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Reverse thinking: taking a healthy diet perspective towards food systems transformations

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Contents

Abstract

Food systems are increasingly under pressure to deliver healthy diets without exceeding the boundaries of planetary resources. These healthy diets also need to be safe, accessible and affordable for all segments of the population, including disadvantaged and nutrition-vulnerable groups of smallholder producers, traders and consumers in low- and middle-income countries. Globally, food systems have undergone rapid and dramatic changes, and are increasingly failing to fulfil these multiple duties simultaneously, in high-, middle- and low-income countries alike. The international community therefore calls for rigorous food systems transformations and policy solutions to support the achievement of healthy diets for all. The proposed strategies, however, are essentially supply- and market-oriented. A healthy diet perspective in food systems transformation is essential to ensure that consumers can access nutritious foods and achieve healthy diets. This paper argues that a dietary perspective should be incorporated in food systems transformation and guided by existing information on diets, dietary trends, consumer motives and the food environment characteristics. Based on data and the food systems typology of the recently released Food Systems Dashboard, this paper shows that dietary trends differ by food system development stage. Different transformational approaches are thus required for different food system types to ensure healthier diets for systems at different stages of development. We review the current knowledge on drivers of consumer choices at the individual and food environment levels and discuss the conflicting objectives and trade-offs among the multiple food systems actors, and argue that failure to resolve these may lead to unintended consequences in food systems outcomes. The paper illustrates some of these trade-offs, including those related to animal-sourced foods, ultra-processed foods and healthy diet affordability. It describes a menu of promising policy options to adopt in the food systems transformation agenda and reflects on how a dietary perspective may contribute to sustainable food systems transformations. Pathways of impact for the options proposed need to be identified clearly, and the evidence of their impact on healthy diets among consumers in low- and middle-income countries is urgently needed.

Keywords: Food systems, nutrition, consumers, sustainability, healthy diets.

1. Introduction

Diets play a central role in present food systems (GLOPAN, 2020), and they are seen either as “victims” or “instigators”. The diet is considered a victim, or an outcome, of those food systems in which diets change due to urbanization, changing food environments and climate change constraints, or it is considered an instigator, or a driver, where food system transitions are seen as a consequence of changing consumer demand due to shifts in dietary patterns and population growth. Irrespective of which of these perspectives is taken, there is a growing recognition of the need to improve diet quality and reduce inequalities in access to nutritious, affordable and sustainably produced foods in all countries. Poor diets are a major driver of malnutrition, mortality and morbidity worldwide, exceeding the burdens attributable to many other global health challenges (GBD 2017 Diet Collaborators, 2019). While some progress has been made in reducing the prevalence of undernutrition (stunting and wasting), micronutrient deficiencies persist, and the prevalence of overweight, obesity and diet-related non-communicable diseases (NCDs) is rising across the globe, the fastest in low-income countries (Development Initiatives, 2020; Popkin et al., 2020). Most countries are burdened by multiple forms of malnutrition, especially low- and middle-income countries (LMICs) (Popkin et al., 2020). The most nutritionally vulnerable groups are women of reproductive age and young children. Inequalities in the burden of malnutrition are largely driven by socio-economic disparities determined by location (urban/rural or geographical), wealth and education, and are further compounded by conflict and other forms of fragility (Development Initiatives, 2020). Improving the quality of diets is one of the key strategies to prevent or reverse all forms of malnutrition and related NCDs.

A global nutrition transition was documented for the first time more than 25 years ago, described as a shift from diets with a high proportion of a limited set of staples towards more-diversified diets that are higher in energy and macronutrients, as in specific food groups, such as meat, sugar, processed foods and foods eaten outside the home (Popkin, 1993). Dietary changes are driven by urbanization, increased disposable incomes, societal changes such as greater participation by women in labour markets, and developments in technology, marketing strategies and public policy (Popkin et al., 2020; Vermeulen et al., 2020). People are eating more food and more energy, protein and fats, and although diets have diversified for individuals, globally they have become more homogenous, relying on the same small number of traded commodities (Khoury et al., 2014). While from 1990 to 2010 the consumption of healthy foods (vegetables, fruits, nuts, seeds) increased around the world, so did the consumption of foods containing ingredients known to carry health risks (Imamura et al., 2015). Meat consumption increased globally by 20 kg per capita between 1961 and 2014 (Vermeulen et al., 2020), and volume sales of ultra-processed foods (UPFs) increased rapidly worldwide (Vandevijvere et al., 2019; also see box 2). There is a large heterogeneity in these dietary changes across regions and countries (Imamura et al., 2015).

There is a concern, especially for LMICs, that dietary changes are occurring rapidly, impacting younger population groups and happening in circumstances in which infectious diseases and diseases of nutritional deficiency continue to persist, creating a dual challenge of undernutrition and overnutrition within families, communities and nations (Popkin et al., 2020; Raj, 2020). The impact of these changes on nutrition and health is complex, as certain dietary shifts are negative and others are positive in terms of populations meeting national (where available) and global dietary intake recommendations (Mozaffarian, 2016).

The nutrition transition and the related dietary changes are intrinsically connected to the dynamics of food systems changes, which take place along a continuum from rural to industrialized food systems. The dietary changes needed to move towards healthy diets depend on the stage of food systems change. Growing pressures on the environment complicate the healthy diet objective further as agricultural production intensifies to meet rising global demands for more diverse diets. Food is being transported over long distances from where it is grown to where it is consumed, creating mixed consequences for diets (Kimenju et al., 2015), the environment (Born and Purcell, 2006), and food safety hazards and risks (Grace, 2015; Tschirley et al., 2015), depending on the context. Climate change leads to food systems degradation, with direct consequences of a lower availability of nutritious foods, especially in tropical areas (Challinor et al., 2014), reduced nutrient levels of crops (Myers et al. 2014), reduced food safety levels and in increased food losses and waste due to higher humidity and temperature (FAO et al., 2018; Tirado et al., 2010). Meanwhile, the gap in costs between recommended and affordable diets is increasing. It is estimated that

around 3 billion people around the world cannot afford a recommended healthy diet (FAO et al., 2020). This is primarily due to the high cost of nutrient-rich non-staples, which drive consumption patterns among the poor towards cheap, monotonous, starch-heavy diets. The challenge for food systems transformations is to move towards healthy, safe, affordable and sustainable diets for all, but trade-offs between the short- and long-term interests of food systems actors and outcomes are unavoidable and need to be navigated explicitly.

To achieve the goal of sustainable, healthy diets for all, the present food systems need urgent transformation (FAO et al., 2020; GLOPAN, 2020; Young et al., 2019). Efforts to transform the food systems have traditionally focused on increasing production quantity and efficiency to produce enough food (grains) and increase producer income. This has contributed largely to reducing hunger – although hunger has been going up in the last few years (FAO et al., 2020) – but has not contributed to improved diets, better health or environmental sustainability. To the contrary, present food systems are not aligned with todays' constraints (GLOPAN, 2020). To reverse this, we propose the adoption of a healthy diet perspective, whereby consumer needs and preferences are put at the centre of food systems solutions to enable longer-term consumption shifts through linking healthy food consumption to markets, distribution, production and agriculture (Béné et al., 2019; Brouwer et al., 2020), making sustainable, healthy diets available, accessible and desirable for all. This paper argues that such a dietary perspective should make use of adequate information on diets, dietary trends, consumer motives and the food environment characteristics.

