

# Measures and metrics of sustainable diets with a focus on milk, yogurt, and dairy products

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*The 4 domains of sustainable diets are nutrition, economics, society, and the environment. To be sustainable, foods and food patterns need to be nutrient-rich, affordable, culturally acceptable, and sparing of natural resources and the environment. Each sustainability domain has its own measures and metrics. Nutrient density of foods has been assessed through nutrient profiling models, such as the Nutrient-Rich Foods family of scores. The Food Affordability Index, applied to different food groups, has measured both calories and nutrients per penny (kcal/\$). Cultural acceptance measures have been based on relative food consumption frequencies across population groups. Environmental impact of individual foods and composite food patterns has been measured in terms of land, water, and energy use. Greenhouse gas emissions assess the carbon footprint of agricultural food production, processing, and retail. Based on multiple sustainability metrics, milk, yogurt, and other dairy products can be described as nutrient-rich, affordable, acceptable, and appealing. The environmental impact of dairy farming needs to be weighed against the high nutrient density of milk, yogurt, and cheese as compared with some plant-based alternatives.*

## INTRODUCTION

The definition of sustainable diets, as developed by the Food and Agriculture Organization,<sup>1</sup> is broadly organized around 4 principal domains: nutrition, economics, society, and the environment. Sustainable food patterns need to be nutritionally adequate, economically affordable, and socially acceptable, as well as sparing of ecosystems and biodiversity.<sup>1,2</sup> Sustainability has been defined as a state in which population food and nutrient needs are fully met at all times and will continue to be met for future generations.<sup>3</sup>

Concerns about the sustainability of human diets have been incorporated into some dietary guidelines, but not all.<sup>4,5</sup> Much of the debate has centered on agricultural production methods and on the environmental footprint of livestock as opposed to grains and other

plant foods.<sup>6,7</sup> The prevailing view has been that plant-sourced foods are more environmentally sustainable than are animal products, meat, milk, and dairy<sup>4</sup> and provide equivalent if not better nutritional value. Studies have explored the likely environmental benefits of replacing current diets with vegetarian, vegan, or Mediterranean-style food patterns.<sup>4,7</sup> Widespread adoption of plant-based diets was expected to spare natural resources while improving diet quality and global public health.<sup>8,9</sup>

Designing food patterns that are simultaneously nutrient-rich, low-cost, culturally acceptable, and environmentally friendly is more challenging than it first appears.<sup>2,10</sup> There are some inherent tensions and contradictions across the 4 sustainability domains. First, higher dietary nutrient density is linked to higher per-calorie diet cost.<sup>11</sup> Analyses of diet costs, conducted in

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**Table 1 The 4 domains of food sustainability and the corresponding metrics**

Sustainable foods	Measures and metrics
Nutrient-dense	Nutrient profiling
Affordable	Affordability, value chains
Cultural and societal value	Context and patterns of use
Planet-friendly	Land, water, energy, greenhouse gas emissions

the United States,<sup>12</sup> France,<sup>13,14</sup> the United Kingdom,<sup>15</sup> and now Mexico,<sup>16</sup> all showed that empty calories were cheap, whereas more nutrient-rich diets were generally more expensive.<sup>11,12,17</sup> Second, the more nutrient-rich diets carried a higher environmental cost.<sup>18,19</sup> Animal-sourced foods, including meat, poultry, fish, milk, and dairy, had a higher nutrient content per calorie but were also associated with higher water, land, and energy uses than were staple grains.<sup>18–21</sup> Food waste at the consumer level was higher for nutrient-rich fresh produce than for some shelf-stable processed and packaged foods. Finally, cultural factors had a major impact on food choices, both regionally and globally. Foods inconsistent with societal norms were often viewed as not socially or culturally acceptable.<sup>22</sup> Foods may be nutrient-rich, affordable, and even environmentally friendly, but they can still be rejected by the consumer.

