than one. This ratio correlates well with modelled diets that meet a full set of nutrient recommendations: the median SAIN/LIM of the foods included in modelled diets increases with increasing nutritional quality of the diets[46].

The UK Ofcom nutrient profiling model is a two-category model, scoring food and drinks separately but using the same basic algorithm (a semi-continuous score based on nutrient content) as a basis to define products that are 'healthy' (or at least not 'unhealthy') and therefore which can be advertised to children[45]. The UK Ofcom incorporates on a single scale composition of the following components per 100 g of food: (i) saturated fat, sodium, total sugar and energy as the negative nutrients; and (ii) protein, fibre, and fruit, vegetable and nut content as the positive nutrients. To ease interpretation of results, the Ofcom scale from 1 to 100 scale, in which higher scores indicated a healthier food/drink[45], was used.

Functional unit

GHGE and prices were first calculated per 100 g of edible food (i.e. after the changes in weight associated with the trimming or cooking processes were taken into account using the appropriate conversion factors). They were then computed per 100 kcal (or 420 kJ) of edible food. The two nutrient profiling models included both energy and weight

in their algorithm, and the scores were not modified for the purpose of the present analyses.

Analyses, sustainability score

In order to better discriminate the GHGE associated with animal products and based on the classification of foods in the INCA2 database, ruminant meat was analysed separately from other animal sources. As a result, nine food groups were used in the following analyses: (i) ruminant meat; (ii) other meats (pork, poultry, eggs; including deli meats); (iii) fish products; (iv) dairy products; (v) fruit and vegetables; (vi) mixed dishes; (vii) fats and condiments, (viii) salted snacks and sweets; and (ix) starchy foods (including potatoes and legumes).

The SAIN/LIM ratio could not be calculated for energy-free foods (e.g. water and diet soft drinks) and both nutrient profiling models were not designed to score alcoholic drinks. As a result, all virtually energy-free (i.e. hot drinks and artificially sweetened beverages) and alcoholic drinks were excluded from the analyses, resulting in a final sample of 373 foods. Sweetened beverages were reclassified in the snacks and sweets food group, fruit juices in the fruit and vegetables group, and soya-based drinks in the dairy products food group. Rank correlations were computed to assess the relationship between GHGE (per 100 g and per 100 kcal), the SAIN/LIM ratio, the UK Ofcom score and the prices (per 100 g and 100 kcal) for all foods.

The sustainability score was based on the overall medians of the GHGE, the SAIN/LIM ratio or the UK Ofcom score and the price of each food. It ranged from 0 to 3, with each food scoring 1 point if its GHGE was under the median, 1 point if its price was under the median and 1 point if its SAIN/LIM or UK Ofcom score was above the median. On this basis, the 373 foods were classified based on the score (0, 1, 2 or 3) and the most sustainable foods (with a score of 3) were identified. The sustainability score was computed four times: with the 100 g functional unit for GHGE and price, and the two nutrient profiling models separately; then with the 100 kcal functional unit for GHGE and price, and the two nutrient profiling models.

All analyses were computed using the SAS 9·3 statistical software package.

Results

Greenhouse gas emissions, price and nutritional quality by food group

The influence of the functional unit for GHGE and price is illustrated in Fig. 1, which displays medians and interquartile ranges for GHGE and price for both functional units.

