



Advancing an Integrative Framework to Evaluate Sustainability in National Dietary Guidelines

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The food system is responsible for some of society's most pressing sustainability challenges. Dietary guidelines are one policy tool to help address the multiple sustainability challenges associated with food systems through dietary recommendations that better support environmental and human well-being. This article develops and applies a sustainability framework scoring tool comprised of four key dimensions (environmental, economic, human health, and sociocultural and political) and 32 sub-dimensions of sustainable food systems for the analysis and modification of national dietary guidelines. Two coders pilot tested the framework to quantify the occurrence of sustainability dimensions and sub-dimensions in national and regional dietary guidelines of 12 randomly selected high-income and upper-middle income countries including Albania, Australia, Brazil, the Grenadines, Grenada, Qatar, Netherlands, Nordic Countries, St. Vincent, Sweden, Thailand, the United Kingdom, and the United States. Sustainability Dimension Scores (SDS) were calculated as a percentage of the occurrence of the eight sub-dimensions comprising each sustainability dimension and Total Sustainability Scores (TSS) were calculated as a percentage of the occurrence of the 32 sub-dimensions in each guideline. Inter-rater reliability of TSS and SDS indicated high validity of applying the sustainability framework for dietary guidelines. SDS varied between the four sustainability dimensions with human health being the most represented in the dietary guidelines examined, as hypothesized (average SDS score of 83%; range from 50 to 100%). Significant differences ($p < 0.0001$) were found in mean SDS between the four sustainability dimensions. Overall, results indicate that the ecological (average SDS score of 31%; range from 0 to 100%) economic (average SDS score of 29%; range from 0 to 100%), and socio-cultural and political (average SDS score of 44%; range of 0–100%) dimensions of sustainability are underrepresented in the examined national dietary guidelines with significant differences in SDS between guidelines ($p < 0.0001$). TSS varied by country between 12 and 74% with a mean score of 36% ($\pm 20\%$). Brazil had the highest TSS (74%) followed by Australia (69%). The sustainability framework presented here can be applied by policy makers, researchers, and practitioners to identify gaps and opportunities to modify national dietary guidelines and associated programs for transforming food systems through diets that support planetary health.

Keywords: dietary guidelines, sustainability, sustainable diets, integrative framework, food policy

INTRODUCTION

It is widely recognized that the way humans produce, distribute, consume, and waste food through the food system is responsible for some of society's most pressing sustainability challenges (Horrihan et al., 2002; Gomiero et al., 2011; Edenhofer et al., 2014; Tilman and Clark, 2014; He et al., 2018; Willett et al., 2019). Food systems are composed of complex sub-systems of diverse components, stakeholders, and processes from production to consumption to waste including communities and policies at local, national, and global scales (Herforth et al., 2017; Ahmed and Byker Shanks, 2019). While processes of the food system are linked with numerous environmental externalities, such as climate change, biodiversity loss, and water and air pollution (Vermeulen et al., 2012), human nutrition is critically dependent on multiple ecosystem services including water, soil fertility, pollination, climate regulation, and food quality (Deckelbaum et al., 2006). The sustainability challenges of the food system are exacerbated by climate change and variability (Vermeulen et al., 2012; Wheeler and von Braun, 2013) that threatens food security and public health through decreased agricultural production (Ewert et al., 2005; Avnery et al., 2011a,b; Tai et al., 2014), increased food contamination (Tefera, 2012), disruption of food supply chains (Campbell et al., 2016), increased prices (Tai et al., 2014), and reduced food quality (Myers et al., 2014; Ahmed and Stepp, 2016). The concept of sustainable diets has been promoted in recognition of the complex and interconnected challenges facing food systems (Gussow and Clancy, 1986; Burlingame, 2012).

Sustainable diets are healthy diets from sustainable food systems that advance the human condition and conserve ecological resources in socially acceptable ways (Burlingame, 2012; Johnston et al., 2014; Jones et al., 2016; Ahmed and Byker Shanks, 2019). Four key dimensions of sustainable diets have been identified based on the multiple dimensions of sustainability including ecological, economic, human health, and sociocultural and political (Jones et al., 2016; Downs et al., 2017; Mason and Lang, 2017). The ecological dimension of sustainable diets is characterized by the environmental aspects of agriculture toward minimizing the negative externalities of production while promoting biodiversity and ecosystem services (Nelson et al., 2009). The economic dimension of sustainable diets pertains to the activities and actors along food value chains from farm-to-fork and waste (Garnett, 2011; Barilla Center for Food and Nutrition, 2015; Fanzo et al., 2017). The human health dimension of sustainable diets involves health, nutrition, and food environments and relates to ensuring that diets are holistic and diverse, contain less meat, and are accessible to everyone, including the most vulnerable populations (Jones et al., 2016; Downs et al., 2017; Herforth et al., 2017; Mason and Lang, 2017). The sociocultural and political dimension of sustainable diets takes into account food culture, equity, skills, knowledge, and values as well as broader food system issues including labor rights, animal welfare, and food sovereignty (Downs et al., 2017; Mason and Lang, 2017; Ahmed and Byker Shanks, 2019).

Dietary guidelines are one policy tool that can help address the multiple sustainability challenges associated with diets and food

systems through recommendations that better support human nutrition and public health while enhancing the ecological, economic, and cultural aspects of food systems. National dietary guidelines provide a unified voice to the public regarding where the government stands on dietary advice to inform food choices in the context of health promotion and disease prevention (Dietary Guidelines Advisory Committee, 2015). Different national and international institutions as well as scientific organizations have developed dietary guidelines over the past few decades to promote healthy lifestyles aimed at mitigating diet-related chronic disease (Magni et al., 2017). In addition to informing consumers about dietary choices, national dietary guidelines serve as the foundation for information on food and nutrition policies and programs instituted within a country, often with budgetary allocations (Dietary Guidelines Advisory Committee). For example, national dietary guidelines of the United States inform multiple national programs including the formulation of lunches as part of the National School Lunch Program, and the composition of the safety net provided by the Supplemental Nutrition Assistance Program as well as the Women, Infants, and Children (WIC) program. The food and beverage industry often responds to changes proposed in dietary guidelines by reformulating products.

The focus of dietary guidelines in the past was largely based on meeting nutrient requirements regarding how people should eat in their specific socio-ecological contexts to support nutrition and health (Magni et al., 2017). In more recent times, it has been acknowledged that dietary guidelines have the potential to not only support citizens on how to make healthier choices about food (and sometimes about physical activity), they can also serve to guide consumers in a country to make food choices that support the multiple dimensions of sustainable diets (Garnett, 2014; Donini et al., 2016; Nelson et al., 2016). The role of dietary guidelines has broadened in view of the multiple environmental constraints that put pressure on the food system and the resulting need to preserve natural resources and ecosystem health (Fischer and Garnett, 2016; Nelson et al., 2016). For example, several countries including Germany, Brazil, Sweden, and Qatar have incorporated aspects of sustainability into their dietary guidelines in recent years (Fischer and Garnett, 2016). Integrating recommendations for supporting the four dimensions of sustainable diets in national dietary guidelines has the potential to transform the food system toward enhancing planetary health by influencing the food choices and actions of consumers, food and nutrition programs, as well as the food and beverage industry.

The objective of this study was to develop, apply, and validate an integrative framework scoring tool to examine the presence of the environmental, economic, sociocultural/political, and human health dimensions of sustainability and associated sub-dimensions in national dietary guidelines. The goal of applying the integrative framework is to address the following research question: How are environmental, economic, sociocultural/political, and human health dimensions of sustainability and associated sub-dimensions represented in national dietary guidelines and, how does this vary between guidelines? We compared variation of the occurrence of the

sustainability dimensions and sub-dimensions between 12 randomly selected national dietary guidelines of high-income and high-middle income countries toward validating the integrative framework for broader application. We hypothesized that the human health dimension of sustainability would be most well-represented in national dietary guidelines compared to the ecological, economic, and socio-cultural and political dimensions of sustainability given the overarching goal of dietary guidelines to improve well-being. In addition, we hypothesized that countries that are recognized to explicitly integrate sustainability into their dietary guidelines would demonstrate greater presence of the ecological, economic, and socio-cultural and political sustainability sub-dimensions. The sustainability framework and findings presented here have the potential to inform the evaluation and modification of national dietary guidelines by pointing to gaps and opportunities regarding the representation of the multiple dimensions of sustainability. Ultimately, taking an integrative sustainability approach to dietary recommendations helps support multiple Sustainable Development Goals (SDGs) toward advancing healthy diets from sustainable food systems that support planetary health.