What is healthiest for people may not be optimal for the planet and vice versa. By all reports, the plant crop with lowest land, water, and energy costs was sugar.<sup>19,23,24</sup> Focusing on the environmental footprint of food production as the sole standard for sustainable diets can run counter to human nutritional needs. For example, livestock remains a major source of key nutrients in the human diet.<sup>25</sup> The environmental impact of alternative food patterns needs to be weighed against their cost and nutritional value.<sup>20</sup> Recent studies from the United Kingdom<sup>10–12</sup> and France<sup>13–16</sup> have identified hybrid diets that preserved animal-sourced foods but had a lower impact on the environment relative to current diets.

The 4 domains of food sustainability and the corresponding metrics are shown in Table 1. The creation of each of the metrics requires specific input data at the local or national level. To identify food patterns that are optimally sustainable for both people and the planet, some trade-offs across the 4 sustainability domains may need to be made. Linear programming models have become useful tools in identifying optimized food patterns that are subject to multiple nutrition, cost, environmental, and consumption constraints.<sup>26,27</sup>

## ENERGY AND NUTRIENT DENSITY OF FOODS

The nutrient profiling (NP) methodology rests on the twin concepts of energy density and nutrient density of

foods.<sup>28</sup> Energy density is expressed as kilocalories per 100 g. Nutrient density is variously expressed as nutrients per 100 g, per 100 kcal, or per serving size.<sup>29</sup> The purpose of NP models is to distinguish foods that are energy-dense from those that are nutrient-rich.<sup>30</sup>

Nutrient profiling models have been used for multiple purposes. Originally intended to justify the adjudication of nutrition and health claims,<sup>28</sup> NP has been used as the basis for front-of-pack logos and to restrict marketing of food products to children. Energy density metrics and NP models have also been used to justify taxation of selected beverages and foods.<sup>16</sup> More recently, the food industry has been using NP tools to assess and improve the nutrient quality of product portfolios.<sup>31</sup> Among recent entrants to NP initiatives for health promotion are the World Health Organization Regional Office for Europe and the Pan American Health Organization.<sup>32,33</sup>

Developing NP models for single foods (or food patterns) requires access to nutrient composition, prices, and consumption data. Input data for the nutrition, affordability, and acceptance metrics in the present analyses came from the US Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies (FNDDS 2009–2010). The FNDDS nutrient composition databases are used to analyze food consumption data from the What We Eat in America (WWEIA) dietary intake interview in the National Health and Nutrition Examination Survey (NHANES). National food prices for all foods consumed by NHANES 2009–2010 participants came from the USDA national food prices database, adjusted for inflation and matched with FNDDS 2009–2010 food codes, as described previously.<sup>34</sup> Consumption frequencies, a reliable measure of food acceptance across population subgroups, came from the NHANES 2009–2010 survey.<sup>34</sup>

Analyses reported herein were restricted to foods that were listed 5 or more times on the first day of the NHANES 2009–2010 survey. Following past procedures,<sup>34</sup> baby foods and formula diets were excluded. Foods with energy density <10 kcal/100 g (noncaloric beverages, unsweetened coffee, and tea) were excluded from energy cost calculations. All analyses were based on 2342 foods, aggregated to 9 USDA major food groups and to approximately 150 WWEIA food categories, also developed by the USDA.<sup>35</sup> Data presented herein are for selected food categories only, to better illustrate differences among milk and dairy; meat, poultry, and fish; eggs and beans; grains; vegetables and fruit; and fats and sweets.

The analyses herein illustrate how the concepts of nutrient density, affordability, and cultural acceptance apply to milk and dairy products. Input data for developing metrics based on the environmental footprint of individual food or food patterns tend to be more

limited. Although the carbon footprint of foods and food patterns has been estimated in the United States,<sup>36</sup> United Kingdom,<sup>37</sup> France,<sup>19</sup> the Scandinavian countries,<sup>38</sup> and globally,<sup>7</sup> data on GHGE emissions associated with individual foods in the FNDDS 2009–2010 dataset are not available.