Foods of animal origin and mixed dishes containing animal-based ingredients were the highest emitters on a weight basis, while fruit and vegetables, starchy foods, and
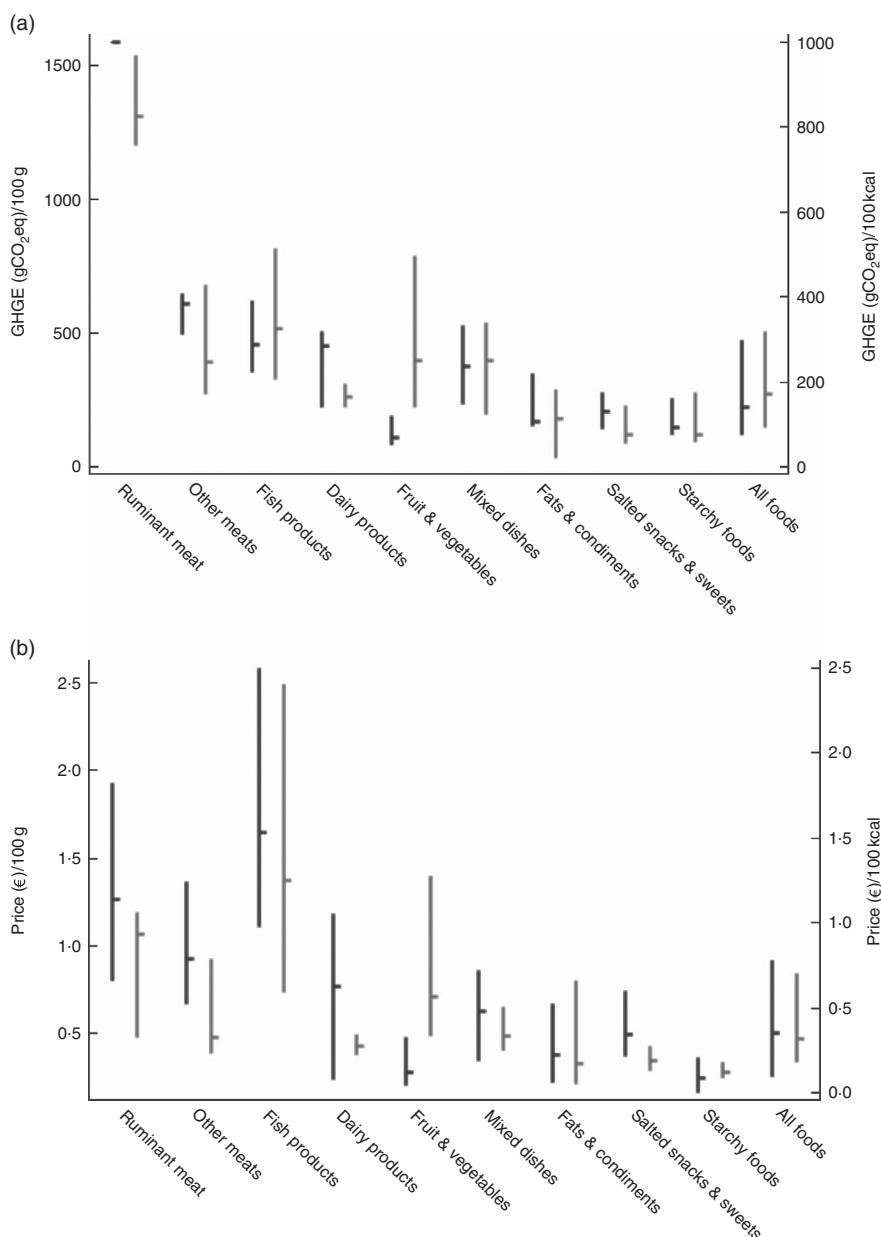
Fig. 1 (a) Greenhouse gas emissions (GHGE; in grams of CO_2 equivalents) and (b) price (in Euros) by food group according to functional unit: ——, 100 g; ——, 100 kcal. 100 kcal = 420 kJ. Values are medians with interquartile ranges represented by vertical bars

salted snacks and sweets were the lowest (Fig. 1(a) and Table 1). On an energy basis, ruminant meats remained the largest emitters; the median GHGE for fruit and vegetables was similar to the median for other meats and mixed dishes, and above the median for dairy products. The lowest emitters per 100 kcal were starchy foods, salted snacks and sweets, and added fats and condiments.

Similar trends could be observed for price (Fig. 1(b) and Table 1). Foods of animal origin, in particular fish products, were the most expensive on a weight basis, while starchy foods and fruit and vegetables were the least expensive food groups. On an energy basis, fish products remained the most expensive food group and starchy foods the least expensive one.