METHODS

Development of Integrative Sustainability Framework

We developed a sustainability framework tool for quantitatively assessing the four key dimensions of sustainability in national dietary guidelines that was adapted from a previously developed sustainable diets framework published by two of this study's authors (Downs et al., 2017). The previous sustainable diets framework examined food policy in Nepal (Downs et al., 2017). In this study, we drew from this previous study (Downs et al., 2017) along with prevalent constructs of sustainable diets and sustainable food systems described in the literature that are applicable to recommendations in dietary guidelines (**Supplementary Table 1**).

Specifically, the search terms used to identify dimensions of sustainable diets and sustainable food systems that are evidence-based and applicable for inclusion in dietary guidelines included the following: sustainable OR sustainability AND diet OR food OR dietary guidelines. The search terms were entered into multiple publication databases including Web of Science, Science Direct, and Google Scholar. Two coders validated the inclusion of articles resulting from this search. The resulting articles (**Supplementary Table 1**) were scanned to identify specific attributes of sustainable diets and sustainable food systems associated with the environmental, economic, sociocultural/political, and human health dimensions of sustainability. We validated the inclusion of the identified attributes to include as constructs in our integrative framework through a primary literature in multiple publication databases to ensure each construct is supported by evidence.

Based on the resulting evidence in the literature, the study team consisting of experts in sustainable food systems, diets,

and nutrition had a discussion regarding the inclusion of the prevalent constructs characterizing sustainable diets and sustainable food systems that are supported by evidence that are applicable to national dietary guidelines. The resulting constructs that are supported by primary evidence were grouped as sub-dimensions of the four ecological, economic, and sociocultural and political, and human health dimensions of sustainability (**Table 1**). In some cases, similar constructs were combined to result in a total of eight sub-dimensions for each dimension of sustainability in the resulting sustainability framework tool (**Table 1**). Additionally, in some cases, specific sub-dimensions of sustainability could potentially be grouped in more than one sustainability dimension due to the interconnectedness of aspects of sustainability. In such cases, we tried to refine the sustainability sub-dimension and its description to be more aligned with a specific sustainability dimension. For example, food security touches upon issues that are connected to human health, economics, and social dimensions of sustainability. We thus broke out the components of food security as nutrition aspects of food security and economic aspects of food security and refined their descriptions.

Selection of Dietary Guidelines

In order to evaluate the applicability of the resulting integrative framework, the study team compiled all national dietary guidelines that are available in English that are either classified as high-income or upper-middle income. A total of 34 national dietary guidelines were identified that are in English from high-income and upper-middle income countries. As the goal of this study was to test the applicability of the framework in evaluating the representation of sustainability in national dietary guidelines, we focused on national dietary guidelines that are available in English as a convenience sample. We further focused on high-income and upper-middle income countries as advancing sustainable diets may not be as equitable or ethical of an approach in low-income country settings because of the prevalence of undernutrition (Milner and Green, 2018). Our sample size of 12 guidelines represents a sample size of 35% of the available ($n = 34$) national dietary guidelines in English from high-income and upper-middle income countries.

The resulting dietary guidelines were grouped into two categories based on their recognition of integrating sustainability in the literature. Specifically, all high-income and middle-income countries in the sample group that were recognized in the literature (Barilla Center for Food and Nutrition, 2015; Monteiro et al., 2015; Seed, 2015) to integrate sustainability were categorized as Group 1 countries and all other dietary guidelines were categorized as Group 2 countries. A total of seven countries that are either high-income or high-middle income that have national or regional dietary guidelines available in English were assigned as Group 1 countries including: Brazil (Monteiro et al., 2015), Qatar (Seed, 2015), Germany (Barilla Center for Food and Nutrition, 2015), Netherlands (Barilla Center for Food and Nutrition, 2015), Sweden (Barilla Center for Food and Nutrition, 2015), United Kingdom (Barilla Center for Food and Nutrition, 2015), and Nordic Countries (Barilla

TABLE 1 | Sustainability framework tool for evaluating national dietary guidelines.

Sustainability dimensions and sub-dimensions	References
ECOLOGICAL DIMENSION	
Production quality: The dietary guidelines support production systems that cultivate for nutritional quality (crop quality).	Welch and Graham, 1999; Graham et al., 2001; Hunter et al., 2011; Rich et al., 2011; Miller and Welch, 2013; Hallström et al., 2018
Adequate production: The dietary guidelines promote adequate food production and agricultural productivity, such as incentives for production.	Boody et al., 2005; Havstad et al., 2007; Swinton et al., 2007; Levidow and Psarikidou, 2011; Govindan, 2018
Biodiversity, agrobiodiversity, and ecosystem services: The dietary guidelines support conservation and maintenance of biodiversity and agrobiodiversity as well as associated ecosystem services.	Costanza et al., 1997; Tilman et al., 2002; Dudgeon et al., 2006; Frison et al., 2006; Swinton et al., 2007; Johns et al., 2013; Eshel et al., 2014; Hanes et al., 2018
Sustainable agriculture: The dietary guidelines support sustainable agricultural practices and sustainable intensification that limit pesticide, herbicide and fertilizer use.	Tilman et al., 2002, 2011; Sarkar et al., 2017; Lal, 2018; Veltman et al., 2018
Local and seasonal foods: The dietary guidelines support the procurement of foods that are in season and are local.	Edwards-Jones, 2010; Kremer and Deliberty, 2011; Cleveland et al., 2014; Macdiarmid, 2014; Esteve-Llorens et al., 2019; Profeta and Hamm, 2019
Clean energy: The dietary guidelines support the use of clean energy and green or sustainable technologies	Kamat, 2007; Copena and Simón, 2018; Ferrer-Martí et al., 2018; López-González et al., 2018; Terrapon-Pfaff et al., 2018a,b; Vergé et al., 2018
Soil, land, and water conservation and protection: The dietary guidelines support the procurement of food in ways that prevent contamination of soil, land, and water resources, such as protecting watersheds from pollutants.	Carpenter et al., 1998; Tschamtko et al., 2005; Ruini et al., 2015; Biagini and Lazzaroni, 2018; Hu et al., 2018; Soteriades et al., 2018; Thorlakson et al., 2018
Low GHGE and climate resilience: The dietary guidelines support production methods with relatively low GHG emissions; designing and managing for agricultural systems for climate change/climate resilience	Lipper et al., 2014; Ruini et al., 2015; Eory et al., 2018; González-García et al., 2018; Leon and Ishihara, 2018; Singh et al., 2018; Vetter et al., 2018; Westermann et al., 2018
ECONOMIC DIMENSION	
Distribution, supply chains, and transport: The dietary guidelines take into account food distribution, supply chains, and transport, such as direct sales between producers and consumers.	Kuo and Chen, 2010; Poppe et al., 2013; Accorsi et al., 2018; Meneghetti et al., 2018; Stellingwerf et al., 2018
Economic aspects of food security: The dietary guidelines recognize the importance of having healthy and recommended foods being affordable to overcome economic barriers of access to safe, nutritious, and desirable foods.	Shreck et al., 2006; Duffey et al., 2010; Carter et al., 2011; Cole and Tembo, 2011; Galhena et al., 2013; Ward et al., 2013; Jones et al., 2016; Martin et al., 2016; High Level Panel, 2017; Jessiman-Perreault and McIntyre, 2017; Dizon and Herforth, 2018
Food loss and waste: The dietary guidelines recommend reducing food waste across the food system from farm through fork.	Thyberg and Tonjes, 2016; Abdelradi, 2018; Bjørn et al., 2018; Edwards et al., 2018; Schanes et al., 2018; Schmidt and Matthies, 2018
Food packaging: The dietary guidelines promote reduced food packaging and recycling.	Khan and Tandon, 2017; Dilkes-Hoffman et al., 2018; Fu et al., 2018; Sánchez-Safont et al., 2018; Song et al., 2018; Venkatesh et al., 2018
Food system livelihoods: The dietary guidelines promote livelihoods to support stakeholders in the food system from on farm and throughout food value chains.	Dupuis and Goodman, 2005; Bravo-Ureta et al., 2006; Price and Leviston, 2014; Sulemana and James, 2014; Lalani et al., 2016; van Dijk et al., 2016
Farmers' markets and local food systems: The dietary guidelines recognize the importance of local food systems including farmers' markets, community supported agriculture (CSA), food cooperatives, and food hubs.	Cone and Myhre, 2000; Hinrichs, 2000; King, 2008; O'Neill, 2014; Forssell and Lankoski, 2015
Food storage and preparation: The dietary guidelines make recommendations to avoid resource-intensive food storage of cold chain items and high-energy preparation, such as the use of a microwave.	Lado and Yousef, 2002; Wood and Newborough, 2003; Canals et al., 2007; Zaroni and Zavanella, 2012; Lelieveld et al., 2015; Li et al., 2017; van Holsteijn and Kemna, 2018
Food advertising: The dietary guidelines recognizes the role of food advertising and marketing on food choices.	Vermeir and Verbeke, 2006; Friedmann, 2007; Dodds et al., 2008; Vogt and Kaiser, 2008; Magnus et al., 2009; Macrae et al., 2012; Grunert et al., 2014; Kemps et al., 2014
HUMAN HEALTH DIMENSION	
Dietary diversity: The dietary guidelines promote dietary diversity to reduce risk of nutrient deficiencies.	Kant et al., 1993; Onyango, 2003; Arimond and Ruel, 2004; Mirmiran et al., 2004; Remans et al., 2014; Berg et al., 2018; Keffie et al., 2018
Regular exercise and physical activity: The dietary guidelines promote physical activity and movement away from sedentary lifestyles.	Pan et al., 1997; Ussher et al., 2007; Barton et al., 2009; Chodzko-Zajko et al., 2009; Melzer et al., 2010; Södergren et al., 2012; Barwais et al., 2013; Tozzi et al., 2016; Edwards and Loprinzi, 2017
Food safety: The dietary guidelines promote food safety to prevent foodborne illness, contamination, negative health influence of agriculture and diseases linked to chemicals and pesticide use.	Lee et al., 2001; Antunes et al., 2003; Lin et al., 2009; Moffatt et al., 2011; Kataoka et al., 2014; Hoelzer et al., 2018; Rivera et al., 2018; van Asselt et al., 2018
Energy limitation: The dietary guidelines promote the limitation of energy/calorie consumption and reduce portion sizes to prevent overweight, obesity, and diet-related non-communicable diseases.	Lowe and Butryn, 2007; Misra et al., 2011; Eyles et al., 2012; Deepika and Vijayakumar, 2017; Popkin and Reardon, 2018

