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A comparative analysis of sustainability of the usual food intakes of the Iranian population, Iranian food-based dietary guidelines, and optimized dietary models

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Promoting sustainable diets might contribute toward achieving sustainable development goals. Considering the importance of national food-based dietary guidelines (FBDGs), this study aimed to assess and compare the sustainability dimensions of the usual Iranian dietary intakes with sustainable optimal diets based on Iranian (2006 and 2015 versions), Mediterranean, and vegetarian FBDGs. The usual dietary intakes of Iranian households were estimated using household expenditure survey data. Diet sustainability, including environmental (water, carbon, and land) footprints, cost, and nutrient-rich food (NRF) index, was calculated for the usual diet and compared with those of different FBDGs. Using linear and goal programming, optimal food models were calculated by minimizing environmental footprints and cost and maximizing NRF simultaneously for each FBDG, while maintaining nutritional considerations recommended by the FBDGs. Replacing the usual dietary intake of Iranians with the optimal diet based on the 2016 Iranian FBDG was associated with reductions equal to 20.9% for water footprint, 22.48% for carbon footprint, 20.39% for land footprint, 31.83% for cost, and 7.64 % increase in NRF index. The optimal model based on the 2016 Iran FBDG was 10% more sustainable compared with the 2005 version. Changing the usual consumption of Iranians to the optimal model based on the Mediterranean pyramid was accompanied by the highest NRF index, lower environmental footprints, and cost compared to other models. The recent Iranian FBDG, compared with the older one, was more sustainable. Considering the dimensions of a sustainable diet for future FBDG revisions is recommended.

KEYWORDS

Iran, sustainable diet, goal programming, optimization, food-based dietary guidelines

Introduction

Economic and environmental issues confronting modern food systems threaten global long-term food security and natural resource management (El Bilali et al., 2019). On the one hand, the triple burden of malnutrition (micronutrient deficiencies, undernutrition, and diet-related noncommunicable disease) continues as one of the most serious socioeconomic and health problems (Horton et al., 2009), and on the other hand, 29–30% of all greenhouse gas emissions (Vermeulen et al., 2012) are produced due to the current food system. Therefore, an urgent transition toward a sustainable food system that provides for a healthy diet is proposed as one of the solutions to provide planetary health, fulfill adequate and healthy food for the growing population, and might contribute toward achieving SDGs by 2030 (El Bilali et al., 2019; Fanzo, 2019). Such a transition requires changes in food production and processing subsystems as well as consumer education and empowerment to adopt a sustainable diet. Sustainable diets are not only healthy, safe, nutritionally adequate, culturally acceptable, and accessible but also have reduced environmental impacts. The composition of a sustainable diet is context-specific and based on the health and disease profile of each country, the current food habits, and the associated socioeconomic factors (Tuomisto, 2019). For example, typical vegetarian or Mediterranean diets are considered sustainable, but they might not be applicable in many lower-middle-income countries (LMICs) without taking into account considerations based on specified micronutrient deficiencies within the population (Tuomisto, 2019). Therefore, evaluation and integration of sustainability aspects while considering context-specific adaptations in the current food and nutrition action plans and consumer education programs is an essential step to promoting sustainable diets in each country (Downs et al., 2017; Sobhani et al., 2018; Tuomisto, 2018; Ahmed et al., 2019).

Food-based dietary guidelines (FBDGs) are tools used to guide consumers and policymakers toward nutritionally protective dietary patterns at national, regional, and international levels (Montagnese et al., 2019). The Food and Agriculture Organization (FAO) promotes incorporating sustainable diets into national FBDGs to ensure a win-win situation for health and the environment (Montagnese et al., 2019). However, only a few countries, e.g., the Netherlands and Sweden, have integrated sustainability into FBDGs and revised their FBDG to take into account environmental sustainability, e.g., by limiting meat consumption and choosing sustainably produced fish (Horgan et al., 2016). Measuring the magnitude of benefit from the aspects of the incorporation of a more sustainable diet into FBDGs is an initial step to understanding the impact of adding sustainability to FBDGs. There have been some studies in western countries that evaluated the sustainability aspects of dietary recommendations promoted by different FBDGs and compared usual public dietary intakes with them (van Dooren et al., 2014; Kesse-Guyot et al., 2020). In addition, some studies projected the changes associated with substituting the sustainable diet models with usual dietary intakes while adhering to different FBDGs (Blackstone et al., 2018; Brink et al., 2019; Kesse-Guyot et al., 2020; Springmann et al., 2020). However, such efforts are still rare in low- and middle-income countries.