In terms of nutritional quality, the fruit and vegetables food group was the 'healthiest' one whatever the nutrient profiling model. The least healthy food group was salted snacks and sweets with the SAIN/LIM score and the dairy products food group with the Ofcom score, linked to the high number of cheeses in this group (twenty-eight out of forty-three foods, Table 1). Low scores for the 'Other meats' were explained by the inclusion of deli meats in this category.

Correlations between the three dimensions of sustainability

Across all foods, GHGE and price were positively correlated when using the same functional unit (100 g or 100 kcal),

Table 1 Median values for all sustainability indicators per food group and for the 100 g and 100 kcal functional units (n_{foods} 373)

Food group	n	GHGE (gCO$_2$eq)/ 100 g	GHGE (gCO$_2$eq)/ 100 kcal	Price (€)/100 g	Price (€)/100 kcal	SAIN/LIM score	Ofcom score
All foods	373	226	172	0·50	0·32	0·84	66
Ruminant meat	10	1589	824	1·27	0·94	1·70	71
Other meat (pork, poultry, eggs, deli meats)	21	609	248	0·92	0·33	0·33	36
Fish products	26	458	324	1·65	1·26	3·19	72
Dairy products	43	455	165	0·77	0·28	0·24	32
Fruit & vegetables	92	111	251	0·28	0·57	9·93	80
Mixed dishes	44	376	252	0·63	0·33	0·54	64
Fats & condiments	30	168	112	0·38	0·17	0·61	45
Salted snacks & sweets	73	208	75·9	0·49	0·19	0·12	44
Starchy foods	34	151	74·6	0·25	0·12	1·56	72

GHGE, greenhouse gas emissions (in grams of CO$_2$ equivalents); SAIN/LIM, derived from the SAIN,LIM nutrient profiling model[44]; Ofcom, UK Ofcom nutrient profiling model[45]. 100 kcal = 420 kJ.
Price (in Euros), data obtained from Kantar Worldpanel[43].

Table 2 Spearman correlations between all sustainability indicators (n_{foods} 373)

	GHGE/100 g	GHGE/100 kcal	Price/100 g	Price/100 kcal	SAIN/LIM score	Ofcom score
GHGE/100 g	1·00					
GHGE/100 kcal	0·36	1·00				
Price/100 g	0·59	0·06	1·00			
Price/100 kcal	0·11	0·67	0·47	1·00		
SAIN/LIM score	−0·34	0·51	−0·25	0·51	1·00	
Ofcom score	−0·43	0·47	−0·33	0·46	0·87	1·00

GHGE, greenhouse gas emissions; SAIN/LIM, derived from the SAIN,LIM nutrient profiling model[44]; Ofcom, UK Ofcom nutrient profiling model[45].
100 kcal = 420 kJ.
Price data obtained from Kantar Worldpanel[43].

indicating that more expensive foods were more likely to emit more greenhouse gas (Table 2 and Fig. 2). Nutritional quality was negatively correlated with GHGE per 100 g and with price per 100 g, further indicating that overall, using the 100 g functional unit, healthier foods had lower GHGE and were less expensive. Yet, the association was reversed when using the energy functional unit: a higher nutritional quality was associated with higher GHGE per 100 kcal and a higher price per 100 kcal. This is illustrated well in Fig. 2, in which healthier foods according to the two nutrient profiling systems (i.e. SAIN/LIM or Ofcom score above the median) were predominantly in the low GHGE/low price quadrant with a 100 g functional unit and in the high GHGE/high price quadrant with a 100 kcal functional unit.

Sustainability score, identification of sustainable foods

The relationships between nutritional quality, GHGE and price are reflected in Fig. 3, which presents the percentage of sustainable foods in each food group; meats, fish and eggs never obtained the maximum score of 3. The detailed lists of foods identified as sustainable is given in the online supplementary material, Supplementary Table 1.

