

Chapter 2

Sustainable, Healthy Diets: Models and Measures

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Abstract The definition of sustainable food and nutrition security involves four principal domains. Foods and food patterns need to be nutrient-dense, affordable, culturally acceptable, and sparing of the environment. Each domain has its own metrics. Nutrient density is measured in terms of nutrients in relation to calories. Affordability is measured in terms of calories and nutrients per unit cost. Cultural acceptance can be measured in terms of frequency of consumption by population subgroups. Lifecycle analysis (LCA) of the environmental impact of foods is based on the use of land, water, and energy resources during food production and utilization. Nutrient profiling models separate foods that are energy-dense from those that are nutrient-rich. Global economic pressures, exacerbated by climate change, may push the agro-food industry toward producing more low-cost calories and insufficient nutrients. Social disparities in diet quality may increase not only in low- and middle- income countries (LMIC) but also in the developed world.

Keywords Sustainable food and nutrition security • Sustainable diets • Nutrient density • Nutrient profiling models • Affordability • Cultural acceptance • Lifecycle analysis

2.1 Introduction

The Food and Agriculture Organization (FAO) of the United Nations has defined sustainable diets as nutritionally adequate, economically affordable, culturally acceptable, accessible, healthy, and safe [1] (Table 2.1). The FAO definition also noted that sustainable diets needed to be protective of both natural and human resources and be respectful of ecosystems and biodiversity [1].

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Table 2.1 Definitions of sustainable diets**FAO 2010**

Sustainable diets are those diets with low environmental impacts that 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 optimizing natural and human resources

Foresight 2010

Sustainability implies a state where the needs of the present and local population can be met without diminishing the ability of future generations or populations in other locations to meet their needs or without causing them harm to environment and natural assets

US Farm Bill. U.S. Code Title 7, Section 3103

Sustainable agriculture will in the long term: satisfy human food needs; enhance natural resources and the environment; use non-renewable resources in the most efficient manner; make farming economically viable; enhance the quality of life for farmers and society as a whole

The popular view seems to be that the most sustainable diets are those that are most environmentally friendly, with minimal impact on land, water, and energy resources. The environmental cost of farming and food production has been measured in terms of greenhouse gas emissions (GHGEs) expressed in carbon dioxide equivalents (CO₂e) per kg of food. Such data have been used to support the argument that locally-sourced, plant-based diets were more sustainable than diets that included animal products, mostly dairy and meat [2].

However, the FAO definition of sustainable diets does include nutrient density of the diet, its monetary cost, and likely health outcomes. The diet's impact on the environment is only one aspect of sustainability; its impact on population health is another. These diverse multi-sector criteria demand the development of new metrics to assess the nutrient density, affordability, and acceptability of different diets together with their overall impact on the environment. It may transpire that no single diet or food pattern fits all the criteria; some compromises may need to be made.

For example, studies have already shown that the most nutrient-dense diets were often the least affordable; it was empty calories that were cheap [3]. Studies from France [4] and the United Kingdom [5] have shown that the most nutrient-dense diets were associated with higher, not lower, GHGEs. Further, some affordable healthy foods were not culturally acceptable and were rejected by lower-income groups [6]. There is some question whether diets can be simultaneously low-cost and nutrient-rich, environmentally friendly and culturally acceptable. In published studies, the highest-quality diets were not the most sustainable, whereas the most sustainable diets were not necessarily the healthiest. Indeed, some studies have identified a shocking paradox. By some current metrics, the plant food that was associated with the lowest GHGEs was sugar.

Clearly, diet sustainability metrics need to go beyond carbon footprint and must take the nutritional value of foods and their health impact into account. The concept



Fig. 2.1 The food and dietary pattern metrics for the four domains of food and nutrition security. Source Original figure made for this publication

of sustainable food and nutrition security can be split into four principal domains. The four domains are dietary, economic, sociocultural and environmental. The food and dietary pattern metrics corresponding to each of the domains are indicated in Fig. 2.1 and discussed in detail below.

2.2 The Dietary Dimension

The nutrient density of individual foods can be assessed using a technique known as nutrient profiling [7]. Nutrient profile models assign ratings to individual foods based on their nutrient composition. An alternative approach is to assign foods to categories or classes, based on their overall nutritional value.