(Continued)

TABLE 1 | Continued

Sustainability dimensions and sub-dimensions	References
Ultra-processed food limitation: The dietary guidelines promote the limitation of ultra-processed foods and food high in added sugars.	Monteiro et al., 2011; Poti et al., 2017; Albuquerque et al., 2018; Juul et al., 2018; Larrick and Mendelsohn, 2018; Schnabel et al., 2018
Plant-based diet and nutrient-dense foods: The dietary guidelines promote plant-based diets of nutrient dense foods, such as fruits, vegetables, and legumes to reduce risk of chronic disease while recommending less consumption of non-lean meat and processed meat including selecting of other non-meat choices of protein.	Pimentel and Pimentel, 2003; Bach-Faig et al., 2011; Tektonidis et al., 2015; Kahleova et al., 2018; Salas-Salvadó et al., 2018; Satija and Hu, 2018
Nutrition aspects of food security: The dietary guidelines promote nutrition aspects of food security including access to sufficient quantity and quality of nutritious foods to meet dietary needs.	Rose and Richards, 2004; Bodor et al., 2008; Caspi et al., 2012; Gittelsohn et al., 2012; Barosh et al., 2014
Holistic diets: The dietary guidelines promote a holistic dietary approach of healthy dietary patterns to meet personal, cultural, and traditional preferences that promote overall health.	Lee et al., 2002; Burgess et al., 2005; Frison et al., 2006; Kwon et al., 2007; Johnson-Down and Egeland, 2010
SOCIO-CULTURAL AND POLITICAL DIMENSION	
Food consciousness: The dietary guidelines recognizes the role of food consciousness, consumer knowledge, and education in supporting healthy and sustainable food choices.	Wilkins, 2005; Fresco, 2009; Mancini et al., 2017; Lazzarini et al., 2018; Lentz et al., 2018
Consumer preferences: The dietary guidelines recognize variation of food choice preferences and desirability of different foods on the basis of cultural history and other socio-cultural factors.	Grunert, 2005; Dawson, 2013; Ellison et al., 2014; Asioli et al., 2017; Kalbar et al., 2018
Equity issues: The dietary guidelines support equity in the food system including on-farm, in market, trade, distribution, food service, and policy sectors.	Browne et al., 2000; Maloni and Brown, 2006; Tregear, 2012; Bacon et al., 2014; Nost, 2014
Food sovereignty: The dietary guidelines support food sovereignty, food rights, food justice, and empowerment.	Dupraz and Postolle, 2013; Chaifetz and Jagger, 2014; Shinn, 2016; Steckley, 2016; Leventon and Laudan, 2017; Wittman et al., 2017
Food knowledge and skills: The dietary guidelines recognize variation of knowledge and skills as related to food cultivation, procurement, purchasing, planning, and preparation.	Hyland et al., 2006; Larson et al., 2006; Hersch et al., 2014; Utter et al., 2016; Romani et al., 2018
Food system and cultural values: The dietary guidelines recognize variation of family, community, and traditional values in the food system.	Kalof et al., 1999; Renzaho et al., 2008; Raymond et al., 2009; D'Sylva and Beagan, 2011; Banna et al., 2016
Labor: The dietary guidelines support safe labor conditions and standards for workers in the food system.	New, 2015; Sbicca, 2015; Hendrickson et al., 2018; Mook and Overdevest, 2018; Oya et al., 2018; Staelens et al., 2018
Animal welfare: The dietary guidelines support healthy, comfortable, well-nourished, and safe conditions for animals raised for livestock.	Edge and Barnett, 2009; Thornton, 2010; Ibarra et al., 2018; Rich et al., 2018; Sonoda et al., 2018

This framework integrates the four key dimensions of sustainability including the ecological, economic, and socio-cultural/political, and human health dimensions that are each comprised of eight sub-dimensions of sustainability. We developed this framework by combining the prevalent constructs characterizing sustainable diets and sustainable food systems from a literature search that were applicable to national dietary guidelines into the sub-dimensions of the four dimensions of sustainability (Supplementary Table 1). We validated the inclusion of the identified constructs through a primary literature to ensure each construct is supported by evidence (listed in the References below).

Center for Food and Nutrition, 2015). The Nordic Countries include Denmark, Finland, Iceland, Norway, Sweden, as well as the Faroe Islands, Greenland, and Aland. Although Sweden is included in the Nordic Countries' recommendations, given that they have their own standalone dietary guidelines they have been treated separately in Group 1. We assigned each country a number and used a random number generator to randomly select six dietary guidelines in the Group 1 category and six countries from the Group 2 category. A sample size of 12 national dietary guidelines consisting of six guidelines from Group 1 countries and six guidelines from Group 2 countries was based on a feasible number of guidelines to evaluate by the study team while having relevant power to pilot test the integrative sustainability framework and the research question regarding variation of sustainability dimensions between dietary guidelines of Group 1 and Group 2 countries. The randomly selected Group 1 countries were: Brazil, Qatar, Netherlands, Sweden, the United Kingdom, and Nordic Countries (Barilla Center for Food and Nutrition, 2015; Monteiro et al., 2015; Seed, 2015). The randomly selected Group 2 countries were: Grenada, Albania, Australia,

United States, Thailand, and St. Vincent and the Grenadines. The most current dietary guidelines available in 2017 were used for this study.