Starting with a comprehensive overview of what a healthy (and sustainable) diet is, we describe the evolution of dietary transitions and nutrient gaps at different stages of food systems development using the data and food systems typology available in the recently launched Food Systems Dashboard (Fanzo et al., 2020). We review the current knowledge on the drivers of consumer choices at the individual and food environment levels, and describe the challenges related to the shifts in demand for and consumption of animal-sourced foods (ASFs) and UPFs, and to the unaffordability of healthy diets for a large part of the population in LMICs, highlighting key trade-offs. We also describe promising strategies to influence consumer food choices directly and indirectly through food environment interventions and identify supply-oriented strategies that could support them. Overall, this paper provides a reflection of how a dietary perspective may contribute to sustainable food systems transformations, identifying possible pathways, research needs and limitations.

2. Consumption of a healthy diet: trends and gaps

This chapter describes what is meant by a healthy and sustainable diet, the importance of food-based dietary guidelines (FBDGs) to contextualize healthy diets, and how diets vary by food system types. It also provides a comprehensive overview of the main dietary gaps and trends in the world.

2.1 What is a healthy diet?

A healthy diet ensures the optimal growth and development of infants and children, and throughout adult life it protects against malnutrition in all its forms. As a basic requirement for productive life, a healthy diet is also preventive against diet-related non-communicable diseases (NCDs) such as heart disease, stroke, type 2 diabetes and certain forms of cancer. While there is no general consensus on what a healthy diet should consist of, there are general criteria. According to the World Health Organization (WHO), "The exact make-up of a diversified, balanced and healthy diet will vary depending on individual needs (e.g. age, gender, lifestyle, degree of physical activity), cultural context, locally available foods and dietary customs. But basic principles of what constitutes a healthy diet remain the same" (WHO, 2018). Some of these basic principles include diversity and proportionality between food groups; adequate amounts of fruit and vegetables, whole grains, legumes and nuts; sufficient intake of starchy staples and ASFs (the preferred forms of which are milk, egg, poultry and fish). Definitions of healthy diets also include avoiding or limiting the intake of foods, food groups and nutrients that become unhealthy when eaten in excess, such as free sugars (including sugar-sweetened beverages), too much total energy and unhealthy types of fat (especially saturated fats and trans-fatty acids), salt (which if used should preferably be iodized), red meat, processed meat and UPFs. A healthy diet goes beyond nutrient adequacy – meeting all essential macro- and

micronutrients, for example. It also emphasizes some food groups and components, such as fruit, vegetables and fibre, specifically for the prevention of NCDs, within a palatable, balanced and culturally acceptable diet (Herforth et al., 2020). A healthy diet is also a safe diet, containing minimal or, if possible, zero levels of pathogens, toxins and other agents that can cause food-borne diseases like diarrhoeal disease (FAO and WHO, 2019). These principles of healthy diets apply to all age ranges, from young children to adults. For infants, a healthy diet comprises exclusive breastfeeding until they are 6 months of age, and complementary feeding of adequate, safe, and nutrient-dense foods after 6 months of age, including continued breastfeeding to the age of 2 years (WHO, 2018).

Based on scientific evidence on the association between food and food components with a wide range of health outcomes, WHO (WHO, 2018) and the Global Burden of Disease (GBD) group (GBD 2017 Diet Collaborators, 2019) identified the optimal levels of intake of different food groups (see table 1). These optimal amounts represent the components of diets for which there is the best evidence –positive and negative – for protecting health against diet-related NCDs. Unlike FBDGs, they do not represent a total diet or the proportions of all types of food recommended for energy and nutrient adequacy. Some well-known general health-promoting diets, tailored to a region or certain health outcomes, are the Mediterranean diet, the Nordic diet and the dietary approaches to stop hypertension diet (Trijsburg et al., 2019).

The EAT-Lancet recommended diet is the result of a recent effort by the EAT-Lancet Commission on Food, Planet, Health to summarize the existing evidence on the dietary components and patterns that both optimize health and protect the planet (e.g. minimize the environmental footprint) (Willett et al., 2019). Internationally applicable dietary guidelines are not available, but the EAT-Lancet diet attempts to provide a template for a healthy and sustainable diet. The EAT-Lancet diet is not, however, a recommended diet, nor is it endorsed by WHO. It cannot therefore be used in guidelines to inform the public, until these are further translated and tailored to a local situation (Willett et al., 2019).

Table 1 compares the optimal levels and ranges, against dietary risk factors, of intakes of food groups in each of these diets. Although the recommendations largely overlap in food groups, food components and the nutrients addressed, there are differences in the optimal levels and range of intakes recommended; one reason being that, contrary to the WHO and GBD recommendations, the ones from EAT-Lancet take into account energy and nutrient adequacy.

Table 1
Optimal levels against dietary risk factors, according to different references

Dietary risk	*UN global recommendation (WCRF and AIRC, 2018; WHO, 2018, 2003)*	*Optimal level of intake (optimal range) (GBD 2017 Diet Collaborators, 2019)*	*EAT-Lancet reference diet (Willett et al., 2019)[1]*
Low in Fruits	≥400 g per day (excluding starchy roots)	250 g (200-300) per day	200 g (100-300) per day
Low in Vegetables		360 g (290-430) per day	300 g (200-600) per day
Low in Legumes	A healthy diet includes legumes, nuts and whole grains.	60 g (50-70) per day	75 g (0-100) per day
Low in Whole grains		125 g (100-150) per day	232 g per day (0-60% of daily energy)
Low in Nuts and seeds		21 g (16-25) per day	50 g (0-75) [d] per day
Low in Milk		435 g (350-520) per day fluid milk	250 g (0-500)[e] per day fluid milk equivalent
High in Red meat	≤350 -500 g[f] per week	≤22.5 g[f] per day	14 g (0-14) g per day
High in Processed meat	0 g per day	≤2 g (0-4) per day	
High in Sugar	<10%[a] of total daily energy	≤3 g (0-5)[b] per day	31 g (0-31)[c] per day
Low in Fibre	>25g/day (or 12.5 g/1,000 kcal)	24 g (19-28) per day	
Low in Calcium		1.25 g (1.00-1.50) per day	

Low in Seafood omega-3 fatty acids		250 mg (200-300) per day	28 g[h] (0-100) per day
Low in Polyunsaturated fatty acids	<30% of total energy intake from total fat. Unsaturated fats are preferable to saturated fats and trans-fats.	11% (9-13) of total daily energy	40 g (20-80) per day
High in Saturated fats	<10% of total daily energy		11.8 g (0-11.8) per day
High in Trans fatty acids	<1% of total daily energy; 0g industrially produced trans-fats	≤0.5% (0.0-1.0) of total daily energy	
High in sodium	<5 g salt[i] per day; salt should be iodized.	≤3 g (1-5) per day	

[1] Based on an isocaloric diet of 2503 kcal per day; GBD does not specify an optimal energy intake, and WHO (2018) states "Energy intake (calories) should be in balance with energy expenditure."
[a] free sugars; [b] sugar-sweetened beverages; [c] added sugars; [d] only nuts; [e] whole milk or equivalents; [f] unprocessed red meat; [g] beef, lamb and pork; the EAT-Lancet reference diet additionally has disaggregated recommendations for chicken and other poultry (29 g (0-58) per day), and eggs (13 g (0-25) per day; [h] fish; [i] salt, equivalent to <2 g sodium.