The usual goal of nutrient profiling models is to distinguish between foods that are energy-dense and those that are nutrient-rich. Some profiling models are based on calories and on nutrients that are of public health concern only: saturated fat, added (or free) sugars, and sodium that are often consumed to excess in developed countries. Profiling models can also be based on human nutrient requirements, including some shortfall nutrients that are consumed in inadequate amounts. Generally, such nutrients include protein, fiber, and selected vitamins and minerals. Their content in foods is calculated per reference amount: 100 g, 100 kcal, or serving. Balanced nutrient profiling models are based on some combination of nutrients to limit and nutrients to encourage per reference amount.

The Nutrient Rich Foods (NRF) index is a formal metric of nutrient density [8]. The positive nutrients are protein, fiber, vitamins A, C, and E, calcium, iron, potassium and magnesium, whereas nutrients to limit are saturated fat, added sugar, and sodium. The NRF algorithm is the sum of percentage daily values (DVs) for the 9 positive nutrients, minus the sum of %DVs for 3 nutrients to limit, 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.

The French SAIN,LIM score [3] is the mean of %DVs for five positive nutrients (protein, fiber, vitamin C, calcium and iron) minus the mean of percent daily values for the three nutrients to limit (saturated fat, added sugar, sodium). Unlike the continuous NRF score, SAIN,LIM assigns foods into one of four categories. The SAIN,LIM model has been validated using linear programming [3].

These nutrient profiling models, designed to capture the nutrient quality of individual foods, have been used for various purposes. In the European Union, nutrient profiling provides the scientific rationale for the potential approval of nutrition and health claims. In the US, proprietary profiling models developed by different supermarkets were expected to nudge consumer purchases toward healthier foods. In the UK, nutrient profile models were used to regulate advertising and marketing to children. Increasingly, the global food industry is using nutrient profile models to reformulate its food product portfolios. Nutrient profiling models provide a valuable metric to assess industry progress toward reducing fat, sugar and

sodium in a variety of foods. Importantly, nutrient profiling algorithms developed for use with individual foods can also be adapted to assess the nutrient quality of composite meals and daily food patterns.

There are existing metrics to assess the nutrient quality of the total diet. Measures of diet quality tend to be both food- and nutrient-based. The simplest measures are energy density and mean nutrient adequacy of the diet. Dietary energy density in kcal/g is calculated using solid foods and energy beverages. Mean adequacy ratio (MAR) is the ratio of nutrient intakes relative to the estimated requirements calculated based on national or FAO charts.

Perhaps the best known metric of diet quality is the Healthy Eating Index (HEI) developed to assess compliance with the US Dietary Guidelines for Americans [9]. The HEI is constructed based on 24-h dietary intake data from national surveys such as the National Health and Nutrition Examination Survey (NHANES). The intent of HEI is to monitor the diet quality of the US population with special attention to lower income subgroups. It has also been used to examine the relations between diet quality and health and between diet quality and diet cost.

The HEI was initially created by the US Department of Agriculture Center for Nutrition Policy and Promotion (CNPP) in 1995. It was later revised to reflect the 2005 Dietary Guidelines for Americans, and was updated in 2012 to reflect the most recent 2010 Dietary Guidelines for Americans. Alternative ways of measuring overall diet quality include the Alternative Healthy Eating Index (aHEI); Dietary Approaches to Stop Hypertension (DASH) scores; Mediterranean diet indexes, and other scores. In general, diet quality scores also tracked socioeconomic status: diet quality was higher among the rich than among the poor.

2.3 The Economic Dimension

Food affordability has been calculated in terms of calories or nutrients per unit cost [10]. Metrics of food price per calorie or calories per unit cost are typically deployed to address hunger and calorie deprivation in low- and middle-income countries. Both the FAO and the International Food Policy Research Institute (IFPRI) have used food prices per calorie to evaluate food and agriculture policies in the developing world. The World Bank uses the price of a 2100-kcal basket of reference foods to set the food poverty line. Studies on poverty in rural India calculated the cost of food commodities in rupees per 1000 kcal, showing that cereals and sugar provided calories at far lower cost than did meat, dairy, or vegetables, and fruit.

There has been resistance to applying the same FAO and IFPRI metrics to the US food supply. One view has been that all foods cost the same, such that the use of per calorie pricing is inappropriate. Yet, in the US, higher consumption of added sugars and saturated fats is associated with lower per-calorie diet cost, whereas higher consumption of fiber, vitamin C, potassium, and other nutrients is associated

with higher diet costs. Similarly, refined grains, sweets and fats cost less, whereas green leafy vegetables, seafood and whole fruit cost more.