Evaluation of Dietary Guidelines

Two coders applied the sustainability framework tool to score each dietary guideline in the study. For each of the 32 sub-dimensions in the sustainability framework (Table 1), the coder assigned a 0 for the absence of the sub-dimension in the dietary guidelines and a 1 to indicate the presence of the sub-dimension. The coder further listed the page number(s) which each sub-dimension theme was present in national dietary guidelines as well as highlighted the specific text. Discrepancies between coders were resolved through discussion and support by a third coder where each guideline was revisited and the associated text was discussed.

Data Analysis

We created two scoring indices to evaluate the representation of sustainability dimensions and sub-dimensions in national

dietary guidelines. Sustainability Dimension Scores (SDS) of each of the four dimensions of sustainability were calculated as a percentage by tabulating the total presence of the associated eight sub-dimensions of sustainability. Total Sustainability Scores (TSS) were calculated as a percentage by calculating the presence of the 32 sub-dimensions in each guideline. JMP (version 13.0 SAS Institute Inc., Cary, NC) was used for measuring interrater reliability of coded results, statistical analysis, for and creating graphs. Specifically, Analysis of Variance (ANOVA) and pairwise comparison tests were applied to examine differences in means of TSS and SDS between the sustainability dimensions and between the national dietary guidelines.

RESULTS

Literature Search Outcomes

A total of 101 articles resulted from the literature search on sustainable diets, sustainable food systems, and sustainability in dietary guidelines that were considered suitable by the study team to examine for attributes to include in the integrative framework for evaluating dietary guidelines. The resulting sub-dimensions included in the framework either relate to those being managed by individuals, such as through dietary choices, those that relate to systems-level management by policy makers and institutions, or those that are influenced by both individual and systems-level management. For the ecological dimension of sustainability, the sub-dimensions of production quality and adequate production are managed at the systems level while food procurement that supports the following ecological sub-dimensions of sustainability are influenced by both systems-level and individual choices: biodiversity, agrobiodiversity, and ecosystem services; sustainable agriculture; local and seasonal foods; clean energy; low GHGE and climate resilience. For the economic dimension of sustainability, the following sub-dimensions are managed at the systems level: distribution, supply chains, and transport; economic aspects of food security; food system livelihoods; and food advertising. Food procurement that supports food loss and waste; food packaging; farmers' markets and local food systems; and food storage and preparation are influenced by both systems-level and individual choices for the economic dimension of sustainability. For the human health dimension of sustainability, the sub-dimensions of food safety as well as nutrition aspects of food security are managed at the systems scale while dietary diversity; regular exercise and physical activity; energy limitation; ultra-processed food limitation; plant-based diets and nutrient-dense foods; and holistic diets are influenced at both individual and systems levels. For the sociocultural/political dimension of sustainability, the attributes of food consciousness, consumer preferences, and food knowledge and skills are those related to individual dietary choice while equity issues, food sovereignty, labor, and animal welfare are those related to the systems level of policy and institutions. Food systems and cultural values are influenced by both the individual and systems levels.

Variation of Sustainability Dimension Scores (SDS)

Inter-rater reliability of Total Sustainability Scores (TSS) and Sustainability Dimension Scores (SDS) indicated high validity of applying the sustainability framework for national dietary guidelines. Application of the sustainability framework tool (**Table 1**) for presence of sustainability dimensions found Sustainability Dimension Scores (SDS) varied between the four sustainability dimensions (**Figure 1**) with human health being the most represented dimension in the national dietary guidelines examined (average SDS score of 83%; range from 50 to 100%). Overall, results indicate that the ecological (average SDS score of 31%) economic (average SDS score of 29%; range from 0 to 100%), and socio-cultural and political (average SDS score of 44%; range of 0–100%) dimensions of sustainability are underrepresented in national dietary guidelines. Significant differences ($p < 0.0001$) were found in means SDS between the four sustainability dimensions. Pair-wise comparison between the four sustainability dimensions demonstrates that the mean SDS of the human health dimension was significantly higher ($p < 0.0001$) than that of the economic, ecological, and sociocultural and political dimensions. No significant differences in means of SDS were found between these latter three sustainability dimensions ($p > 0.05$).

For the ecological dimension of sustainability (**Figure 2**), the most represented sub-dimensions were local and seasonal foods (present in 50% of the dietary guidelines) followed by sustainable agriculture practices and production quality (each present in 33% of the dietary guidelines). The least represented sub-dimension for the ecological dimension of sustainability was clean energy and sustainable technologies (present in 17% of the dietary guidelines). The SDS for the ecological dimension of sustainability ranged from 0 to 100% between national dietary guidelines with significant differences between national dietary guidelines ($p < 0.0001$); the dietary guidelines of Brazil (SDS of 100%), Nordic Countries (88%), Australia (88%), and Sweden (50%) had the highest scores. Average SDS for the ecological dimension of sustainability of Group 1 countries that are recognized to integrate sustainability in dietary guidelines in the literature was 33% and 31% for Group 2 countries; this difference was not significant ($p = 0.94$).

For the economic dimension of sustainability (**Figure 3**), the most represented sub-dimensions were food advertising (present in 42% of the dietary guidelines) followed by costs of diets, food loss and food waste, and food packaging and recycling (each present in 33% of the dietary guidelines). The least represented sub-dimension for the economic dimension of sustainability was distribution, supply chains, and transport (absent in all of the dietary guidelines). The SDS for the economic dimension of sustainability ranged from 0 to 100% with significant differences between national dietary guidelines ($p < 0.0001$); Australia (SDS of 100%), Brazil (88%), and Qatar (50%) had the highest scores. Average SDS for the economic dimension of sustainability of Group 1 countries was 38 and 23% for Group 2 countries; this difference was not significant ($p > 0.50$).

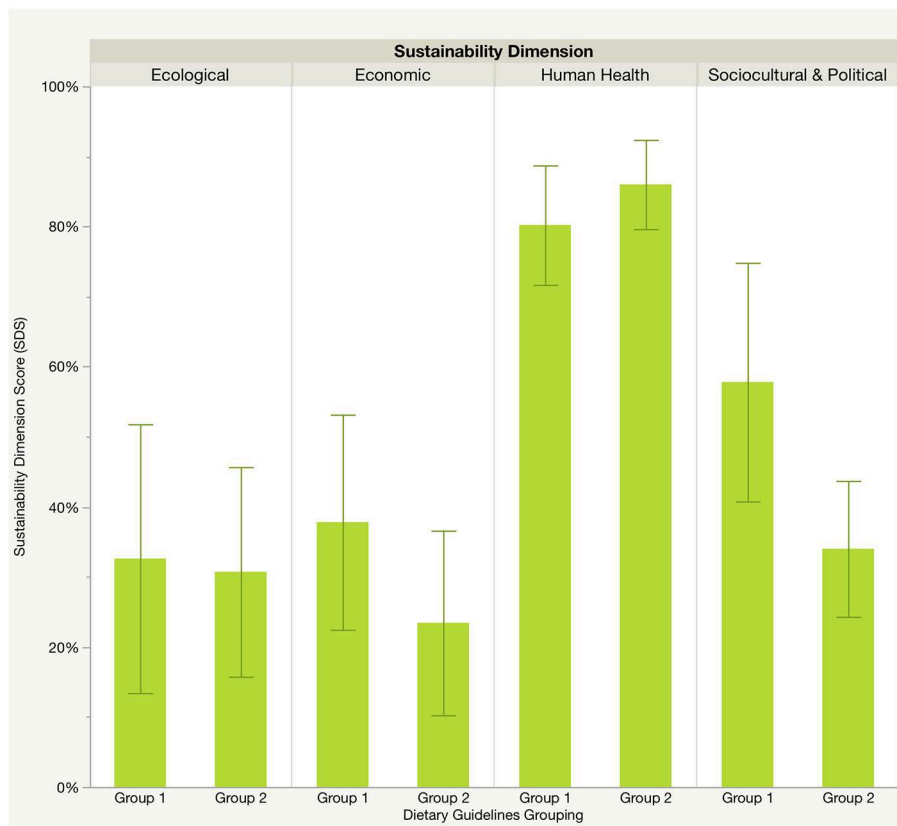


FIGURE 1 | Variation of sustainability dimension scores (SDS) between ecological, economic, human health, and socio-cultural and political sustainability in national dietary guidelines. Application of the sustainability framework tool (Table 1) for presence of sustainability dimensions found sustainability dimension scores (SDS) varied between the four sustainability dimensions with human health being the most represented dimension in the national dietary guidelines examined. Overall, results indicate that the ecological, economic, and socio-cultural and political dimensions of sustainability are underrepresented in national dietary guidelines. Significant differences ($p < 0.0001$) were found in means SDS between the four sustainability dimensions. Pair-wise comparison between the four sustainability dimensions demonstrates that the mean SDS of the human health dimension was significantly higher ($p < 0.0001$) than that of the economic, ecological, and sociocultural and political dimensions. No significant differences in means of SDS were found between these latter three sustainability dimensions ($p > 0.05$). There were no significant differences in the SDS for the dimensions of sustainability between Group 1 countries that are recognized in the literature to integrate sustainability in dietary guidelines compared to Group 2 countries.