National FBDGs are designed to represent healthy diets that are culturally appropriate to the country. Multidisciplinary task forces develop national FBDGs by reviewing the existing evidence on the country's prevailing diseases and nutrition problems, food availability, and food preferences using modelling techniques to arrive at dietary recommendations for specific target groups defined by age and sex but also sometimes by geographical location (Bekele et al., 2019). While being designed for specific countries, contexts and populations, different FBDGs show many similarities on the key elements of a healthy diet. Almost all national FBDGs emphasize proportionality, diversity, an abundant intake of fruit and vegetables, the inclusion of whole grains, and limited amounts of ASFs (especially red meat), and they limit the intake of salt, fat and sugar (Herforth et al., 2019).

Unlike the global optimal levels defined by researchers (e.g. for the EAT-Lancet diet and GBD dietary risk factors), national FBDGs are policy documents. FBDGs not only define the minimum dietary standard and inform the population on what to eat to prevent all forms of malnutrition and NCDs, but they may also facilitate policy decisions. FBDGs can: impact food assistance and social safety net policies, for example; affect public procurement in government institutions such as schools, hospitals, prisons and government-run offices; are relevant to the regulation of the industry in food product formulation; and potentially impact agriculture and food systems investment strategies for healthier diets. Global and national dietary guidelines have been underutilized as tools for informing rural investment strategies, both in terms of agricultural development (e.g. research focused on fruit and vegetables, or rural-ready cold chains) and safety nets tailored to rural areas to facilitate access to diets that meet dietary guidelines (e.g. the distribution of seeds or other supplies for homestead food production). Although there is some evidence on the understanding and adoption of FBDGs by consumers (Brown et al., 2011; Keller and Lang, 2008; Nguyen et al., 2015), there is no information available on the impact of using FBDGs in guiding policy or programme investments towards healthy diets.

2.2 Can healthy diets be sustainable?

A sustainable diet is one that has a low environmental impact while being nutritionally adequate (HLPE, 2017). The environmental indicators that are commonly used to evaluate the environmental impact of diets or individual food items are greenhouse gas emissions, water use/water scarcity, land use, acidification and eutrophication.[1] The analysis of these can be combined with a life cycle assessment to measure impact at stages of production, use, waste and recycling. Information for these environmental indicators generally

[1] Eutrophication is the gradual increase in the concentration of phosphorus, nitrogen and other plant nutrients in an ageing aquatic ecosystem.

originate from datasets that are based on the urbanized and industrialized food systems present in high-income countries, with limited applicability to low- and middle-income countries (LMICs), where food systems are less complex (Behrens et al., 2017; Eme et al., 2019). To cover LMIC settings, elaborate life cycle assessments are needed, which require resources, time and capacities that are often not available. Although healthy diets are not necessarily sustainable diets (and vice versa), evidence suggests that synergies can be identified (Béné et al., 2019; FAO et al., 2020; Springmann et al., 2016). This evidence is coming from studies comparing the environmental sustainability and healthiness of hypothetical diets (Kim et al., 2020; van Dooren et al., 2014) or evaluating the environmental impact of food-based guidelines, averaged using population level data (Behrens et al, 2017), or of the actual dietary intake data of individuals (van de Kamp et al., 2018). In general, the addition of healthy food items (from the food groups whole grain, cereals, fruits, vegetables, legumes, nuts and olive oil) to a diet has low environmental impact. Furthermore, processed or red meat has the highest contribution to both disease risk and negative environmental impact (Clark et al., 2019).

Authors of FBDGs are being challenged to explicitly incorporate environmental sustainability considerations (see box 1) in the development of these recommendations for a healthy diet (Gonzalez Fischer and Garnett, 2016). In the absence of such considerations, most FBDGs are incompatible with the Paris Agreement on climate change and other environmental targets (Springmann et al., 2020). According to current models, the sustainability of guidelines in most cases could be strongly improved by providing guidance to balance the consumption of meat (particularly meat from ruminants) and dairy (Blackstone et al., 2018; Ritchie et al., 2018; Springmann et al., 2020). In this sense, the EAT-Lancet diet offers a template from which a proportional sustainable diet can be adapted to country contexts within FBDGs.

Whether the transition towards healthier diets translates into more sustainable diets, however, is highly context-specific. In general, the adoption of FBDGs would lead to a lower environmental impact compared with that created by the current global dietary consumption, according to an analysis by Behrens and others (2017), although very few diets from LMICs were included in it. A recent modelling study with data from 85 countries concluded that the current national FBDGs could be more environmentally sustainable and also healthier, regarding global environmental and NCD targets (Springmann et al., 2020). Aligning with the EAT-Lancet diet would require a global shift towards a much greater consumption of plant-based foods and a lower consumption of ASFs, especially red meat. The need for these global changes is driven by consumption patterns in high-income and industrialized countries, which currently consume excessive amounts of ASFs. In countries where ASFs are consumed in very low amounts (such as LMICs in sub-Saharan Africa and South Asia), their increased consumption could be beneficial for health (by enhancing bioavailable micronutrients and high-quality protein in the diet) without exceeding the thresholds set by the EAT-Lancet reference diet on sustainability. Optimal dietary patterns that align with both sustainability and health goals vary considerably between countries, depending on how and where the foods are produced. This makes a nuanced approach important, along with acceptance that the need to ensure adequate intake for chronically undernourished people might come with increases in greenhouse gas emissions and water footprints (GLOPAN, 2020; Kim et al., 2020).

Box 1: Sustainability considerations in food-based dietary guidelines

Despite the growing awareness of the influence of dietary choices on the environment and the accelerated demand to include environmental sustainability aspects within FBDGs, there are few countries that have included, or attempted to include, environmental sustainability in their FBDGs, and only quasi-officially and to various degrees. These are all high-income countries, like Australia, Canada, France, Germany, the Netherlands, Qatar, Sweden, the United Kingdom and the United States (Brink et al., 2016; Gonzalez Fischer and Garnett, 2016; Health Canada, 2019; Public Health England, 2018). All highlight that a plant-based diet has advantages for the environment and health. All include advice to eat more fruit and vegetables, most mention the high environmental impact of red meat and dairy products, and some include sustainability concerns around fish, but these recommendations often lack specificity on quantity (or the ranges of intakes recommended) and on which sustainably produced food items should replace those recommended to be left out of the diet (e.g. replacement sources of high-quality protein or other essential nutrients). In general, guidelines do not address sustainability concerns around packaging and plastic waste. Some, like Brazil's and Uruguay's, include advice to avoid UPFs, although the evidence on environmental impact is still unclear (Gonzalez Fischer and Garnett, 2016). Furthermore, the absolute quantity of foods eaten impacts the sustainability of diets – the higher the intake of calories, the higher the environmental impact of the diet (Vieux et al., 2012) – so a general message for improving diet sustainability is to eat enough to cover energy and nutrient needs, but not to eat too much (a message that is appropriate to highlight only for populations with risks of overeating).