The cost gradient may vary depending on population eating habits, agricultural subsidies, or the use of fortified or supplemented foods. For example, potassium costs might be lower if beans were the principal source of potassium in the US diet as opposed to coffee and French fries. Higher calcium consumption was not associated with higher cost, probably because of the availability of low-cost milk products in the US food supply. Likewise, folate intakes were not associated with higher diet costs, because of fortification—an important point in the nutrition of children and pregnant women.

Studies have also found direct links between HEI scores and per-calorie diet costs. More costly diets were of higher quality, and higher-quality diets did cost more. The observed social gradient in diet quality, noted in both developed and middle-income countries, may be explained in part by food prices and diet costs.

The present affordability metrics for foods and food patterns followed directly from nutrient profiling and diet quality measures. Having a global measure of nutrient density for individual foods and for total diets permitted the subsequent calculations of calories and nutrients per unit cost.

2.4 The Sociocultural Domain

Sustainable food plans need to be socially acceptable as well as affordable and nutritious. In higher-income countries, it is the lower-income groups that have low-quality diets and suffer from higher rates of obesity and non-communicable disease (NCD). One way to link food, health and incomes is through food prices and diet costs.

The search for the affordable nutrient-rich foods was made possible by nutrient profiling and by the new metrics of nutrients per energy and nutrients per unit cost. Based on analyses of nutrient composition and national food prices data, it became clear that some nutrient-rich foods were inexpensive. In the US, the USDA Thrifty Food Plan has featured ground turkey, chickpeas, and condensed or powdered milk. Rice and beans and home-cooked lentil soup have been proposed as staple diets for the US poor. Cost analyses and value metrics for US foods showed that nuts, seeds, legumes, cereals, carrots, potatoes and cabbage offered good nutrition at an affordable cost.

However, many low-cost yet nutritious foods were rejected by the consumer. Their frequency of consumption in the population was close to zero. Assuming that non-consumption equals rejection, the hypothesis was that such foods deviated from the current consumption standards; failed to meet cultural requirements; and could be socially or culturally inappropriate. The custom of the country may have placed such foods outside the accepted social norms. Frequency of consumption of a given food by the total population or its subgroups is one metric of cultural acceptance.

Mathematical optimization models, based on linear programming, have long shown that high-quality diets could be obtained at very low cost. The USDA Thrifty Food Plan (TFP) was intended to be as close as possible to the diets of low-income Americans, while simultaneously meeting both nutritional and cost constraints. The nutrient and food group constraints were based on the DGAs and MyPyramid, respectively, whereas the cost constraint was based on the amount of food assistance. To arrive at the solution, the TFP tolerated up to tenfold deviations from the current eating habits, effectively ignoring the current eating habits of the population.

To highlight the importance of cultural acceptance, a French study [6] used linear programming to develop food plans that met three levels of nutritional requirements and seven levels of increasingly stringent consumption constraints, all at the lowest possible cost. Significant deviations from the existing mainstream French diet were progressively disallowed, so that the final model had little tolerance for any deviation from the French diet. The intent was to estimate the cost of culturally acceptable healthy diets that were also consistent with French cultural expectations and societal norms.

The nationally representative INCA (National Individual Survey of Food Consumption) dietary survey study of 1332 adults provided population estimates of dietary intakes [6]. The lowest-cost food plans that provided adequate calories and met nutrient adequacy standards could be obtained for as little as 1.50 EUR/day. However, meeting nutrition standards at the lowest possible cost led to food plans that provided little variety and were unacceptable. The progressive imposition of consumption constraints based on cultural norms sharply increased costs, without improving nutritional value. In summary, modeled food patterns that were healthy and culturally appropriate were much more expensive than food patterns that were simply healthy. Food plans designed for low-income groups need to be socially acceptable as well as affordable and nutritious.

2.5 The Environmental Domain

One of many metrics of the environmental impact of foods is based on greenhouse gas emissions or GHGEs, otherwise known as carbon footprint or carbon costs. GHGEs (mostly methane gas) are often expressed in grams of CO₂ equivalents per package, can, or bottle of product. Lifecycle Analyses (LCAs) have associated different amounts of GHGEs with agricultural production, food processing, packaging, transport, distribution, and retail. Some LCAs have calculated carbon cost through the post-purchase life of the food product, including preparation, cold storage, disposal, and waste.