Furthermore, data on land and water uses associated with agriculture and livestock farming are context specific, given that natural resources and agricultural practices can vary widely by geography and climate. Data on the environmental footprint of food production collected in the United Kingdom, France, or the Netherlands may not readily apply to Australia, South East Asia, or the United States.<sup>39</sup> These constraints make the modeling of the environmental impacts of the human diet a conceptual and methodological challenge.

### ENERGY DENSITY

The energy density of foods is defined in terms of dietary energy per unit weight of food, edible portion (kcal/100 g). In general, energy density of foods is largely driven by their water content. Figure 1 shows the strong relationship between mean energy density (kcal/100 g) and mean water content (g/100 g) for selected food and beverage categories in the FNDDS 2009–2010 dataset. The size of the bubble represents the relative number of foods within each category in the FNDDS 2009–2010 dataset.

Fluid milk, juices, soft drinks, vegetables, and fruit had high water content and therefore low energy density. Dairy products, including yogurts and cheeses, and meats, poultry, and fish contained 30%–60% moisture. At the other extreme, the most energy-dense foods were foods that were dry, including grain snacks, candy, and chocolate, as well as fats and oils. Energy-dense foods, which deliver the most calories per unit volume, have been linked to overeating in laboratory-based studies.<sup>40</sup>

Figure 2 shows the relationship between mean energy density of foods (kcal/100 g) and mean calories per serving. Servings were based on reference amounts customarily consumed (RACC), as defined by the US Food and Drug Administration (FDA) and used to calculate percentage daily values for the nutrition facts panel. In general, the FDA-assigned RACC values are inversely linked to the energy density of foods: for example, only 30 g for dry cereals but 240 mL for fluid milk.

As shown in Figure 2, low energy density vegetables and fruit generally provided <100 kcal per serving. Low energy density milk and yogurt provided 100–200 kcal per serving on average. The dry and more energy-dense grains, fats, and sweets provided equivalent amounts of energy but contained in a much smaller volume.

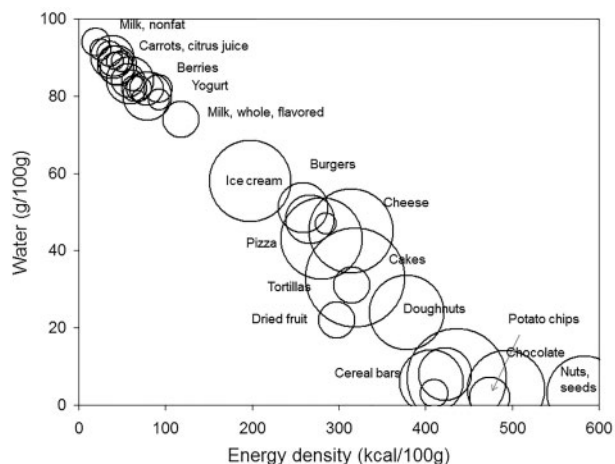


Figure 1 The relationship between mean energy density (kcal/100 g) and mean water content (g/100 g) for selected food categories in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset. The size of the bubble represents the number of foods within each category.

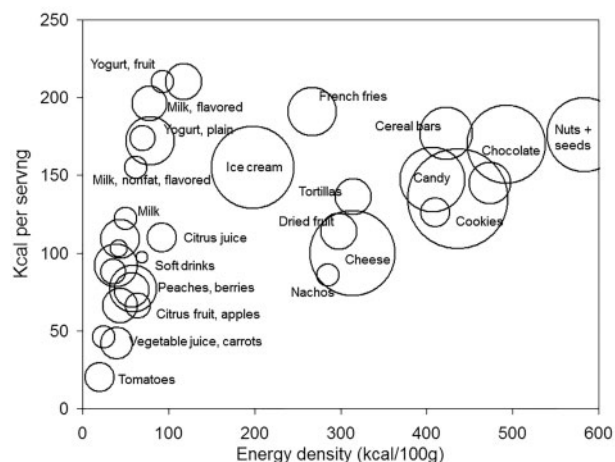


Figure 2 The relationship between mean energy per serving (kcal/reference amounts customarily consumed) for selected food categories in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset and their mean energy density (kcal/100 g). Servings are based on US Food and Drug Administration reference amounts customarily consumed. The size of the bubble represents the number of foods within each category.