The development of FBDGs is led and owned mostly by ministries of health or their equivalent, but the commitment from governments to integrate health and sustainability necessitates collaboration with individuals with a broad range of expertise. Including experts in environmental sciences, fisheries or forestry, for example, increases the likelihood of incorporating environmental considerations into FBDGs. Although the mathematical optimization (linear programming) of diets for multiple outcomes could be a useful approach to generate diets that optimize nutrient adequacy and environmental sustainability, very few countries use these techniques. This is because of a lack of available representative data on food consumption and of data on the environmental impacts of different food production systems, plus a lack of modelling expertise (van Dooren, 2018). The Netherlands provides an example of, in the process of revising FBDGs, including environmental impact considerations, using a maximum level in the diet-optimization model for animal food groups, based on the evidence of their impact on greenhouse gas emissions (Brink et al., 2019). Applying these constraints led to a lower recommended intake of animal-sourced foods than would have been yielded by the diet optimization if this had been based on the nutrient adequacy of animal-sourced foods. According to a scenario study, the effect of these recommendations of reduced animal-sourced food consumption on greenhouse gas emissions can be considerable, ranging from a 13 per cent reduction for men aged 31 to 50 years, to a 5 per cent increase in emissions for women aged 19 to 30 years. Replacing meat in this diet and/or consuming only foods with relatively low greenhouse gas emissions resulted in average emissions reductions varying from 28 to 46 per cent (van de Kamp et al., 2018). All countries that give guidance on environmental sustainability include broadly similar messages, with some differences in emphasis. Several African countries are developing FBDGs and including the discussion of sustainability in this process (Downs et al., 2020).

2.3 Overview of dietary transitions and dietary gaps by food system types

Making use of the recently launched Food Systems Dashboard (Fanzo et al., 2020), complemented with data across income groups from the State of Food Security and Nutrition in the World (SOFI) report – co-authored by the Food and Agriculture Organization of the United Nations (FAO, 2020) with other international organizations – this section illustrates dietary patterns and their heterogeneity across food system types. The diversity analysis of edible quantities of food groups is from FAO food balance sheets, as reported in SOFI 2020 (FAO et al., 2020), while the sections on dietary risk factors draw from the Food Systems Dashboard indicators on adult dietary intake data, which are based on the GBD study (GBD 2017 Diet Collaborators, 2019). Annex 1 gives details on the indicators of food availability and dietary intake selected from the 150 food systems indicators in the Food Systems Dashboard (for example, the share of

dietary energy from cereals, roots and tubers, or the estimated consumption per capita of fruit, vegetables, whole grains, red meat and sugar-sweetened beverages). This analysis draws on existing data that can be compared across countries, and it is important to note that it has the same limitations in the interpretation of these data as are reported elsewhere (Development Initiatives, 2020; FAO et al., 2020). Most importantly, there is a lack of nationally and globally representative data on food consumption patterns. The most comprehensive available evidence comes from the GBD study, which is modelled on the best available evidence of global dietary intake (GBD 2017 Diet Collaborators, 2019).

Food systems typology

The food systems typology defined in the Food Systems Dashboard (Fanzo et al., 2020) is used to describe dietary risk factors. Its five food system types (rural and traditional, informal and expanding, emerging and diversifying, modernizing and formalizing, and industrialized and consolidated) are based on a composite of four indicators: agriculture value added per worker, the share of dietary energy from cereals, roots and tubers, the number of supermarkets per 100,000 population and the percentage of the urban population in the total population. Box 2 describes the five system types in more detail. Figure 1 reveals the heterogeneity of these food system types across regions, with Africa having four of the five types, Asia representing all five types, Europe showing three types and North and South America having three and four types, respectively. This typology is intended to help with describing current food systems; it should not be considered to be drawing value judgements or promoting one particular type of food system. Urban and rural areas of the same country might have very different food system characteristics, particularly in terms of market type, food availability and the food environment where consumers interface with the foods they acquire. Such subnational heterogeneity is not captured in the Food Systems Dashboard.

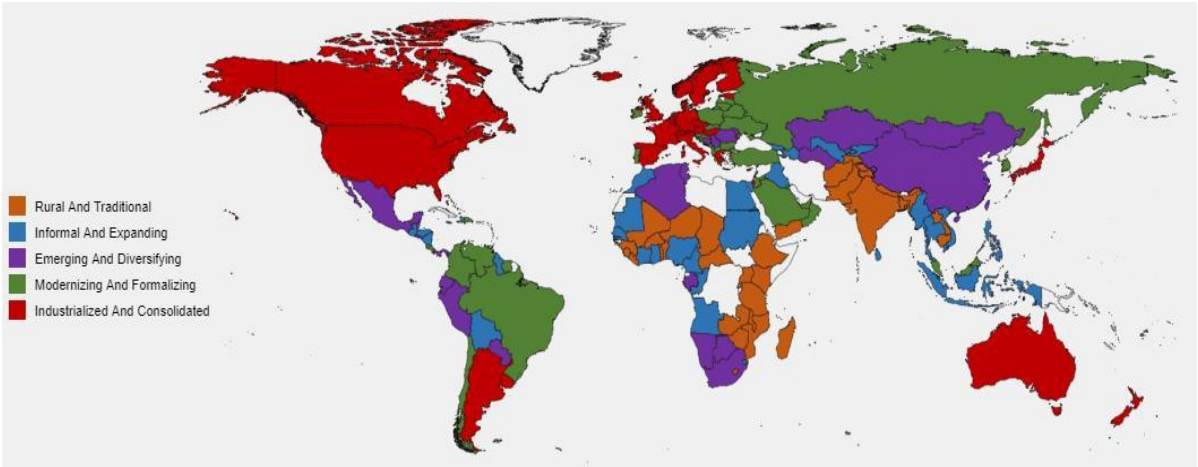

Figure 1: Countries by food system type defined by the Food Systems Dashboard

Source: https://foodsystemsdashboard.org

For the indicator behind the five food system types that gives the share of dietary energy from cereals, roots and tubers, the global average is 51 per cent. This share ranges across countries from 22 per cent in the Bahamas to 79 per cent in both Bangladesh and Madagascar (Food Systems Dashboard, 2020). Moving from the rural and traditional food systems to the industrialized and consolidated food systems, the weighted average share halves, from 61 per cent to 30 per cent. The 2020 SOFI report also shows that the percentage share of dietary energy from cereals, roots and tubers decreases dramatically with national income. Low-income and lower-middle-income countries rely more on staple foods than high-income countries (FAO et al., 2020), although the level of income does not necessarily align with the food system type. As seen in Figure 1, not all high-income countries have industrial and consolidated food systems; there is a heterogeneity of food system types across middle-income countries; and not all low-income countries have rural and traditional food systems (Food Systems Dashboard, personal information).