Using the weight functional unit (Fig. 3(a)), just above a quarter of all foods were identified as sustainable with

both the SAIN,LIM and Ofcom nutrient profiling models. Fruit and vegetables and starchy foods were the food groups with most sustainable foods. Fruit and vegetables that were not identified as sustainable were either more expensive because of their foreign origin or their high seasonality, or had a higher sugar content which hindered their nutritional quality (some dried fruits, and canned fruits in syrup). Among starchy foods, only breads and crackers were not identified as sustainable due to their higher salt content. On the other hand, very few salted snacks and sweets were identified as sustainable (mainly soya-based desserts; see online supplementary material, Supplementary Table 1). Among dairy products, fresh products such as milks and unsweetened yoghurts did obtain the maximum sustainability score.

Computing the sustainability score with GHGE and price expressed on a 100 kcal basis considerably reduced the total number of sustainable foods (Fig. 3(b)). Less than 10 % of fruit and vegetables were identified as sustainable, in comparison with the more than 60 % when using a weight basis. All fresh dairy products lost their maximum score, except the non-dairy soya-based drink. These results were linked to the lower energy content and hence the higher GHGE and price per 100 kcal of these products. The starchy foods food group was the only one which maintained a higher proportion of sustainable foods with both functional units: 38 % and 53 % of starchy foods were
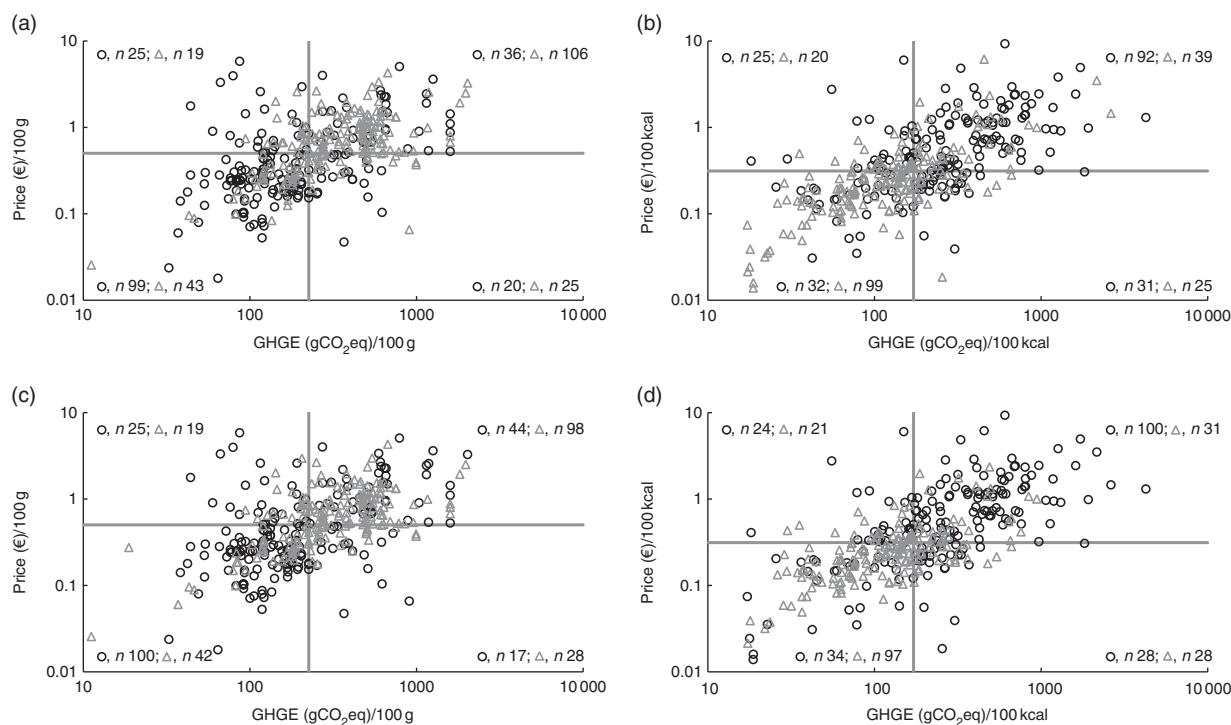
Fig. 2 Scatter plots representing food price (in Euros) *v.* food greenhouse gas emissions (GHGE; in grams of CO_2 equivalents), using either a 100 g (a, c) or a 100 kcal (b, d) functional unit. 100 kcal = 420 kJ. The Ofcom (a, b) and SAIN/LIM (c, d) nutrient profile scores were used to identify healthier (◯) and less healthy (△) foods; ——, medians. The total number of foods is 373. The SAIN/LIM was based on the SAIN,LIM nutrient profiling model[44]; Ofcom refers to the UK Ofcom nutrient profiling model[45]