For the human health dimension of sustainability (Figure 4), dietary diversity, ultra-processed food limitation, and plant-based diets were present in all of the dietary guidelines examined. Regular exercise and physical activity (present in 92% of the dietary guidelines), energy limitation (92% prevalence), and holistic diets (75% prevalence) were other prevalent sub-dimensions of the human health dimension of sustainability. The least represented sub-dimension for the human health of sustainability was nutrition aspects of food security related to food environments (present in 42% of the dietary guidelines). The SDS for the human health dimension of sustainability ranged from 50 to 100% without significant differences between national dietary guidelines ($p = 0.06$). The dietary guidelines of Brazil, Australia, and the United States all had the presence of all human health sustainability sub-dimensions. The other dietary guidelines examined also had high SDS for the human health dimension of sustainability including 88% each for Qatar, Sweden, Nordic Countries, Grenada, Albania, and Thailand.

Average SDS for the human health dimension of sustainability of Group 1 countries was 80% and 86% for Group 2 countries; this difference was not significant ($p = 0.59$).

For the socio-cultural and political dimension of sustainability (Figure 5), the most represented sub-dimensions were food consciousness (present in 83% of the dietary guidelines) followed by food knowledge and skills and food system and cultural values (both present in 58% of the dietary guidelines). The least represented sub-dimension for the socio-cultural and political dimension of sustainability was labor (present in 17% of the dietary guidelines). The SDS for the socio-cultural and political dimension of sustainability ranged from 0 to 100% with significant differences between national dietary guidelines ($p < 0.0001$); Brazil (SDS of 100%), Qatar (88%), and Australia (88%) had the highest scores. Average SDS socio-cultural and political dimension of sustainability of Group 1 countries was 58% and 34% for Group 2 countries; this difference was not significant ($p = 0.22$).

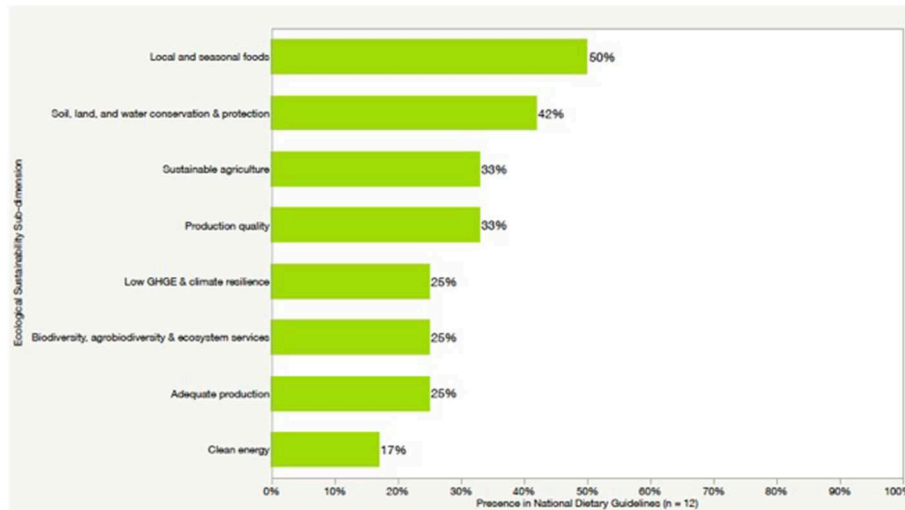


FIGURE 2 | Presence of ecological sub-dimensions in national dietary guidelines. This figure demonstrates the presence of the eight sub-dimensions of ecological sustainability in the 12 national dietary guidelines evaluated in this study.

Variation of Total Sustainability Scores (TSS)

Total Sustainability Scores (TSS) varied by dietary guidelines of the different countries between 12 and 74% with a mean score of 36% (**Figure 6**). Brazil had the highest TSS (74%) followed by Australia (69%). All other dietary guidelines had TSS <50%. Comparison of Group 1 countries (that are recognized in the literature to integrate sustainability in dietary guidelines) with Group 2 countries found that while Group 1 countries overall had higher TSS (39%) than Group 2 countries (33%), this difference was not significant ($p = 0.59$; **Figure 7**). Of note, Australia was categorized as a Group 2 country but had the second highest TSS in this study following Brazil.

DISCUSSION

This study applied and validated a sustainability framework tool to examine national dietary guidelines based on the ecological, economic, sociocultural/political, and human health dimensions of sustainability. The inter-rater reliability of Total Sustainability Scores (TSS) and Sustainability Dimension Scores (SDS) across coders highlights the validity of applying the sustainability framework for evaluating dietary guidelines. Overall, findings demonstrate notable variation in the presence of the multiple sub-dimensions of sustainability in national dietary guidelines of high- and upper-middle income countries with TSS ranging from 12 to 74% and a mean TSS of 36%. Significant differences were further found in mean SDS between the ecological, economic, sociocultural/political, and human health dimensions of sustainability. For the limited sample size of 12 national dietary guidelines from high- and upper-middle income countries analyzed in this study, findings confirm the hypothesis that the human health dimension of sustainability is well-represented while the ecological, economic, and socio-cultural and political

dimensions of sustainability are underrepresented, with several exceptions. This finding supports the overarching goal of dietary guidelines which has been to support human health (Magni et al., 2017). More recently, dietary guidelines have been recognized to have the potential to also support the multiple dimensions of sustainable diets (Garnett, 2014; Donini et al., 2016; Nelson et al., 2016). However, our findings did not support the hypothesis that countries that are recognized to explicitly integrate sustainability into their dietary guidelines demonstrate greater presence of the ecological, economic, and socio-cultural and political sustainability sub-dimensions. Policy makers, researchers, and practitioners can apply the sustainability framework presented here to analyze existing guidelines with the view to identifying sustainability gaps and opportunities that can be addressed in future iterations of the guidelines toward supporting both human and planetary health.

Advancing an integrative sustainability framework through national dietary guidelines recognizes the interrelationship of sustainability challenges and opportunities toward meeting multiple Sustainable Development Goals (Global Panel, 2017; Sabbahi et al., 2018; Ahmed and Byker Shanks, 2019). As the current world population of over 7.6 billion is projected to notably increase to 9.3 billion by 2050 (Food and Agriculture Organization, 2009), there is a need for production systems to supply increased levels of food (Alexandratos and Bruinsma, 2012). The increased production of this food should be cultivated in ways that support biodiversity and don't burden ecosystems (Foley et al., 2011; West et al., 2014) while mitigating greenhouse gas emissions (Intergovernmental Panel in Climate Change, 2013; Intergovernmental Panel on Climate Changes, 2014). Concurrently, this food should be produced, distributed, and consumed in ways that recognize the importance of socio-cultural factors in the food system. Inequality in access is a pressing social challenge facing current diets