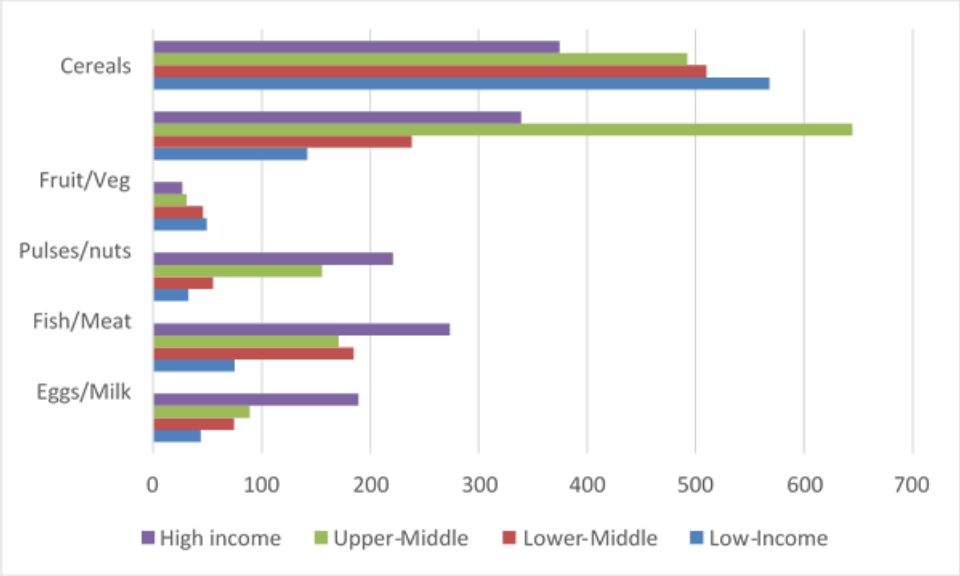

Figure 2: Edible quantities available (g/d/day) by food groups

Source: Adapted from SOFI, 2020 (FAO et al., 2020).

The 2020 SOFI report estimates the availability of food groups at the national level, showing a range of grams per capita per day available across the four income groups, classified as high, upper-middle, lower-middle and low (FAO et al., 2020). As shown in Figure 2, the supply of cereals and pulses is largest in low- and lower-middle-income groups compared with wealthier countries. By contrast, the availability of fish, meat, sugar and oil is greater in the high- and upper-middle-income groups. Demand for ASFs has been rising alongside rising incomes. The proportion of dietary energy derived from ASFs varies, and is often high (over 30 per cent) in high-income countries, compared with 5 to 10 per cent in LMICs (Dasi et al., 2019). Despite much controversy around ASFs, their high nutritional value contributes to nutrient adequacy and is especially noted for preventing iron-deficiency anaemia in women of reproductive age and in young children and, for the latter, in supporting motor and cognitive development (Grace et al., 2018; Neumann et al., 2003) (see section 3.2). The supply of fruit and vegetables is lower than the recommended 400 g/capita/day in all types of country except the upper-middle-income ones, but the reasons for the higher supply in these countries are not known.

While instructive, this analysis does not distinguish foods by dietary risk factor. For example, what proportion of the grains consumed are whole grains, and what proportion of meat is red or processed meat? The analysis also does not provide information on the regional, community or household distribution of different food categories, let alone on actual dietary intakes. The next section illustrates these patterns by food system types.

Box 2: The five types of food system in the Food System Dashboard

Rural and traditional	In rural and traditional food systems, farming is done mainly by smallholders, and agricultural yields are typically low. Limited infrastructure for refrigeration and storage can result in large food losses for some crops and can limit diversification into perishable foods. The quantity and diversity of foods available varies seasonally. Food is sold mainly in informal market outlets, including independently owned small shops, by street vendors and in central/district markets. Supermarkets are rare outside of capital cities, though they are beginning to grow in number along with fast food chains.
Informal and expanding	Processed and packaged foods are available in both urban and rural areas. Food processing may include a combination of locally sourced and imported ingredients. Demand for convenience foods increases as the formal labour force grows and includes more women. Urbanization and income growth also play roles in dietary shifts. Supermarkets and fast food are rapidly expanding and are more accessible (to middle-class consumers) compared with rural and traditional food systems. However, most consumers continue

	to obtain most of their food from informal market outlets, especially for animal-sourced foods, fruit and vegetables. Few food-quality standards are in place and advertising is not regulated.
Emerging and diversifying	In emerging and diversifying food systems, an increased number of medium- and large-scale commercial farms coexist with large numbers of small-scale farms. These small-scale farms are more linked to markets than in more traditional food system types. Modern supply chains for fresh foods, including fruit, vegetables and animal sourced foods, are developing more rapidly. Supermarkets are common, even in smaller cities and towns, and their market share is growing rapidly. Processed foods, including ultra-processed foods, are common in urban areas and also found in many rural areas. Most fresh food continues to be acquired through informal markets, but the share of supermarkets is rising and significant. A greater proportion of countries in this food system type than in the rural/traditional and emerging/diversifying types have adopted food-based dietary guidelines.
Modernizing and formalizing	In modernizing and formalizing food systems, agricultural productivity is generally higher than in emerging, informal and traditional systems. Larger farms rely more on mechanization and input-intensive practices. Food supply-chain infrastructure is more developed, which results in fewer food losses on the farm and beyond the farm gate. Better national distribution chains enhance the role of food imports in enabling more year-round availability of diverse foods. There are multiple supermarket chains operating within cities and larger-sized towns. These and other modern retail outlets hold a large share of processed and dry goods sales, have captured a larger market share of fresh foods, and low-income consumers are much more likely to shop in them. Government regulation and monitoring of food-safety and quality standards are more common. Most recently, aggressive food labelling is emerging for ultra-processed foods.
Industrialized and consolidated	In industrialized and consolidated food systems, farming is a small proportion of the economy. There are a small number of large-scale, input-intensive farms that serve specialized domestic and international markets (e.g. horticulture, animal feed, processed food ingredients, biofuels). Supermarket density is high in cities and most towns have multiple outlets. The formal food sector has captured nearly all the food eaten domestically, including fresh foods. There is growth in luxury food retail and “fast-casual” restaurants, which market higher-quality fast food. Pockets of food insecurity persist, along with economic disparities. A greater proportion of countries in this type of food system have adopted policies that ban the use of industrial trans fats and encourage the reformulation of processed foods to reduce salt intake.

Source: Adapted from Food System Dashboard, available at https://foodsystemsdashboard.org

Consumption of healthy and unhealthy foods by food system type

The analysis of patterns of consumption of healthy food groups and less healthy food groups by food system types basically confirms that the nutrition transition has happened, as predicted 25 years ago (Popkin, 1993). Certain elements of a higher-quality diet, such whole grains and pulses, appear in more rural and informal food system types, while the consumption of fruit and vegetables peaks in the emerging and industrializing food system types.

Figure 3 shows the mean daily consumption of healthy food groups (vegetables, fruit and whole grains), based on the data provided by the Food Systems Dashboard. Mean daily consumption of vegetables is highest (227 g/day) in the emerging and diversifying food system, followed by consumption in the industrial system (194 g/day), the informal and expanding system (168 g/day) and the rural and traditional system (137 g/day) – a large range across the food system types. Mean daily consumption of fruit is highest (122 g/day) in the modernizing and formalizing system, followed by the industrial type, falling to the lowest mean daily consumption (68 g/day) in the rural and traditional food system type. In all food systems, none of the diets reaches the WHO recommendation of 400 grams of fruit per day. The SOFI report has reported that low-income countries rely less on fruit, vegetables and FBDGs than high-income countries, and that enough fruit and vegetables are available only in Asia and upper-middle-income countries to meet the FAO/WHO recommendations of 400 g/person/day (FAO et al., 2020).