Dietary energy density is calculated as the energy contained in the total weight of the daily diet. Water and noncaloric beverages are generally excluded from calculations.<sup>41</sup> High dietary energy density has been associated with lower nutrient density but also with lower per-calorie diet cost.<sup>42</sup>

### NUTRIENT DENSITY METRICS

The goal of NP is to distinguish between energy-dense and nutrient-rich foods. By popular definition,

energy-dense foods contain more calories than nutrients, whereas nutrient-rich foods contain more nutrients than calories. Nutrient profiling models can be used to rank individual foods or assign foods into categories based on their nutrient content relative to food energy. Although the base of calculation can vary (100 g, 100 kcal, or serving), the nutrients-to-calories ratio is perhaps the most common approach. Although many composite NP systems now exist,<sup>32,33</sup> 1 way to illustrate the concept of nutrient density is 1 nutrient at a time.

Figure 3 shows mean calcium content in milligram per 100 kcal for selected USDA food categories in relation to their energy density (kcal/100 g). As noted before, most dairy products were low in energy density, providing < 120 kcal/100 g. Milks and yogurts, and especially cheeses, provided substantial amounts of calcium per 100 kcal. By contrast, the more energy-dense foods to the right of the chart (mostly grains and sweets) had a low calcium-to-calories ratio.

Nutrient profiling models generally use > 1 nutrient. A crude 2-nutrient NP model can be constructed using protein and calcium only. Figure 4 shows the relationship between mean calcium content (x axis) and mean protein content (y axis), both expressed per 100 kcal. First, only animal-sourced foods had > 4 g protein per 100 kcal on the average. Although plant foods did contain protein, the ratio of protein to calories (effectively, protein density) was less favorable. These differences might be greater if protein quality were included in the NP model. Based on some estimates, plant protein consumption would need to increase by 30%–40% to equal protein quality from animal-sourced foods.

Second, only a few food categories combined high calcium and high protein content with relatively low energy density. Milk and milk products were the only food groups that provided both protein and calcium at relatively low energy cost. Burgers, pizza, and ice cream also provided protein and calcium, but their energy content was higher. As shown in Figure 4, milk and dairy products had a more favorable 2-nutrient matrix than did many other foods and could therefore be classified as nutrient-rich foods, providing relatively more nutrients than calories.

In practice, existing NP models are much more complex and are based on > 2 nutrients.<sup>30</sup> The number of index nutrients in published NP models has ranged from 5 to 40.<sup>29,43</sup> Generally, qualifying nutrients have included protein, fiber, and selected vitamins and minerals. Their content was calculated per reference amount: 100 g, 100 kcal, or serving. Disqualifying nutrients have typically included saturated fat, added sugar, and sodium.<sup>29,30</sup> Nutrient bioavailability has not been a part of mainstream NP models. However, as

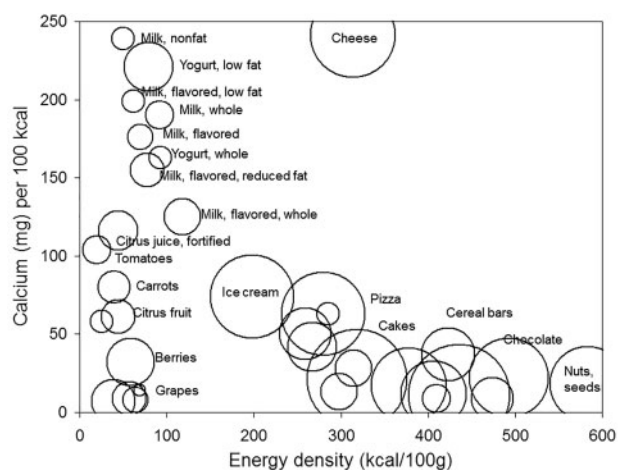


Figure 3 The relationship between mean calcium content in milligrams per 100 kcal (mg/100 kcal) for selected food categories in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset and their mean energy density (kcal/100 g). The size of the bubble represents the number of foods within each category.