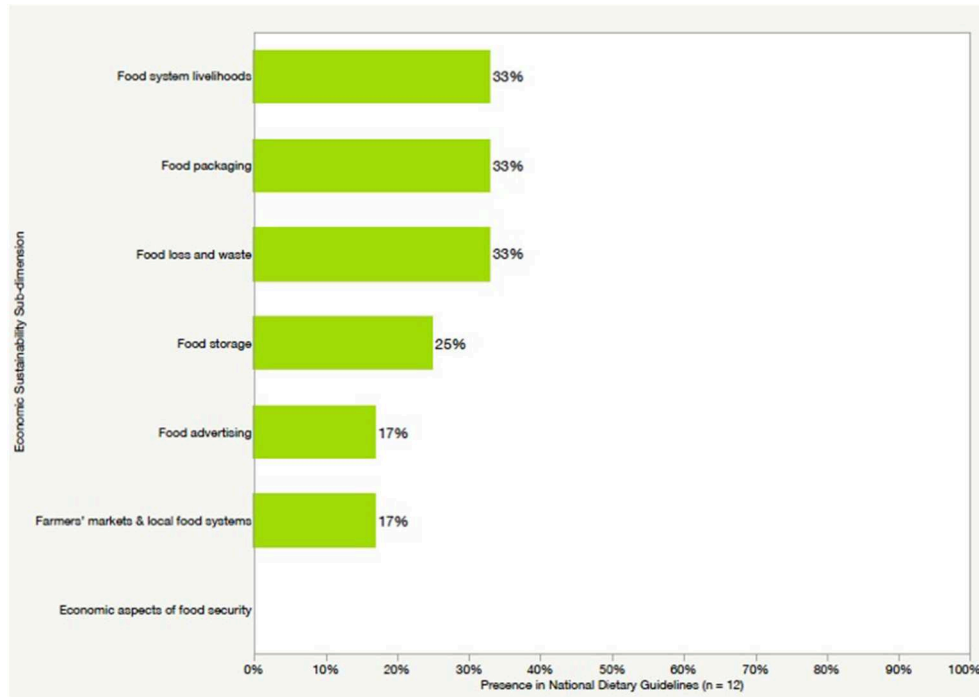


FIGURE 3 | Presence of economic sub-dimensions in national dietary guidelines. This figure demonstrates the presence of the eight sub-dimensions of economic sustainability in the 12 national dietary guidelines evaluated in this study.

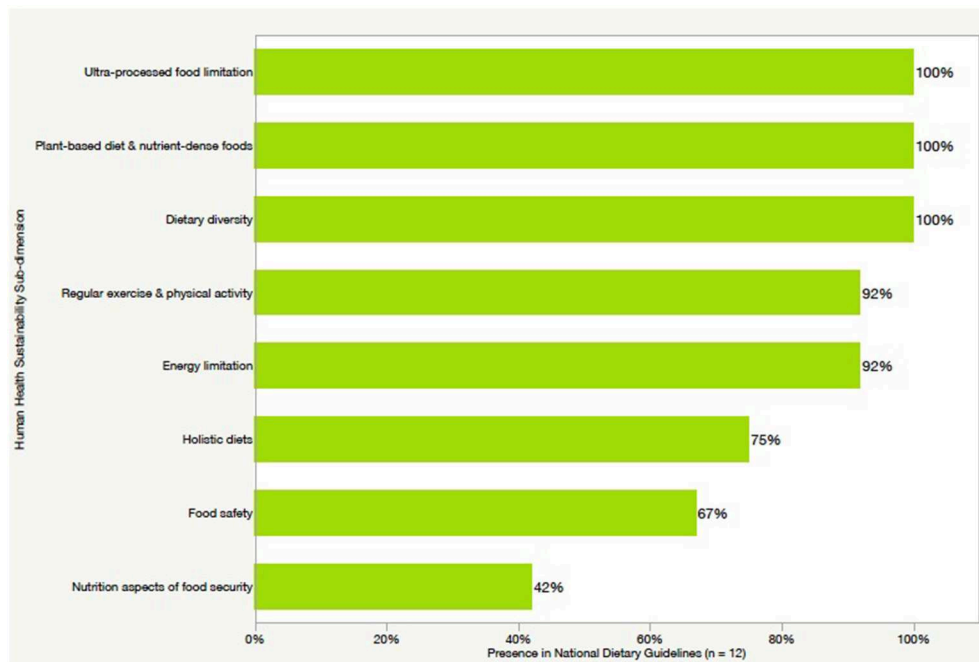


FIGURE 4 | Presence of human health sub-dimensions in national dietary guidelines. This figure demonstrates the presence of the eight sub-dimensions of human health sustainability in the 12 national dietary guidelines evaluated in this study.

that is directly linked to health disparities among vulnerable populations including the lowest income and marginalized groups (Alesina and Glaeser, 2004). Ultimately, taking an

integrative sustainability approach to dietary recommendations helps support multiple Sustainable Development Goals (SDGs), such as ending hunger, achieving food security, improving

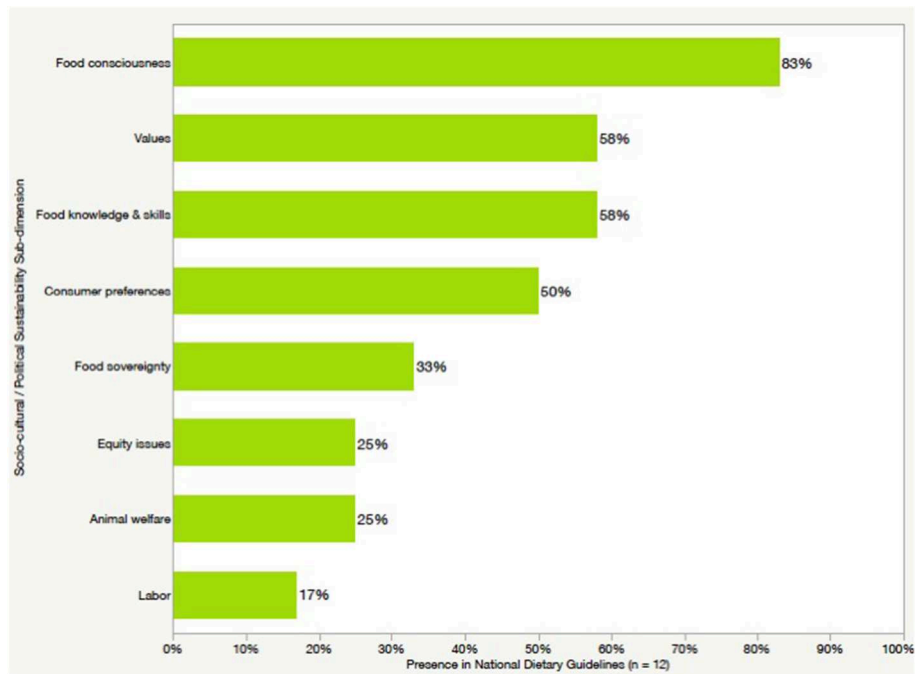


FIGURE 5 | Presence of socio-cultural and political sub-dimensions in national dietary guidelines. This figure demonstrates the presence of the eight sub-dimensions of socio-cultural and political sustainability in the 12 national dietary guidelines evaluated in this study.