In terms of the mean daily consumption of whole grains, it is highest in the informal and expanding systems, followed by the rural and traditional ones. Again, intakes are much lower than globally recommended (see the recommendations in table 1). The contributing factors related to the food system type are likely to be less industrial processing and more local and home processing (hand pounding and local milling), more fragmented distribution channels and more local marketing.

While the picture for fruit, vegetables, whole grains and pulses is mixed across food system types, there are clear patterns seen with the modernizing and industrializing system types, of increased consumption of foods containing ingredients that present health risks (referred to as unhealthy foods), such as processed meat and sugar-sweetened beverages (Figure 4). The consumption of sugar-sweetened beverages rises from 7.8 g/person/day in the rural and traditional food system type to 131 g/person/day in the industrialized and consolidated type. Red meat consumption shows a substantial jump when moving from the informal and expanding type to the emerging and diversifying one.

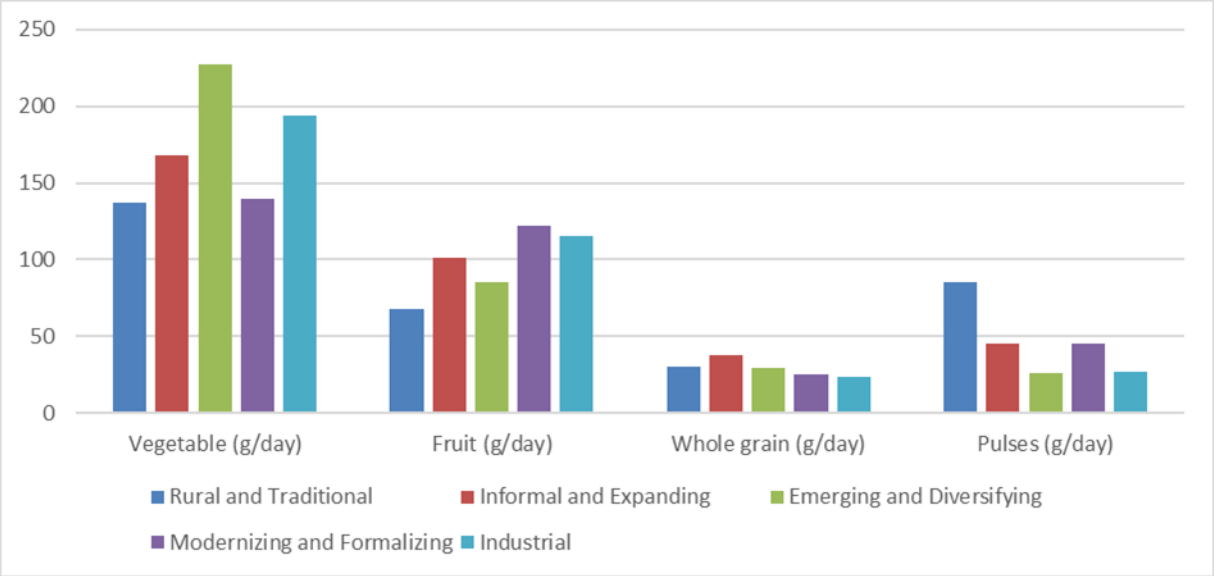

Figure 3: Mean daily estimated consumption of vegetables, fruits, whole grains and pulses by food systems type (g/person/day)

Source: https://foodsystemsdashboard.org

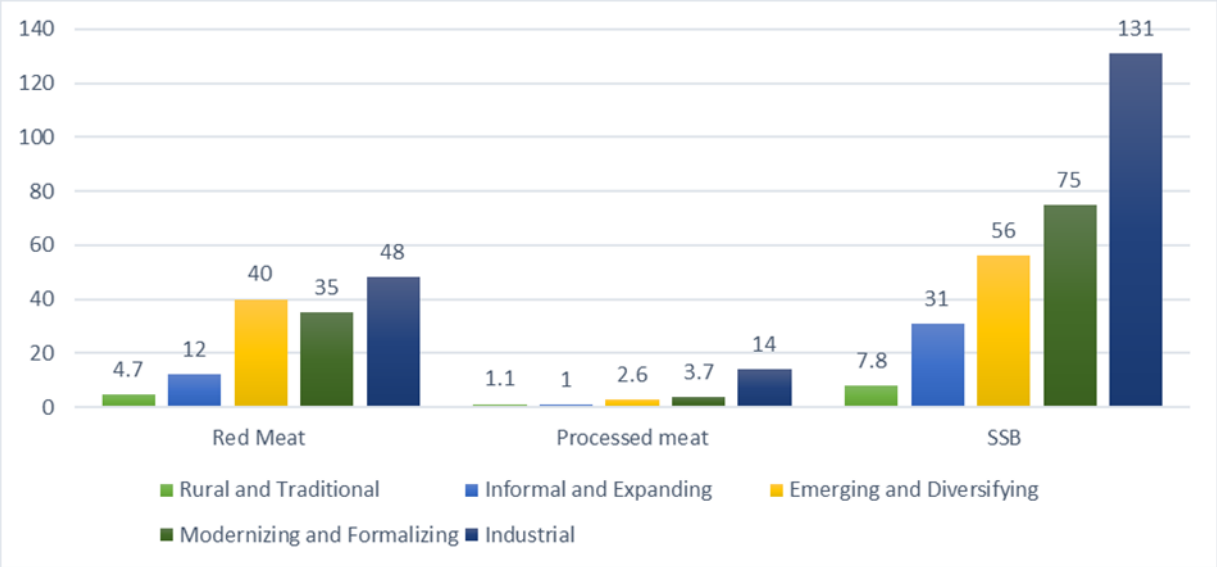

Figure 4: Mean estimated daily consumption of red meat, processed meat and sugar-sweetened beverages by food systems type

Source: https://foodsystemsdashboard.org

As populations shift consumption away from cereals and starchy crops, diets tend to become more varied, in terms of both healthy and unhealthy items. Intakes of nutrient-dense foods such as fruit and vegetables, dairy, poultry and fish tend to increase, reflected in both higher dietary diversity/variety and nutrient

adequacy (the intake of essential vitamins and minerals improves). On the other hand, the boundaries of eating in moderation become exceeded, especially in terms of sugar-sweetened beverages and processed meats. Table 2 shows a summary of the adherence to WHO-recommended intake levels under the different food-system types.

Table 2
Diets meeting WHO recommended targets for healthy and unhealthy foods in different food systems types[1,2]

	Rural and traditional	*Informal and expanding*	*Emerging and diversifying*	*Modernizing and formalizing*	*Industrial and consolidated*
Fruits					
Vegetables					
Whole grains					
Pulses					
Red Meat[3]					
Processed meat[3]					
SSB[3]					

Notes:
1 For definitions of food system types see Fanzo et al (2020) and box 2.
2 Colours indicate adherence to WHO intake recommendations (WHO, 2018), green: above recommended intake; yellow: below 50% of recommended intake; red: below 50% of recommended intake.
3 Colours for foods that should be consumed either with moderation or not at all indicate above 50% of recommended intake (yellow) or above recommended intake (red)

UPFs become a much larger part of the diet as income levels rise. In general, UPFs contain more sugar, salt and fat, including saturated fat, and facilitate overeating (Hall et al., 2019). There is evidence of associations between the rise in consumption of UPFs and dietary outcomes and NCD risk outcomes (see section 3.1). A recent study of UPFs sold worldwide found the substantial increases in the types and quantities happening most rapidly in LMICs. These increases are closely linked with the industrialization of food systems, technological change and globalization, which includes growth in the market and reflects the political activities of transnational food corporations and the inadequate policies to protect nutrition in these new contexts (Baker et al., 2020). Also, in Africa, consumers have purchased increasing amounts of processed foods over the past 50 years and, linked with the rise of the double burden of nutrition, a growing proportion of these are packaged, industrialized UPFs, and sugar-sweetened beverages (Reardon et al., 2021).