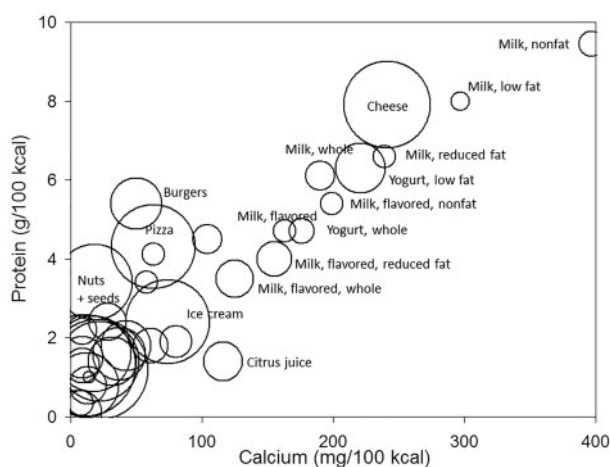


Figure 4 The relationship between mean calcium content in milligrams per 100 kcal (mg/100 kcal) and mean protein content per 100 kcal (g/100 kcal) for selected food categories in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset. The size of the bubble represents the number of foods within each category.

high-income countries trend toward more plant-based diets, protein quality and the bioavailability of calcium and iron may become future issues of concern, as they already are in low- and middle-income countries.<sup>44</sup>

The Nutrient-Rich Foods (NRF) family of scores is based on a varying number of qualifying nutrients and 3 disqualifying nutrients.<sup>30</sup> The best-described NRF9.3 index is based on 9 qualifying nutrients: protein, fiber, vitamin A, vitamin C, vitamin E, calcium, iron, potassium, and magnesium. The 3 disqualifying nutrients (otherwise known as nutrients to limit) are saturated



fat, added sugar, and sodium. The NRF algorithm is the sum of percentage daily values (DV) for the 9 qualifying nutrients minus the sum of percentage DVs for the 3 disqualifying nutrients, each calculated per 100 kcal and capped at 100% DV. The NRF score has been validated in regression models against the Healthy Eating Index, an independent measure of a healthy diet. In recent studies, the NRF index has been applied to the nutrient density of snacks,<sup>45</sup> foods and beverages,<sup>46</sup> and the total diet.<sup>47</sup>

The French SAIN,LIM nutrient density score classifies foods into 4 classes based on two scores: a nutrient density score (NDS) called SAIN and a score of nutrients to limit called LIM. This scoring system, also described in the literature,<sup>11</sup> uses the mean of percentage DVs for 5 qualifying nutrients (protein, fiber, vitamin C, calcium, and iron) minus the mean of percentage DVs for the 3 disqualifying nutrients (saturated fat, added sugar, sodium). Unlike the continuous NRF score, the SAIN,LIM score assigns foods into 1 of 4 categories. The SAIN,LIM system has now been superseded by the simplified nutrition labeling system, known as the SENS algorithm.<sup>48</sup>