The Eastern Mediterranean region, based on the World Health Organization (WHO) regional classification, comprises 22 countries and is a region experiencing health and nutrition transition over the last decades (Galal, 2003). The development of official FBDGs in the countries of the region is fairly recent, and so far only 10 countries have their own official FBDGs (Montagnese et al., 2019). Iran is one of the first countries in the region with an official FBDG launched in 2006 and updated in 2015 (Safavi et al., 2007). The new version of the Iranian FBDG has eight food groups and is accompanied by a list of 13 recommendations (Safavi et al., 2007). In the new version, the meat and egg group has been separated from plant sources of protein, including legumes, nuts, and seeds which are categorized into a separate group. This change was intended to put more emphasis on the daily intake of plant sources of protein (Safavi et al., 2007).

In Iran, due to the emerging concerns regarding the aging population, climate change, drought, and water resource limitations (Lotfalipour et al., 2010; Abarghouei et al., 2011; Tabari et al., 2011), moving toward a sustainable FBDG is a priority. Therefore, considering the research gap in this regard, and to provide a basis for evidence-informed policymaking, this study aimed to assess and compare nutritional, environmental, and economic aspects of recommendations promoted in the new version of Iranian FBDGs-2016 with its old version FBDGs-2005, as well as the Mediterranean, flexitarian, and vegan food pyramids.

Materials and methods

Setting and study design

This study was performed in two phases. First, the old (2005) and new (2016) Iran FBDGs, the Mediterranean, flexitarian, and vegan food pyramids, and a proxy of household food consumption based on the Iranian Households Income and Expenditure Survey (HIES) data of 2018[1], were evaluated with regard to sustainable diet components. To calculate real consumption in this data, FAO estimates of waste percentages for each food group in the consumption step "from supply to consumption chain" were considered (Eini-Zinab et al., 2021).

1 Available online at: https://www.amar.org.ir/english/Metadata/Statistical-Survey/Household-Expenditure-and-Income. This link is accessible with an Iranian IP and may not be accessible outside Iran. Please contact the corresponding author if more information is required.

Diet sustainability components included (a) environmental components (water footprint, carbon footprint, and land use), (b) nutritional quality (The Nutrient Rich Food (NRF) index), and (c) cost (see Supplementary Table 1). In the second phase, sustainable food baskets were developed based on the different FBDGs, using linear and goal programming, and the changes required in the usual consumption were calculated. Details of each step are described as follows.

Data collection

Measuring the sustainability of FBDGs

To calculate the five dimensions of sustainable diets in this study, the serving size of each food item in each food group recommended in different FBDGs was converted to equivalent grams. Then each dimension was calculated as follows:

Environmental footprint

Water footprint quantifies the amount of direct and indirect water use for a processed product or sector. The green and blue water footprints refer to both consumptive use of rainwater, surface, and groundwater, respectively. The gray water footprint shows the freshwater needed to dilute pollutants, ensuring that the quality of the water remains above existing quality standards. In this study, the green, blue, and gray water footprint data for Iran were matched to food items in our study and were converted into the water volume in cubic meters per gram (m^3/gr) (Hoekstra et al., 2009). The water footprint data for each food item, usually reported as water volume in cubic meters per ton (m^3/ton), is available for Iran. Water footprint data were converted to water volume in cubic meters per gram (m^3/g) of the foods.

To calculate the amount of carbon dioxide emission produced during food production, the 'carbon footprint' method was used. "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emission that is directly and indirectly caused by an activity or is accumulated over the life stages of a product." We used a global database for carbon dioxide emissions of each food item from the "BCFN Double Pyramid Database" (Ruini et al., 2016). The specific land requirements per food item (m^2 yearkg−1) values were obtained from different resources (Song, 2017; Kesse-Guyot et al., 2020). To calculate the water, carbon, and land footprints of each FBDG, the amount of water used, carbon food print, and land use for each food item were calculated by multiplying the related footprint by its recommended or actual consumption amount.