sustainable using the energy functional unit with the SAIN/LIM and Ofcom models, respectively.

Discussion

The present study shows the importance of the functional unit when trying to identify foods with lower GHGE, higher nutritional quality and lower price. Using a weight unit (i.e. expressing GHGE and price per 100 g), the results confirmed previous observations[31] and did suggest a compatibility between the three sustainability criteria: foods for which production, transformation, distribution and use involved higher GHGE were more likely to be more expensive and to have a lower nutritional quality. Foods of animal origin were confirmed as the food group with the highest GHGE per 100 g (with ruminant meats being the highest emitting foods) and the highest price per 100 g. Fruit and vegetables were the lowest emitters and had the highest nutritional quality. The identification of sustainable foods using a 100 g functional unit for GHGE and price reflected these associations, with more than 60 % of fruit and vegetables and no meats, fish or eggs being identified as such. However, when using a 100 kcal functional unit to express GHGE and price, nutritional quality of foods was positively correlated with both indicators, i.e. healthier foods were more likely to have higher GHGE and higher price. The effect of changing the

functional unit was most apparent for the fruit and vegetables group: their mean GHGE per 100 kcal was higher than for meats (except ruminant meat) and dairy products, and their mean price per 100 kcal was the second highest, after fish products. This was mainly explained by the low energy density of fruit and vegetables, linked to their high water content. This was consistent with previous results obtained at diet level: a simulation study based on French data showed that a reduction of ruminant and deli meats compensated for by an isoenergetic increase of fruit and vegetables led to higher diet-related GHGE[47]. Foods which combined low GHGE and price per 100 kcal were starchy foods, salted snacks and sweets, and dairy products. Starchy foods, except breads due to their high salt content, was the only food group for which the proportion of sustainable foods was little affected by the functional unit choice and it stood out as the most sustainable food group. Therefore, the use of an energy functional unit did not go against existing nutritional guidelines which do promote a high dietary share of complex carbohydrates[48–50]. In France, individuals consuming diets with lower GHGE and higher nutritional quality did consume similar or higher amounts of starchy foods, dairy products and vegetable oils than the general population[19]; although they also consumed more fruit and vegetables and less meats. In summary, the present results – similar with both nutrient profiling models – confirmed that messages suggesting a natural compatibility between the environmental,