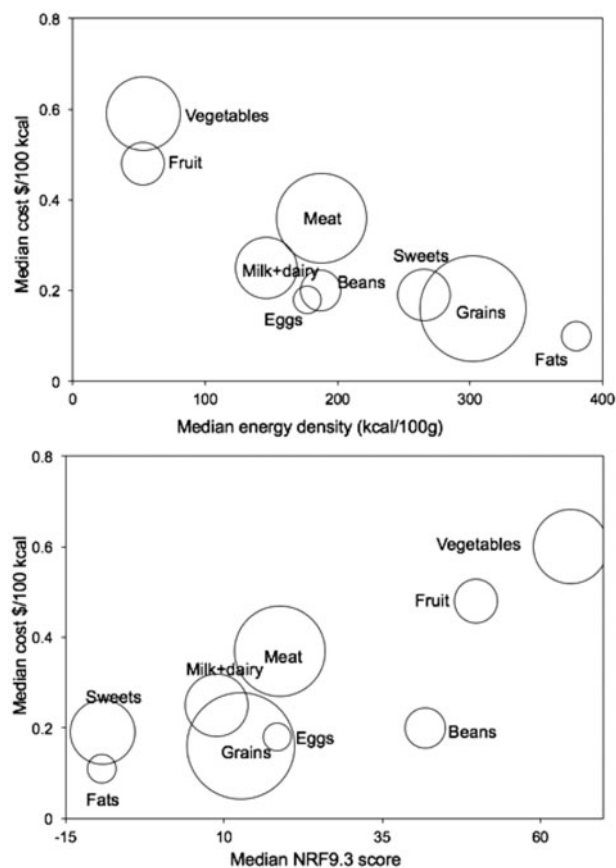
The concept of nutrient density permits further calculations of monetary and environmental costs of individual foods and composite food patterns.<sup>49</sup> Vitamin D may be included in future NRF models now that the nutrient composition data have become available. Future NRF models might also consider food sources of saturated fat, given current research on dairy saturated fats and health.<sup>50,51</sup>

### FOOD AFFORDABILITY METRICS

Food affordability has been measured in terms of calories or nutrients per penny.<sup>12,17</sup> Nutrient profiling methods can identify the lowest-cost foods in the food supply.<sup>34</sup> Figure 5 shows the relationship between median energy density (kcal/100 g) and nutrient density of selected USDA food categories and their median cost per 100 kcal (\$/100 kcal). Nutrient density was measured using the NRF9.3 score.<sup>49</sup>

The data are for 2342 foods from FND DS 2009–2010, now aggregated into 9 major USDA food groups. The groups were milk and dairy; meat, poultry, and fish; eggs; dry beans and legumes; grains; fruits; vegetables; fats and oils, and sweets, including sugar-sweetened beverages. Figure 5A shows that vegetables, fruit, and meat, poultry, and fish cost more per 100 kcal, whereas sweets, grains, and fats cost less. Milk and dairy had lower energy density than sweets, grains, and fats and cost less than meat, poultry, and fish. In Figure 5A, the cost and energy density of milk and dairy were close to those of beans and eggs.

Figure 5B shows that fats and sweets had the lowest NRF scores. Vegetables and fruit had the highest NRF.3 scores, followed by beans. Within the milk group, low-fat



**Figure 5 A, The relationship between median energy density (kcal/100 g) and median cost per 100 kcal (\$/100 kcal) for foods in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset aggregated to 9 major US Department of Agriculture food groups. B, The relationship between median nutrient density (Nutrient-Rich Foods 9.3 score) and median cost per 100 kcal (\$/100 kcal) for foods in the Food and Nutrient Database for Dietary Studies 2009–2010 dataset aggregated to 9 major US Department of Agriculture food groups. The size of the bubble represents the number of foods within each group. Abbreviation: NRF9.3, Nutrient-Rich Foods 9.3.**

milk, and low-fat yogurt had the highest NRF scores. Cheeses generally obtained lower scores; although high in protein and calcium, cheeses also contain sodium and saturated fat. Whereas the milk and the sweets groups were roughly equivalent in terms of per-calorie cost, the milk group had a higher overall nutritional value.