The development of environmental impact metrics to calculate carbon cost per calorie or per nutrient was exactly analogous to the development of affordability metrics. In both cases, calories or nutrient density measures were related to the estimates of the monetary or carbon cost. These metrics of nutrient density in relation to environmental cost were developed for individual foods and for total diets.

Some paradoxes were uncovered [5, 6]. In general, healthy diets are supposed to be more environmentally friendly because plant-based foods have lower GHGEs per unit weight than do animal-based foods. However, calculating carbon cost per 2000 kcal diet changes the picture completely, as illustrated by some recent studies.

In a recent study of 1918 French adults, higher-quality diets were defined as those of lower energy density, higher mean nutrient adequacy ratio (MAR), and lower intakes of nutrients to limit [5]. Such diets contained more plant-based foods, fruit and vegetables, and fewer sweets and salted snacks than did lower-quality diets. However, calorie for calorie, higher quality diets were associated with significantly higher GHGEs. Whereas energy-rich sweets and grains had a lower carbon footprint, better diets that were higher in fruits, vegetables, and animal products had a higher carbon footprint. The study concluded that the higher quality diets also had a higher carbon cost.

The question whether healthy diets are also good for the planet would benefit from a more extended debate. Animal food products, meat and dairy, are said to consume land and water resources to excess and to contribute to greenhouse gas emissions more than other foods. On the other hand, transport of out-of-season fresh produce by air has its own very considerable carbon costs.

However, additional indices of environmental impact will be needed. Agricultural production has an impact on soil, water, air, agro-ecosystem biodiversity, wildlife habitats, and landscape. Among the many indicators of sustainable farming are soil quality and soil protection, fertilizer and pesticide use, land conservation, and other aspects of land management. Other measures have included water quality and resources, fertilizer runoff, air pollution, crop modeling, labor and economics.

The US legal definition of sustainable agriculture is based on the 1990 Farm Bill. It is sufficiently broad to encompass the ecological, economic, and social components of sustainable agriculture, referring not only to food production, but also to economic viability, and quality of life. Sustainable farms need to be viable businesses, contributing to the rural economy in terms of employment and incomes. At this time, these new domains have not yet been incorporated into the framework shown in Fig. 2.1.

2.6 Integrated Modeling

Diet quality and health outcomes are very much a part of the ongoing sustainability debate. Global food policies should address the complex interplay between diet quality, monetary costs, and cultural and environmental factors in relation to health. The existing food systems need to assure global food security in the face of population growth and climate change. Sustainable nutrition needs to provide a balance of both calories and nutrients, prevent malnutrition and hidden hunger, and minimize obesity risk [11].

Ongoing research tells us that sugars and grains are generally cheaper per calorie than are some nutrient-rich foods [12]. Cereal and oilseed crops, not meat or dairy, account for most of the calories in the global food supply. Corn, wheat, rice, soy, and sugar cane are all staples that yield inexpensive dietary energy and provide fat, refined carbohydrates, and protein. Climate change will only intensify the pressure to increase the yields of low-cost, energy-dense crops.

Clearly, diet sustainability metrics must go beyond mere carbon footprinting to take the nutritional value of foods into account. Feeding the world in the face of population growth, poverty, and climate change poses new challenges to agro-food industries. Global agriculture is highly vulnerable to the depletion of natural resources, land, water, and energy that may result from global warming. Hidden hunger is one potential consequence as the global food production shifts toward more calories, rather than nutrients.

2.7 Summary: : Key Messages

- Sustainable food and nutrition security involves four principal domains: Foods and food patterns need to be nutrient-dense, affordable, culturally acceptable, and sparing of the environment.
- Each domain has its own metrics. Nutrient density is measured in terms of nutrients in relation to calories. Nutrient profiling models separate foods that are energy-dense from those that are nutrient-rich. Affordability is measured in terms of calories and nutrients per unit cost. Cultural acceptance can be measured in terms of frequency of consumption by population subgroups.
- Lifecycle analysis (LCA) of the environmental impact of foods is based on the use of land, water, and energy resources during food production and utilization.
- Global economic pressures, exacerbated by climate change, may push the agro-food industry toward producing more low-cost calories and insufficient nutrients. Social disparities in diet quality may increase not only in low- and middle- income countries (LMIC) but also in the developed world.

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