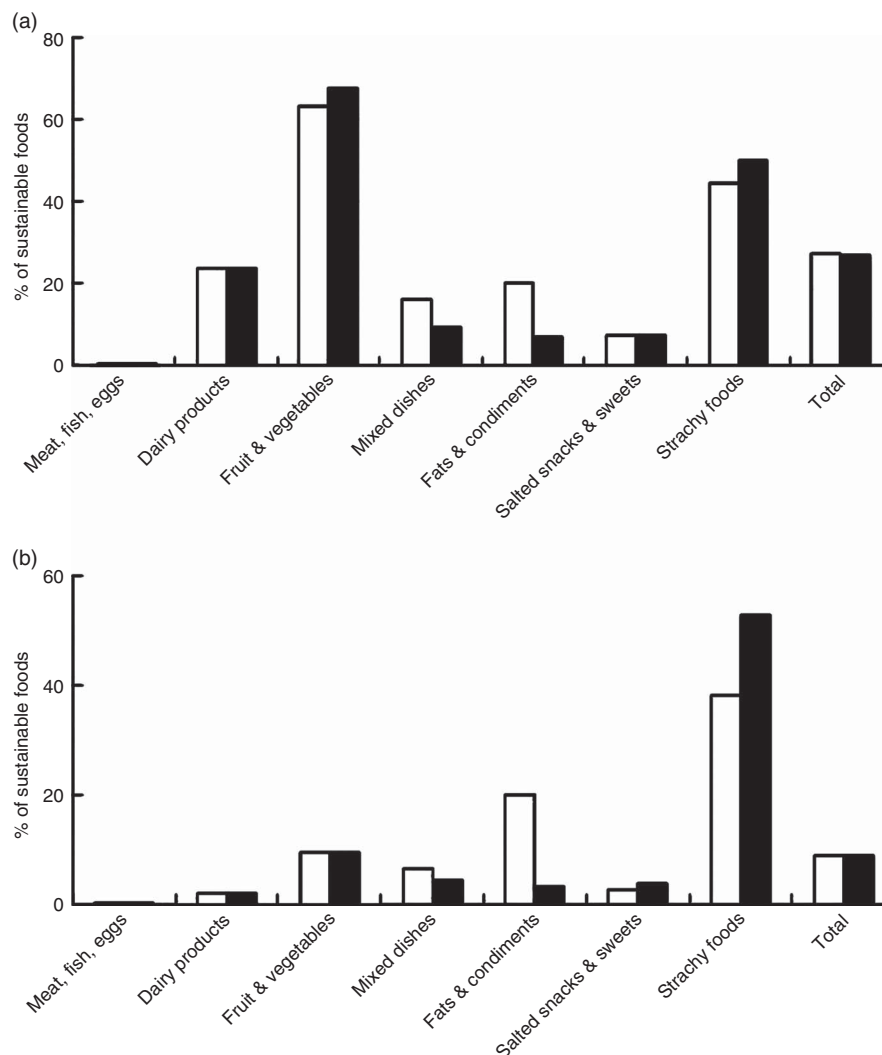
Fig. 3 Percentage of 'sustainable' foods by food group and across all foods, using either a 100 g (a) or a 100 kcal (b) functional unit. 100 kcal = 420 kJ. 'Sustainable' foods were those with their greenhouse gas emissions and price under the overall median, and the nutrient profiling score (□, SAIN/LIM; ■, Ofcom) above the overall median. The SAIN/LIM was based on the SAIN,LIM nutrient profiling model[44]; Ofcom refers to the UK Ofcom nutrient profiling model[45]

economic and nutrition dimensions of food sustainability were over-simplistic. The data presented in the current study reinforced the rationale for an integrated evaluation of all sustainability dimensions and consequently emphasized the importance of an appropriate choice of functional unit when analysing individual foods.

The use of a weight basis to express sustainability indicators does have several practical benefits. First, the compatibility message it strengthens may be beneficial for consumers who should find it easier to combine the healthy choice with the environment-friendly and/or the less expensive choice. The general population still falls short of meeting existing dietary guidelines[51,52]; highlighting the wider beneficial effects of such guidelines could facilitate the orientation of consumers towards healthier food choices. Second, a weight basis is already in use in the EU and other countries for regulation purposes,

in particular nutrient content information on food packaging[53]. Using the same basis for the calculation of environmental impact indicators could ease the implementation of tools including such indicators, for example in relation to claims made on foods[54]. However, as underscored above, using a weight basis to combine GHGE, price and nutritional content information of individual foods could also lead to misleading conclusions, especially considering that similar foods can provide very different amounts of energy (e.g. standard *v.* artificially sweetened food products). Hence, the use of an energy basis as functional unit to identify more sustainable foods may also be relevant for some. Computing sustainability indicators per 100 kcal would ensure that drinks which contain little energy are not over-rated as environment-friendly foods and that foods with a high energy density but consumed in smaller amounts (e.g. added fats, sauces)