The relationship between diet quality and cost is a global health issue. To date, most studies on the relative affordability of healthier diets have been conducted in high-income countries.<sup>11</sup> There is a need for comparable studies to be conducted in low- and middle-income countries and across different socioeconomic groups. A recent econometric study of the cost of diets in Mexico showed that local food patterns were also driven by food prices and socioeconomic status.<sup>16</sup> The structure of food prices was such that energy-dense grains, fats,

and sweets cost less per calorie than did milk and dairy, meat, vegetables, and fruit.<sup>16</sup> Lower-cost diets in Mexico derived more calories from tortillas, tamales, beans, and sugar, whereas higher-cost diets contained more nonessential energy-dense foods, sugar-sweetened beverages, fruits, and vegetables.<sup>16</sup> Lower-cost diets with more tortillas and lard were more likely to be consumed by the rural poor. Obesity rates in Mexico, once restricted to the rich, are now increasing among the poor.<sup>16</sup>

## FOOD ACCEPTANCE MEASURES

Sustainable food patterns need to be socially acceptable. Identifying nutritious foods at lowest cost is only a part of the challenge. The USDA Thrifty Food Plan identified ground turkey, chickpeas, and condensed or powdered milk as being both nutrient-rich and inexpensive. Calculated value metrics for US foods showed that nuts, seeds, legumes, cereals, carrots, potatoes, and cabbage all offered good nutrition at an affordable cost.<sup>52</sup> However, not all nutrient-rich foods find universal acceptance: some can be socially or culturally inappropriate and fall outside the accepted social norms.<sup>22</sup>

Foods that are consumed by a small minority of the population are not a part of mainstream eating habits. Foods that are eaten rarely may be unpopular or inaccessible. In past studies, food frequency of consumption across population subgroups has been used as 1 metric of cultural acceptance. Diet optimization conducted in France using linear programming models has generally excluded rarely eaten foods that were not a part of the cultural food repertoire.<sup>22</sup> The French view is that rarely eaten or unpopular foods have no place in realistic dietary guidelines.<sup>22</sup> By contrast, the prevailing US view is that dietary habits must change.<sup>53</sup> The healthy food patterns created by the USDA<sup>54</sup> require that the consumption of selected foods or food groups come down to zero or, alternatively, increase by several hundred percent.

French linear programming models were used to develop food plans that were both nutrient-dense and inexpensive. The cheapest food patterns that provided adequate calories and nutrients cost as little as €1.50/day. However, such patterns provided little variety and were socially unacceptable in France. The progressive imposition of cultural norms sharply increased costs without improving nutritional value. Food patterns that satisfied cultural norms turned out to be more expensive than the simple provision of nutrients and calories.

The search for alternative proteins illustrates some of the necessary trade-offs among nutrition, economics, environmental impact, and cultural acceptance. Here, food preferences are the expression of social and

cultural identity. Although red meat and fish are acceptable sources of quality protein and other nutrients, their production is associated with depletion of natural resources and high environmental cost. Although plant proteins from pulses and soy are well-established in human diets, proteins from insects or from brown and green algae may have different degrees of sensory or cultural appeal.<sup>55</sup> Selection of dietary sources of protein, in particular, may be determined by religion, society, and culture,<sup>56</sup> in addition to economics. Furthermore, the amount and quality of protein from meat and dairy are higher than what can be obtained from any plant foods. As the search for affordable, nutrient-rich foods continues, the social and cultural drivers of food choice need to be addressed as well.

## ENVIRONMENTAL IMPACT METRICS

The production, processing, transportation, retail, and storage of foods are each associated with greenhouse gas emissions (GHGEs), otherwise known as the carbon footprint or carbon cost. Greenhouse gas emissions (mostly methane gas) calculated through lifecycle analyses are often expressed in grams of carbon dioxide equivalents per unit weight.<sup>36</sup> Measures of land and water use associated with agricultural production and food processing are not as readily available for individual foods or food categories.