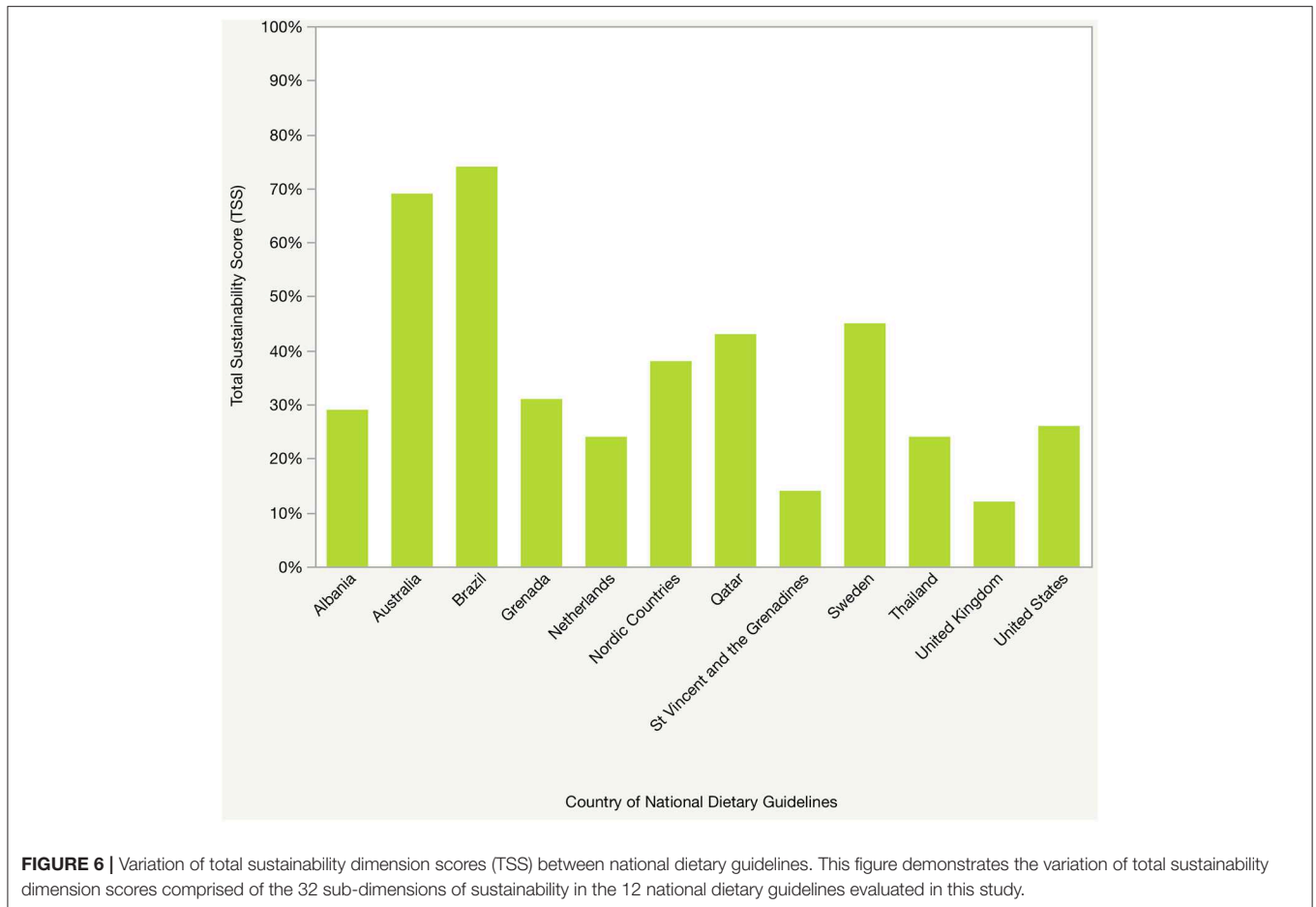
nutrition, and promoting sustainable agriculture (SDG 2); promoting well-being for all (SDG 3); reducing poverty (SDG 1); addressing inequality (SDGs 5 and 10); improved work and productivity (SDG 8); and addressing consumption, waste, the effects of climate change, and the use of natural resources (SDGs 12, 13, 14, and 15) (Sabbahi et al., 2018; Ahmed and Byker Shanks, 2019). While these SDGs are being prioritized by international organizations and national governments, they often compete with each other as well as other societal goals.

Our results regarding the general underrepresentation of the ecological, economic, and socio-cultural and political dimensions of sustainability highlight a need to expand the integration of multiple sub-dimensions of sustainability in national dietary guidelines while suggesting complexity of managing multiple dimensions of sustainability (Tuomisto, 2019) including their tradeoffs. For example, previous research has highlighted that the global supply of fruits and vegetables is insufficient to meet health needs based consumption recommendations of national dietary guidelines (Siegel et al., 2014). Another disconnect between dietary recommendations to support human health and food production practices that support environmental health are recommendations of increased fish consumption; if consumers were to increase their fish intake to meet current dietary recommendations, already fragile fish stocks would feel notable pressure (Jenkins et al., 2009). Many of the sub-dimensions of the ecological, economic, and socio-cultural dimensions of sustainability have historically been viewed as being beyond the remit of dietary guidelines and thus explain the numerous gaps seen in the prevalence of these dimensions of sustainability

in this study (Fischer and Garnett, 2016; Medact and Eating Better Alliance Policy Briefing, 2017). However, as the linkages between the multiple dimensions of sustainability are recognized as being crucial to planetary health, there is a need for a paradigm shift in the way we approach dietary recommendations toward examining diets within sustainable food systems that support planetary health (Fischer and Garnett, 2016).

While the human health dimension is overall very well-represented in the examined national dietary guidelines, the gap that can be addressed for modifying future dietary guidelines and associated programs is the integration of food security and access. Nutrition aspects of food security linked to food environments was the only human health sub-dimension prevalent in <50% of the dietary guidelines examined. Given that the food environment is a key determinant of healthy diets by shaping consumer interactions in the food system and subsequent food purchases based on the availability, affordability, convenience and desirability of food (Herforth and Ahmed, 2015), dietary guidelines should incorporate an understanding of how key aspects of the food environment influence food security, food access, and diets.

The evaluation of multiple sub-dimensions of sustainability included in the framework presented here can help identify possible unintended consequences of implementing specific recommendations for supporting sustainable diets. Future research is called for to evaluate the suitability of the proposed framework for evaluating dietary guidelines of low-income countries. In advocating for the modification of dietary guidelines that more comprehensively integrate sustainability,



it is important to note the multiple tradeoffs and challenges that exist which call for modification of national dietary guidelines on the basis of local contexts. In addition, after sustainability gaps are identified, the next step is to translate these recommendations into practice by identifying context-specific and effective ways of implementing the required changes for food systems transformation. The 32 sub-dimensions of sustainability that were included in the framework emphasize management decisions at various scales of influence that call for associated interventions and programs at different scales. These scales of influence range from those at the individual level, such as through dietary choices to those at the systems level including those influenced by policy makers and the private sector, as well as those influenced by multiple scales of management.

In advocating for the modification of dietary guidelines that more comprehensively integrate sustainability, it is important to note the multiple challenges that exist. One such challenge is the contentious nature of sustainability in some socio-political contexts. For example, the integration of dimensions of sustainability has been contentious or considered beyond the scope of dietary guidelines in the United States and Australia (Fischer and Garnett, 2016; Medact and Eating Better Alliance Policy Briefing, 2017). While the development of the 2015–20 Dietary Guidelines for Americans considered taking into account

sustainability dimensions, sustainability recommendations were ultimately considered beyond the scope of the guidelines due to opposition from agriculture departments and vested interest groups (Medact and Eating Better Alliance Policy Briefing, 2017). However, as demonstrated in this study, even countries that do not explicitly indicate the integration of sustainability into their guidelines, such as Australia can integrate sustainability less explicitly. While Group 1 countries that are recognized in the literature to integrate sustainability in their dietary guidelines had higher SDS for the ecological, economic, and socio-cultural and political dimensions of sustainability compared to Group 2, these differences were not significant. In addition, while Brazil, classified as a Group 1 country in this study had the highest TSS, there were no significant differences in the TSS between Group 1 and Group 2 countries. Despite sustainability being contentious within the Australian national dietary guidelines context, the Australian guidelines had the second highest overall Total Sustainability Scores (TSS) in this study following Brazil. This suggests that countries don't necessarily need to frame their guidelines as "sustainable" in order to include key aspects of sustainability within them. Moreover, those countries that do frame their guidelines as being "sustainable" may only focus on a few aspects of sustainability rather than adopting a more holistic approach. As consumers increasingly expand their