Diet quality

The Nutrient Rich Food (NRF) index was used as a proxy for the quality of the diet. The NRF index provides an overall nutrient density score based on the amount of selected nutrients per reference amount of food (100 kcal, 100 g, or serving size) (Afzali et al., 2020). The development of NRF index scores involves several methodological issues, including the selection of key nutrients, the choice of recommended daily allowances (RDA), and the basis of calculation (per 100 g, 100 kcal, or portion sizes). The NRF index has been previously used to assess Iranian diets. In this study, NRF was calculated in 100 g of each food item and based on nineteen recommended nutrients and three nutrients that should be limited. The positive scores, i.e., recommended nutrients, included protein, PUFA, MUFA, dietary fiber, potassium, vitamin A, vitamin C, vitamin D, vitamin E, thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, magnesium, zinc, calcium, and iron; and the negative scores were related to saturated fat, sodium, and total sugar. By subtracting the negative sub-scores from the positive sub-scores, NRF in 100 g of each food item was calculated. RDA introduced by the WHO and FAO was used as the reference recommended intake (Rahmani et al., 2011; Taghavifar and Mardani, 2015; Mirzaie-Nodoushan et al., 2020; Eini-Zinab et al., 2021).

Cost of diet

The Households Income and Expenditure Survey (HIES) data in Iran includes the price of each food item paid by households. The average price paid for 1 g of each food item over the last year was used to calculate the cost of each diet to consider the economic aspect of the sustainable diet.

Optimization of diets

Linear programming (LP) and goal programming (GL) techniques were used to optimize the sustainable food basket. The MS Excel (version 2013). Solver add-on was used to incorporate the LP and GL techniques (Mirzaie-Nodoushan et al., 2020). LP was used to optimize the sustainable food basket based on the different FBDGs, including the 2016 and 2005 Iranian FBDGs, as well as the Mediterranean, flexitarian, and vegan food pyramids. The main elements of LP models are objective, changing variables, and constraints. For each dietary guideline, LP models were applied to obtain the optimal diets, considering each goal of the sustainable food basket separately, including (1) maximum NRF, (2) minimum cost, (3) minimum water footprint, and (4) minimum carbon footprint. *Changing variables* are those decision variables manipulated to reach the objectives by considering constraints to reach the goal. The *decision variables* in this study were the amount of 194 food items. The model-produced diet is constrained to have energy intake, macronutrients, and the four most limiting micronutrients in the Iranian food basket (i.e., calcium, iron, vitamin A, and riboflavin) to the amount recommended. In addition, salt intake was limited to <5 g/day, according to the WHO recommendation (Edalati et al., 2021). The decision variables are also constrained to follow the advised serving size of food groups by the different dietary pyramids. By changing these constraints, the effect of following each dietary guideline on different aspects of the sustainable diet was investigated. The recommended number of servings for the examined FBDGs

TABLE 1 Sustainability dimensions (water, carbon, and land footprint, NRF index, and cost) of optimized diet models based on different FBDGs and the usual diet of Iranians.

Sustainable diet aspects	Usual consumption of Iranians based on HIES	Optimal model based on Iranian 2006 Pyramid		Optimal model based on Iranian 2015 Pyramid		Optimal model based on Mediterranean Pyramid		Optimal model based on Flexitarian Pyramid		Optimal model based on Vegan Pyramid	
	Total	Total	%change*	Total	%change	Total	%change	Total	%change	Total	%change
Water footprint (m^3)/day	3.9	3.6	−9.4	3.1	−20.9	3.4	−13.3	3.0	−24.01	3.0	−24.0
Carbon footprint (Kg)/day	2,323.9	1,962.9	−15.3	1,801.3	−22.4	1,841.9	−20.7	1,542.9	−33.6	1,542.9	−33.6
Land footprint (m^2)/day	5.1	3.9	−23.2	4.1	−20.3	4.5	−13.0	5.4	5.6	5.3	3.4
NRF index	23.5	21.7	−7.6	25.34	7.6	39.8	69.1	31.5	33.8	29.8	26.7
Cost (Rial)	91,993.9	63,828.7	−30.6	62,705.8	−31.8	72,058.6	−21.6	53,757.8	−41.5638	53,757.8	−41.5
The Area of Radar Chart	4,320.4	5,568.9	28.8	6,166.5	42.7	6,367.5	47.3	6,640.1	53.6	6,579.9	52.3

Percent change in optimized dietary models compared with the usual consumption.

is presented in Table 1. After running the model, the values obtained for each food item were multiplied by its footprint and the total footprint was calculated by adding these values.