3. Food environments and consumer challenges in the trade-offs to achieve healthy and sustainable diets

Striving towards healthier diets requires an enabling food environment that is conducive to the adoption of healthy (and sustainable) diets by consumers. This chapter aims to create a deeper understanding of the challenges and trade-offs involved in transforming the food environment and reshaping consumer choices across the different food system types. Food systems are dynamic and constantly evolving and may represent characteristics of different types at the same time. Consumer choices are influenced by the physical, socio-economic and cultural structure of the food environment, but are also profoundly determined by individual preferences and perceived challenges and benefits. The challenges of such a dynamic situation necessitate managing trade-offs across and within the different components of food systems, between expected outcomes of behaviour (trade-offs, for example, between diets that are healthy or sustainable or affordable), between food environment components (i.e. availability, cost and convenience) and between the objectives and perspectives of the different actors in the food systems (such as farmers, food industry and consumers). Challenges and trade-offs are illustrated in this chapter in three case studies on the costs of healthy diets, ultra-processed foods (UPFs) and animal-sourced foods (ASFs). A better understanding of the determinants of the food environment and consumer food choices will contribute to the

identification and implementation of effective interventions across the food systems, leading to healthy and sustainable diets.

3.1 Challenges in the food environment

There are several definitions of the food environment (Downs et al., 2020; Herforth and Ahmed, 2015; Turner et al., 2018), but only the one by Downs (2020) considers the sustainability properties of foods and beverages:

> *The consumer interface with the food systems that encompasses the availability, affordability, convenience, promotion and quality, and sustainability of foods and beverages in wild, cultivated, and built spaces that are influenced by the socio-cultural and political environment and ecosystems within which they are embedded.*

In this socioecological model, the food environment is the larger piece (characterized by availability, affordability, convenience, promotion, quality) and individual factors interact with it to determine food choices. Food environments include natural (wild and cultivated) and built environments (Downs et al., 2020). Wild food environments include forests and jungles, disturbed habitat, open pastures, and aquatic areas, while cultivated food environments comprise food production for the household's own consumption. Built or retail food environments include informal and formal markets.

The food environments will have different characteristics in the five food system types (see chapter 2 and box 2), as seen in figure 5. For example, in a predominantly rural and traditional food system, populations rely mainly on the cultivated food environment and only partially on the wild food environment. They also increasingly make use of informal food markets, small shops and street vendors. Alongside urbanization, agricultural intensification and increased agricultural production, food systems transition from being "informal and expanding" towards "emerging and diversifying". This transition coincides with an increase in the "built" food environment (initially informal markets and eventually supermarkets and fast-food chains) while the role of the "cultivated" environment is reduced. Though these changes impact urban middle-class populations more, rural areas are also impacted by an increasing availability of processed foods and UPFs. This transition in the food environment is associated with the five patterns of nutrition transition highlighted in the framework of Popkin (Popkin, 2002), as shown in figure 5 (Downs et al., 2020). These patterns are associated with shifts in dietary patterns and levels of physical activity and are related to a transition from receding famine to a domination by obesity and diet-related non-communicable diseases.

Despite the recent increase in the number of studies measuring food environments in low- and middle-income countries, there is limited evidence on the relationships between food environments and diets or health, and most studies focus on the evolving built environment rather than the wild or cultivated food environments (Turner et al., 2020). This section therefore addresses mainly the challenges encountered in the built food environment when transitioning towards healthier diets, and discusses how physical and economic food environments shape access to healthy diets. The physical aspects of food environments cover the places where food is acquired or consumed, including consumer and community food environments. The economic aspects of food environments cover food prices, affordability and convenience.

Figure 5: Transition of food environment typology with development aligned to Popkin's nutrition transition framework

Reproduced from Downs et al. (2020)

Physical aspects

Studies on the relationship between community food environments and diets have focused largely on the formal built food environment in high-income countries. Systematic reviews (Cameron et al., 2016; Glanz et al., 2012; Gustafson et al., 2012; Pitt et al., 2017) have shown that consumer food environments – and, more specifically, food placement, food prominence and shelf labelling – are influencing food purchases in high-income countries. One has found that the availability, in general, of food outlets showed a greater influence on adults' dietary purchases and intake than the proximity to food outlets (Bivoltsis et al., 2018). A recent Australian study showed that moving to a new neighbourhood with more convenience stores, cafés and restaurants was significantly associated with an increase in unhealthy food intake. A greater percentage of healthy food outlets in the new neighbourhood, following a relocation, was significantly associated with an increase in healthy food, fruit and vegetable intake (Bivoltsis et al., 2020). The methods used to assess community food environments have been both objective (spatial measures, geographical analysis, GPS tracking) and subjective (perception surveys). Measures of peoples' perceived food availability or accessibility generally were more consistent in showing a relationship with dietary outcomes than objective measures such as distance to the nearest store (Ni Mhurchu et al., 2013). Associations between exposure to unhealthy community food environments and socio-economic position have often been found (Hilmers et al., 2012; Lovasi et al., 2009; Pinho et al., 2020; Sushil et al., 2017), but depend on the metrics used (Maguire et al., 2017). While community food environments affect food choices among both high- and low-income population groups, the resources available to higher-income groups may have a protective effect on eating behaviour (Ford and Dzewaltowski, 2008).

In low- and middle-income countries (LMICs), food environments are also changing rapidly, with an important increase in supermarkets (Baker and Friel, 2016; Popkin, 2017; Popkin and Reardon, 2018), a related decrease in informal or wet markets in some countries (Banwell et al., 2012), and increases in the supply of UPF products, in away-from-home eating and in snacking (Baker and Friel, 2014; Popkin and Reardon, 2018; Vandevijvere et al., 2019b).