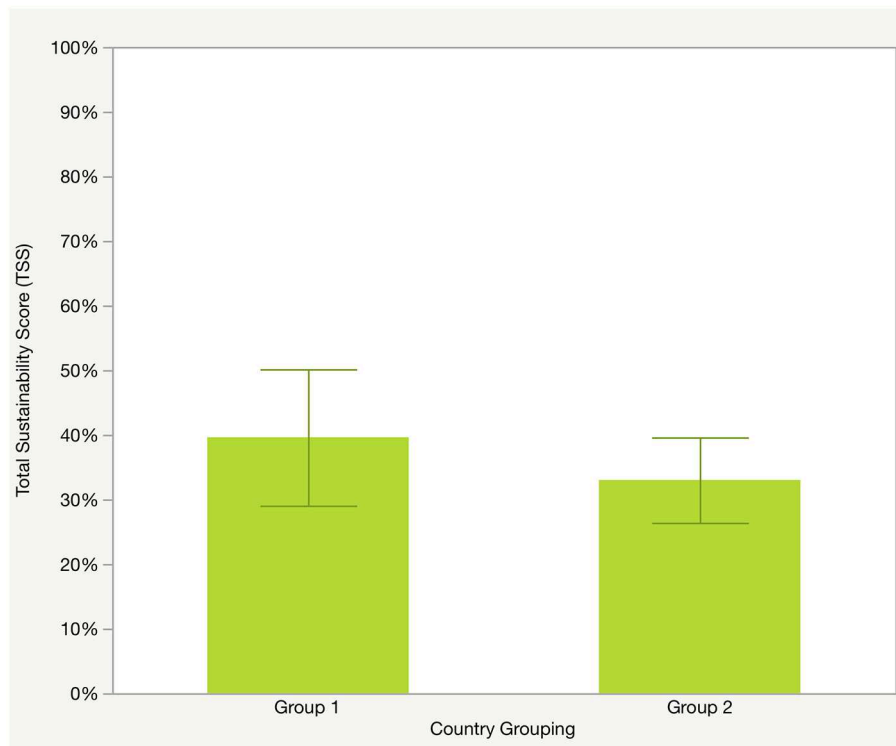


FIGURE 7 | Variation of total sustainability dimension scores (TSS) of national dietary guidelines between country groupings. This figure demonstrates the variation of total sustainability dimension scores comprised of the 32 sub-dimensions of sustainability between countries classified as Group 1 (recognized in the literature to integrate sustainability in dietary guidelines) compared to Group 2. Analysis of variance of TSS between Group 1 and Group 2 found no significant differences.

literacy and values regarding sustainability, the incorporation of sustainability in dietary guidelines will likely increase. A national survey found that 74% of people surveyed in the US agreed that dietary guidelines should include measures of sustainability (John Hopkins Center, 2016). One approach of further increasing sustainability literacy and values is through various curriculum programs targeted at a range of age groups as well as through labeling and advertising.

Another challenge of integrating the multiple dimensions of sustainability in national dietary guidelines is to ensure that associated recommendations and strategies are context specific to a given nation (Tuomisto, 2019) and its' environmental, economic, and socio-cultural factors (Milner and Green, 2018; Springmann et al., 2018) while being applicable to the population as a whole. This requires specific plans and programs associated with the sub-dimensions of sustainability within dietary recommendations to be context-specific to a nation yet applicable and modifiable to the broad population of that nation. For example, recommendations of reducing consumption of animal-source foods in low-income countries may not be as an equitable or ethical of an approach as in high-income country settings because of the prevalence of undernutrition in the former (Milner and Green, 2018). Implementation of a specific approach to sustainable diets may have different implications in different regions (Milner and Green, 2018). Previous research has shown that substituting animal-source foods with plant-based

foods has brought greater benefits for health and reductions in emissions of greenhouse gases in high-income countries while being negated at a global level by water use (Springmann et al., 2018). Thus, strategies are called for to support populations to consume recommended foods and amounts within the contextual constraints faced by these populations within a specific nation. For example, recommendations for adopting nutritionally balanced, low animal-source food diets that allow for dietary diversity may be a more equitable approach in low-income countries (Springmann et al., 2018). As the gap between the rich and the poor continues to widen in many countries throughout the world, a more comprehensive approach to addressing this challenge in dietary guidelines will especially be necessary.

Another challenge of integrating multiple dimensions of sustainability in dietary guidelines relates to the number of government ministries and organizations that influence a nation's food system. Although it is often the Ministry of Health who spearheads the development of national dietary guidelines, integrating multiple dimensions of sustainability within guidelines will necessitate the involvement of ministries beyond health and include multi-sectoral collaborations. Ensuring that key stakeholders from ministries and sectors influencing food systems, such as agriculture, trade, etc. are included as part of the co-development of the guidelines will likely help to increase

buy-in and improve policy coherence (Milner and Green, 2018; Tuomisto, 2019).

Identifying sustainability gaps in dietary guidelines is one step toward enhancing integrating multiple dimensions of sustainability for transforming food systems. The next step is to translate national dietary recommendations based on specific sub-dimensions of sustainability into practice through programs and plans. These programs and plans should be context-specific and can vary throughout a nation depending on ecological, sociocultural, and economic aspects of a place (Milner and Green, 2018). For example, arable farming may not be possible in certain areas within a country with cattle grazing being the most suitable option for food production (Tuomisto, 2019). Suggestions of primarily plant-based diets in those areas may compromise environmental, socio-cultural, health, and economic aspects of sustainability through import of foods to meet dietary recommendations (Tuomisto, 2019) that are not aligned with cultural preferences and historical diets. Programs would be needed in such areas to educate populations about the about preparation of nutritionally adequate plant-based diets (Tuomisto, 2019).

It is increasingly recognized that enhancing sustainability in food systems is shared by all players in the food system and strategies are needed to ensure the long-term commitment by all concerned parties (Food and Agriculture Organization, 2002). Thus, the development and implementation of programs and plans to support sub-dimensions of sustainability are to target different scales of management including individual-level management, systems-level management by policy makers and institutions, and a combination of individual and systems-level management. As consumers can be powerful forces to direct the market place to provide access to specific foods (Food and Agriculture Organization, 2002) associated with sustainable diets, educational efforts are called for to enhance consumer awareness regarding the sub-dimensions of sustainability that are influenced at the individual scale. At the systems-level, different programs and plans are also called for that address the different scales of food systems including the local, regional, national, and global.

Future research is called for to build upon the integrative framework proposed in this study while addressing multiple limitations of the research presented here. A methodological limitation of the integrative framework we applied in this study was that it coded for the presence and absence of specific sub-dimensions of sustainability and did not evaluate frequency or high vs. low presence of specific sub-dimensions within national dietary guidelines. Our experience in coding indicated notable variation in the frequency of occurrence of a specific sub-dimension of sustainability between dietary guidelines. While some guidelines reiterated the importance of a specific sub-dimension multiple times with extensive supporting information, other guidelines only once briefly touched upon the sub-dimension. For example, the dietary guidelines for Brazil mentioned the importance of procuring seasonal and local foods on multiple pages and in multiple contexts while the guidelines of several other countries, such as Grenada mentioned this sub-dimension of sustainability to a notably lesser

extent. However, both scored the same based on the scoring system implemented in this study, yet we can assume that reiterating the importance of a specific sub-dimension multiple times with substantial supporting evidence or recommendations would have greater impact on consumers and the development of supporting programs and policies. Further methodological development is needed in order to systematically evaluate the frequency of the presence of specific sub-dimensions in dietary guidelines. Another limitation of the integrative framework presented here is the equal prioritization of the ecological, economic, socio-cultural/political, and human health dimensions and sub-dimensions of sustainability. Countries implementing national dietary guidelines may have different priorities and can modify the proposed framework and its scoring based on these priorities. Finally, other key limitations of this study were inclusion of dietary guidelines from only upper-middle and high-income countries as well as those available in English. Future analysis of dietary guidelines is called for that applies the integrative approach presented here to include a more representative sample inclusive of low- and middle- income countries as well as in order to identify global patterns and making broader conclusions toward supporting sustainable food systems for all. Further cross-cultural comparison across countries as well as those of different income levels may result in modification of the proposed integrative framework as well as prioritization of the different sub-dimensions of sustainability based on context. The integrative framework and associated scoring indices of Sustainability Dimension Scores and Total Sustainability Scores presented here can further be modified and validated for application for evaluating specific foods (**Supplementary Table 2**), diets (**Supplementary Table 3**), and food environments (**Supplementary Table 4**). This would enable research to evaluate how dietary guidelines of a specific nation translate into impacting local food environments, food availability, and diets.

CONCLUSION

National dietary guidelines are a policy tool that have the potential to shift consumption patterns in directions that support multiple dimensions of sustainability in the food system, while supporting both environmental and human well-being. Given the pressure that food system processes from production through consumption and waste are placing on the planet, coupled with the uncertainty of climate change and variability for food security of a growing population, it is especially critical for food policies, such as national dietary guidelines to support sustainability goals. Effective incorporation of multiple dimensions of sustainability into dietary guidelines has the potential for food system transformation that enables consumers to make food choices that support planetary health.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the manuscript/**Supplementary Files**.

AUTHOR CONTRIBUTIONS

All authors contributed to the study's concept, design, and research questions. SA and SD conducted the data analysis, interpretation, and drafted the manuscript. All authors approved of the final manuscript.

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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.2019.00076/full#supplementary-material>

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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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