are not pinpointed as non-sustainable. The energy basis may therefore suit better public health practitioners, dietitians or public authorities who need to take dietary intakes as a whole when designing recommendations or guidelines for their patients or the general public. On the other hand, using an energy basis may mislead consumers who have been used to messages promoting a high consumption of fruit and vegetables and a moderate consumption of red meats. As a result, the choice of a functional unit should ultimately depend on the intended application, but the two options considered in the present study do not seem ideal and it may be confusing for stakeholders to see both units coexisting.

The sustainability score used in the present study did not integrate the three sustainability criteria on a single scale. In LCA, the use of the appropriate functional unit ensures that the function and use of the product are taken into account when assessing an indicator. In the present study, results of LCA (GHGE of foods) were included in the three-dimensional score, but were not weighted or corrected for the two other sustainability criteria (price and nutritional quality). An option for further investigation would be to follow the 'quality-corrected' functional unit approach[28] by including in the functional unit more details on the nutritional quality, and possibly the price, of individual foods. Another option would be to express sustainability indicators per portion size, i.e. in the way foods are most usually consumed. With respect to foods' nutritional quality, some nutrient profiling models do use portion size as the basis for calculation, and nutrition labelling is based on standard portion sizes in the USA. Since standard portion sizes are not defined in France and the EU, we did not opt for such approach. Nevertheless, further investigation involving both environmental and public health nutrition scientists is needed to explore alternative functional units which could integrate the different sustainability dimensions[55], for example expressing environmental impact on a nutritional quality basis[56].

The present study has several limitations. The environmental dimension of sustainability was only assessed by the GHGE associated with individual foods, i.e. their global warming potential. Agricultural production impacts the environment and natural resources in many other ways, notably in terms of land and water use[57,58]. We did not have access to food-level indicators for such impacts. A recent analysis showed that GHGE of foods were highly correlated with freshwater eutrophication and air acidification[31], suggesting that the present results could apply to these two impact indicators. In addition, the LCA tool used in the study did not account for GHGE arising from indirect land-use change[7]. The sustainability score derived in the present study did not account for the cultural acceptability of foods. Including the acceptability criteria on a food sustainability indicator could be relevant when designing new diets or recommendations.

The results from the study were based on foods most commonly consumed by the INCA2 survey population. While such approach should ensure a good acceptance of foods identified as sustainable, it did not allow use to analyse less commonly consumed foods which could combine favourable values for all sustainability criteria. Last, food groupings as defined in the French INCA2 survey were used. Despite being linked to dietary recommendations, these groupings contain foods of very diverse nutrient composition and environmental footprint; for example, cheese and milk are both classified as dairy products and deli meats were in the same group as fish and eggs. A challenge for future research will be to identify the most adequate food groupings for defining sustainable diets.

Conclusion

In conclusion, it appeared that neither the 100 g nor the 100 kcal functional unit would be 'best' to identify foods more likely to be included in sustainable dietary patterns. An alternative functional unit integrating foods' nutritional quality and possibly other sustainability criteria may represent a more adequate option. The study showed that the choice of functional unit is crucial since it can lead to very different conclusions regarding individual foods. With the perspective of integrating the present data at diet level, both the weight and energy functional units were useful to understand which foods were more favourable on the three sustainability criteria assessed in the analysis. Nevertheless, another option to identify sustainable would be to start by identifying sustainable dietary patterns and then classify foods according to their position in such patterns. In all cases, further transdisciplinary investigations are needed to fill the data gap with respect to food-level environmental impact indicators and to ensure that both the public health and environmental dimensions of sustainable diets are adequately assessed when designing new diet recommendations.

Acknowledgements

Helsinki and all procedures involving human subjects/ patients were approved by the French Data Protection Authority (Commission Nationale Informatique et Libertés).

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1368980015000579

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