Studies on the relationship between the nutrient density of foods and GHGE cost have uncovered some paradoxes. Typically, calculations showing lower environmental impact of plant-based as opposed to animal-sourced foods were calculated per unit weight—that is, per kilogram of food. Here, the base of calculation (100 g or 100 kcal) makes a big difference. Vegetables may have a low carbon footprint per unit weight, but many vegetables are 90% water, which provides no calories and no nutrients. Greenhouse gas emissions associated with the production of vegetables may be low when expressed per 100 g but become much higher when expressed per 100 kcal.<sup>57</sup> Given differences in energy density across food groups (see [Figure 1](#)), continuing to express carbon cost per kilogram makes little sense.<sup>24</sup>

The carbon footprint of diets is normally expressed per calorie, as it should be.<sup>20</sup> That is because human daily energy requirements are invariably expressed in calories; there is no human requirement for a daily weight of foods. Diet quality measures, such as the Healthy Eating Index, are adjusted per 1000 kcal to separate diet quality from total energy intakes. In past studies, diets that contained more fruits and vegetables and fewer sweets and salted snacks and had more favorable nutrient-to-calorie ratios were associated with

significantly higher GHGEs per calorie.<sup>18,19</sup> Based on lifecycle analysis values for France, refined grains, fats, and sweets had a lower carbon footprint per calorie than did animal products, vegetables, and fruit. An increase in diet quality came with a rise in carbon costs.<sup>19</sup>

In addition to calories, the carbon cost of foods can also be expressed per nutrient. This approach was taken in analyses of GHGE values associated with foods sold by a French supermarket chain, Casino.<sup>24</sup> Nutrient composition data for 483 foods and beverages were obtained from the French Agency for Food, Environmental and Occupational Health and Safety. Foods were aggregated into 34 food categories and 5 major food groups as follows: meat and meat products, milk and dairy products, frozen and processed fruit and vegetables, grains, and sweets. The nutrient density of the foods, determined using NP scores for 6 and 15 nutrients, was associated with a higher carbon footprint. Meat, milk, and dairy products had higher GHGE values per 100 g but much lower values per 100 kcal. Grains and sweets had the lowest GHGEs using both methods but were also high in energy and low in nutrients. Determining the point at which the higher carbon footprint of some nutrient-dense foods is offset by their higher nutritional value is a priority area for additional research.

### MILK AND DAIRY FOODS IN SUSTAINABLE DIETS

Milk and dairy products, including yogurt, provide relatively more nutrients than calories and therefore meet the nutrient density test. Based on NP work conducted in France and the United States, milk and dairy account for a small proportion of dietary energy but provide the bulk of dietary calcium and other vitamins and minerals to the population diet. The USDA has noted that dairy products are an important dietary source of multiple micronutrients, including calcium, phosphorus, magnesium, zinc, iodine, potassium, vitamin A, vitamin D, vitamin B12, and riboflavin (vitamin B2).<sup>58</sup>

Milk and dairy products meet the requirements of the affordability test, providing dietary calcium at the lowest cost by far as compared to calcium cost per penny from all other major food groups. Milk and dairy products also provide high-quality protein. Based on data from France, dairy products can meet calcium requirements at a low cost and without burdening the consumer with excessive calories, sodium, or saturated fat.<sup>59</sup>

As low- and middle-income countries undergo nutrition transition, food patterns shift from traditional plant proteins to animal proteins. However, the choice of protein can be specific to a region and country, often driven by custom, religion, and culture. Whereas some populations have increased the consumption of meat, notably pork and beef, others have retained the

traditional plant-based diets. For those countries, milk and dairy products may become the preferred source of animal protein.

Based on these measures and metrics, milk and dairy products can be described as nutrient-rich, affordable, and appealing. Modern farming practices have also lowered the impact on natural resources and the environment.

### CONCLUSION

Few food groups satisfy all 4 domains of sustainability: nutrition, economics, society, and the environment. Some trade-offs need to be made. The main point, inherent in the Food and Agriculture Organization definition of sustainable food patterns, is that the nutrient needs of humans and economic limitations need to be weighed against agricultural production and environmental constraints. There are ongoing efforts to modify agricultural practices and so reduce the environmental cost of livestock and fisheries. There are also ongoing efforts to develop indicators for sustainable diets and resilient food systems.<sup>60</sup> Research in this area would benefit from more input data on the nutrient density and the monetary and environmental costs of different foods, with special attention to animal and plant proteins. Future NP models, coupled with diet optimization techniques, will need to address these emerging concerns.

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