To consider the food preferences (cultural acceptance) of the Iranian population, the decision variables were constrained to vary between 50% lower and 50% higher than usual food intake (Eini-Zinab et al., 2021). The usual food intake of Iranians was obtained from the Households Income and Expenditure Survey (HIES) data (2018, $n = 29{,}473$) converted to the adult male equivalent units of food intake by Eini-Zinab et al. (2021).

Maximizing the NRF index and minimizing cost, water footprint, land footprint, and carbon footprint has been done by utilizing the LP technique, which was applied to each dietary guideline separately. To design sustainable models for each FBDG that simultaneously maximizes/minimizes the five aforementioned goals, the goal programming technique was used. Similar weights ($w = 1$) were allocated to the five dimensions, including water footprint, carbon footprint, land footprint, NRF index, and cost, based on the research team members' opinions. The subsequent changes in the NRF index, cost, water footprint, land footprint, and carbon footprint related to substituting these optimized diets with the usual diet were investigated.

Radar charts were used to plot the values of each aspect of the sustainable diet of usual consumption, as well as the five sustainable models by converting all indicators to a fixed value. Since each of the indicators, including NRF index, cost, water footprint, land footprint, and carbon footprint, did not have a bounded range of possible values, the following equation was used to derive a 0–100 score:

$$\textit{Metric indicator}_i = 100 \times \exp[\ln(0.5) \times (F_i/F_{50})]$$

Where F_i is the factor (e.g., GHG emissions) for the i_{th} unit (e.g., food dietary guideline) under consideration, and F_{50} is the median (50th percentile) of the full range of values for this factor across all units of interest. Therefore, each of the indicators was scored from 0 to 100, with higher values being desirable (Gustafson et al., 2016). To align the changes in the NRF index with other dimensions, the sign of its value was reversed. The area of the radar chart was also calculated. The bigger the area, the higher the sustainability.

Results

Water footprint, carbon footprint, land footprint, NRF index, and cost of the usual diet and the five optimized diets, based on different FBDGs, as well as percent difference from usual consumption and the area of radar chart for each of the five models, are presented in Table 1.

The optimal model based on the new version of Iran FBDGs-2016 compared with its old version (2005) had a 10% bigger area of the radar chart, i.e., 10% more sustainable; however, the

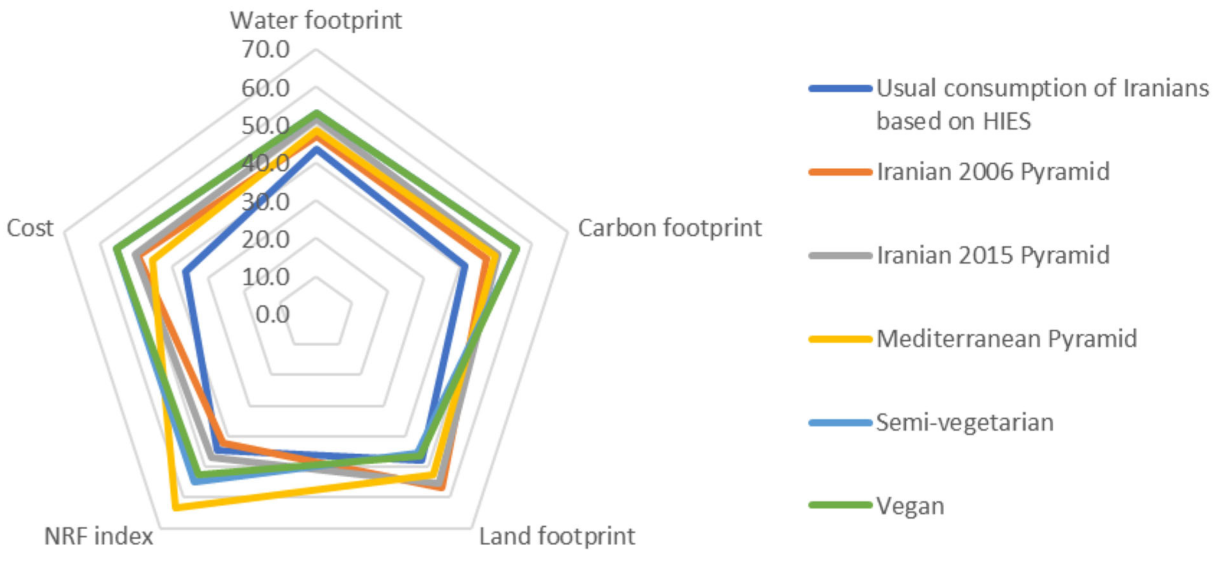

FIGURE 1
Comparison of dimensions of sustainability for the usual diet of Iranians and the optimized five sustainable diet models.

2005 version had a lower land footprint. The recent Iran FBDGs-2016 can result in lower cost, water footprint, and carbon footprint and provide equal nutritional value compared with its old version (2005).

The radar chart compares each dimension of sustainability for the usual Iranian consumption and the five diet models (Figure 1). The models based on flexitarian and vegan diets were overall the most sustainable, considering the higher area of the radar chart. The usual consumption of Iranians deviated the most from the vegan pyramid model in terms of environmental dimensions (water footprint, carbon footprint, and land footprint) and price. Changing the usual consumption of Iranians to the optimal model based on Mediterranean Pyramid was accompanied by the highest NRF index, as well as lower water footprint, carbon footprint, land footprint, and cost.

In addition, the model based on both Iranian dietary guidelines was more sustainable than the usual food consumption of Iranians (Table 1).

The servings for each food group of the five optimal diets are presented in Supplementary Tables 2–6.

Discussion

This study is the first attempt to evaluate the sustainability of Iranian FBDG in comparison with the usual diet and some other food pyramids. Findings show that following an optimized diet, based on recommendations of the recent Iranian FBDGs-2016, can be more sustainable compared with the previous FBDGs-2005 as well as the usual diet. Adhering to this diet can result in a lower cost (31.83%), water (20.9%), and carbon footprint (22.48%) and provide higher nutritional values (7.64%).

Previous studies found that reducing meat consumption, including the main livestock species, by 50% (from 110 to 55 g daily per capita intake) and replacing it with 50 g of beans per day is associated with a 20% reduction in environmental footprint. In addition, this substitution can result in an increased intake of dietary fiber and nutrients such as folate (Röös et al., 2020). It has been shown that a 50% reduction in animal product content in the American diet reduces total water use by 37% (Renault and Wallender, 2000). A high proportion of the water footprint for animal products is due to their consumption of feed, which accounts for 98% of the total water footprint (Alizadeh et al., 2013). Throughout the world, 29% of the total water footprint is related to the production of animal products in the agricultural sector, of which one-third is related to beef cattle production (Alizadeh et al., 2013).

The traditional Iranian diet is rich in legumes and plant-based proteins, and consumption of these elements has decreased over time and been replaced with refined grains and red meat, specifically in urban areas (Sobhani et al., 2021). In a study, the sustainability of three traditional and local foods in northwest Iran (Ashe Reshteh, Mirza-Ghassemi, and Tabrizi Koofteh) was compared with three popular western foods (pizza, beef-stroganoff, and pasta), and found that the traditional cuisine had lower environmental effects compared to the selected western foods (Eini-Zinab and Sobhani, 2017). The traditional Iranian main dishes are mainly composed of combinations of cereals (mainly rice or flat wheat bread) along with beans and vegetables, with a small amount of meat. Herbs are frequently used, along with fresh and dried fruits such as plums, prunes, apricots, raisins, pomegranates, and quince (Eini-Zinab and Sobhani, 2017). Considering the positive role of legumes in increasing the sustainability of the Iranian

FBDGs-2016, emphasis on their consumption through the promotion of traditional cuisines with high content of legumes should be explored in future studies. Such efforts can support evidence-informed policies through a food system approach to increasing the consumption of legumes and nuts.

Despite the high capacity to produce legumes in Iran, the country is presently one of the largest importers of beans in the world. The significant negative trend of drought in many parts of Iran, the traditional agricultural system, and the lack of support for small farmers are the main obstacles that have prevented adequate legume production (Sayari et al., 2015; Veisi et al., 2017). Improving agricultural infrastructure and supporting farmers can pave the way for increased production, improved quality, and reduced prices. Therefore, further emphasis on the consumption of legumes and nuts requires policy, planning, and implementation in order to supply this product by government agencies, NGOs, policymakers, farmers, and rural communities (Alizadeh et al., 2013).

Legumes are known as functional foods, rich in phytochemicals with a low glycemic index, which are all health-protective (Mirmiran et al., 2014; Bahadoran and Mirmiran, 2015). A systematic review conducted by Rebello et al. (2014), aimed to assess the association between legume intake and risk factors for cardiovascular disease, showed that eating more legumes reduced the risk of cardiovascular disease by 10% compared to those with fewer intake of legumes (Rebello et al., 2014). Drewnowski et al. also found that legumes are in a very good position in terms of the number of micronutrients supplied relative to their price (Drewnowski and Rehm, 2013). In addition, there are some studies on the positive effects of increasing legume production on soil quality, biodiversity, and lower need to use nitrogen fertilizers (Meena et al., 2018).

This study also found that the usual food consumption of Iranians is associated with higher water, carbon, and land footprint, as well as cost and lower NRF, compared to optimized diets based on the Iranian FBDGs. Consistent with our findings, Bayer et al. found that the usual dietary intakes of the Spanish population had a higher carbon footprint and lower nutritional quality than the recommended national food pyramid developed in Spain (Batlle-Bayer et al., 2019). Doren et al. found that changing the current dietary patterns of the Dutch population to their national FBDG could reduce carbon and land footprint by 11 and 38%, respectively (van Dooren et al., 2014). This study highlights the need for policies and programs to educate people about the benefits of adherence to Iranian FBDGs in order to ensure more NRF, less cost, and better environmental outcomes. Further qualitative studies are needed to understand the main barriers to adhering to FBDGs.

Although the impacts of the food sector on sustainability are widely accepted, efforts to design and implement integrated policies that address sustainable food production and consumption are largely absent (Sedlacko et al., 2013). For example, the compliance of the Iranian National Nutrition and Food Security Policy (2012–2020) with the components of a sustainable diet was 41.79% when both importance and adequacy were weighted. In this national document, the ecological, social, and cultural components of a sustainable diet have received less attention compared with health and nutrition dimensions (Sobhani et al., 2018).

The results of this study also showed that the mean usual consumption of Iranians has a higher mean carbon footprint, water footprint, land footprint, and cost compared to the optimal diet based on the Mediterranean dietary pyramid. Almendros et al. also found that shifting dietary intakes to more adherence to Mediterranean FBDG resulted in lower carbon, land, and water footprints of 72, 52, and 72%, respectively (Sáez-Almendros et al., 2013). Van Doren et al. also found that substituting the usual intakes of the population in the Netherlands with their FBDG was associated with an 11 and 38% reduction in carbon and land footprints (van Dooren et al., 2014). The findings of this study also showed higher environmental sustainability of the vegan dietary pyramid vs. Iranian FBDG. However, cultural acceptance is important when we make any dietary recommendation to the public (Gazan et al., 2018) and the Iranian usual dietary pattern is too far from the vegan diet. The current findings provide insight into the direction of change in order to move the Iranian diet toward a more sustainable one.

This study adds to the literature regarding the need for further modifications to achieve more sustainable food consumption in Iran and can help to clarify some of the changes required to improve the next national FBDG. However, more research is needed to consider local context and trade-offs as well as health and socioeconomic factors when choosing strategies to develop sustainable diets (Adesogan et al., 2020). When interpreting the results of this study, some limitations need to be considered. Our calculations for the land and carbon footprints were based on international evidence, not specifically for Iran. In addition, we used the Households Income and Expenditure Survey (HIES) data to reflect an estimate of household intake rather than individual intake. Finally, although AME and FAO estimated waste percentages are used to estimate individual real consumption, some overestimation is expected (Eini-Zinab et al., 2021).

Conclusion

Complying with the Iranian FBDGs while optimizing sustainable aspects can result in a more nutritious diet with lower cost and environmental effects compared to the usual diet. The recent version of Iran's FBDG, through the separation of legumes and nuts from meats and animal sources of a protein group, may result in a more sustainable diet compared to the older version. To achieve this, promoting national FBDG and adjusting food production and provision policies to improve its economic access and cultural desirability can help to improve the sustainability of the food and nutrition system.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

This study was conceptualized and designed by NO, SS, HE-Z, and SE. SS performed linear and goal programming and data interpretations. SE contributed to calculating the environmental footprints of food items. SS and SE reviewed the literature and wrote the first draft of the manuscript. NO, HE-Z, and GK revised critically the manuscript. All authors reviewed the manuscript, provided feedback, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.838741/full#supplementary-material

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