A recent systematic review identified the main factors influencing dietary behaviours in urban food environments in Africa (Osei-Kwasi et al., 2020). Out of the 77 factors identified, 12 were related to physical food environments – specifically, factors concerning neighbourhood socio-economic status, affordability, away-from-home eating, convenience, and the availability and type of food source used. Two thirds of

factors were related to the individual and nine were macro-level factors such as food prices and advertising (Osei-Kwasi et al., 2020). A study in an urban poor setting in Ghana (Dake et al., 2016) found a 0.2 kg/m² increase in body mass index (BMI) for every additional convenience store (selling mainly energy-dense processed foods) and a 0.1 kg/m² reduction in BMI for every additional out-of-home cooked food place (offering both healthier options such as staple foods and less healthy options such as stir-fried rice dishes), after controlling for individual sociodemographic characteristics, lifestyle behaviours and community characteristics (Dake et al., 2016). In Brazil, the availability of fruit and vegetables in São Paulo neighbourhoods was found to be significantly associated with their regular consumption among adults (five or more times a week). Regular consumption of fruit and vegetables was significantly lower among lower-income individuals living in neighbourhoods with fewer supermarkets and produce markets (Duran et al., 2016). Another study in São Paulo found that fast food restaurants were more likely, and supermarkets less likely, to be located in low-income neighbourhoods (Duran et al., 2013). A systematic review from China found that the variety, density and proximity of food outlets were positively associated with local residents' dietary diversity, portion size and daily calorific intake. In addition, the density and proximity of fast-food restaurants and convenience stores were positively associated with local residents' adiposity in most but not all studies (An et al., 2020). In southern India, a lower density of fruit-and-vegetable vendors and a higher density of vendors of highly processed/takeaway food were associated with adverse cardiovascular risk profiles (Li et al., 2019). A study in both Ghana and South Africa found the density of food outlets, their variety and the types of food available had associations with household purchasing and consumption patterns. The study also found poverty to be a determinant not only of household consumption but also of local food environments (Kroll et al., 2019). While the evidence is limited, preliminary findings from studies in LMICs suggest linkages between the physical aspects of food environments, such as the density of food outlets or their proximity, and dietary intake or obesity.

Economic aspects

Food prices, which are determined by global commodity prices and local supply and demand, are an important determinant of food choices (Darmon and Drewnowski, 2015). In general, staple foods (wheat, maize, rice, vegetable oil) are cheaper per calorie than fresh, nutrient-dense foods (vegetables, fruits, nuts, ASFs, beans, pulses) (Darmon and Drewnowski, 2015; Mendoza et al., 2017). These relative prices help to explain why the diets of poorer people are often high in starchy staples and lack diversity. The poorest households in LMICs spend 50 to 80 per cent of their total expenditure on food (63 per cent on average) (Herforth et al., 2020), with most purchases directed towards staple grains, some condiments, vegetables and affordable sources of animal protein such as dried fish (Brinkman et al., 2010).[2] While rural households produce a significant portion of what is consumed, few rural households are self-sufficient. For example, in rural Ethiopia, purchases accounted for more than half of the consumption of vegetables, fruits, legumes, fish and meat; home production accounted for more than half of what was consumed for starchy staples and dairy (Sibhatu and Qaim, 2017). Thus, even for rural farming households, the retail prices of most nutrient-dense non-staples are extremely important.

Not only are healthy diets expensive, largely owing to the high absolute and relative prices of non- starchy staples and seasonal effects (Bai et al., 2020); in addition, nutrient-poor foods are relatively cheap and compete for budget share – and diet share – in all countries including LMICs (see box 3 on trade-offs between cost and affordability and a healthy diet).

The high cost of nutritious diets affects what people eat, and in turn their nutritional status. The prevalence of stunting and wasting is correlated with the cost of healthy diets globally (FAO et al., 2020). In Indonesia, the combination of high food prices and reduced incomes during the economic crisis in the late 1990s led to an increase in child anaemia (Block et al., 2004). In Bangladesh, a lower price of rice was associated with a lower prevalence of underweight (Torlesse et al., 2003). Relative food prices partially explain differences across countries in the prevalence of undernutrition and overweight among adults (Headey and Alderman, 2019).

[2] In contrast, American households in the highest income quintile only spend 8.2 per cent of disposable income on food, while households in the lowest quintile spend 35 per cent of their income on food (USDA Economic Research Service, 2019).

Compared with unprocessed and minimally processed foods, UPFs generally have lower nutrient density, higher energy density and lower per-calorie cost (Gupta et al., 2019). In Mexico, nutrient-poor, energy-dense foods were found to be cheaper than healthy foods, and healthy foods became less affordable over time, for lower-income households in particular (Colchero et al., 2019). A recent systematic review found that price promotions are predominantly for unhealthy, rather than healthy foods (Bennett et al., 2020). In Brazil, an inverse association was found between the price per kilogram of UPFs and the prevalence of overweight and obesity, mainly in the population with the lowest socio-economic status (Passos et al., 2020).

It is important to note that researchers' views of food affordability may diverge from the experiences of low-income people. Consumer judgements on food cost reflect not just the price, but also some underappreciated monetary costs, stemming from food waste: packages containing more than needed, food that is consumed too quickly, and foods that do not sate (Daniel, 2020).

Box 3: Cost and affordability of healthy diets and relationship to sustainability

The most recent State of Food Security and Nutrition in the World (SOFI) report (FAO et al., 2020) showed that healthy diets in 2017 were unaffordable for more than 3 billion people in the world, most of whom lived in Africa and Asia. The cost of a healthy diet that meets food-based dietary guidelines (FBDGs) is generally between US$3.27 and US$4.57 per day (Herforth et al., 2020). This is 60 per cent higher than the cost of only meeting nutrient needs, without meeting the recommended food group amounts within FBDGs, and almost five times the cost of meeting energy needs through a basic starchy staple. The cost of a healthy diet exceeds national average food expenditures in most countries in the global South, and exceeds the international poverty line (FAO et al., 2020; Herforth et al., 2020).
The cost of the EAT-Lancet reference diet was found to be similarly unaffordable to many (Herforth et al., 2020; Hirvonen et al., 2020; Willett et al., 2019). In an analysis by the World Food Programme, the price of a basic plate of food (staple and legume stew) in 34 countries demonstrated that people would have to spend 9 to 50 per cent of their income on food in Asia, and 25 to 158 per cent in non-conflict affected countries in Africa (WFP, 2017). Mathematical modelling in Brazil, Ghana, Ethiopia, Malaysia and Mexico found that healthy diets were more expensive than current less healthy diets (Gurmu et al., 2019; Mendoza et al., 2017; Nykänen et al., 2018; Pondor et al., 2017; Verly et al., 2020). The same linear programming has been used in Ethiopia and Ghana to identify nutritionally adequate food baskets with the highest affordability for a typical urban, rural or low-income family. These food baskets may serve as a basis for the development of culturally acceptable FBDGs.
More sustainable diets are generally cheaper because reducing animal-sourced foods (ASFs) typically reduces both cost and environmental impacts (FAO et al., 2020; GLOPAN, 2020; Springmann et al., 2020). In lower-income countries, most ASFs are relatively expensive (Headey and Alderman, 2019). A least-cost healthy diet includes ASFs in amounts above the current consumption among many rural populations in low- and middle-income countries, but in amounts much lower than the current consumption in high-income countries (Willett et al., 2019). Some increases in ASFs will thus be necessary to meet dietary needs in low- and middle-income countries, and these are projected to raise greenhouse gas emissions (FAO et al., 2020). These increases need to be offset globally by reductions of ASFs in high-income countries, which would be recommended for health as well as sustainability (see box 1).

Convenience aspects

Price and affordability have been identified as key factors that determine the food choice of people in low-income populations, whereas convenience has been expected to be more important than price for high-income consumers (Ares et al., 2017; Gama et al., 2018; Kearney, 2010). However, it is likely that convenience has been under-recognized as a driver of food choice among people of all income levels, both in rural and urban populations (Herforth and Ahmed, 2015). A study in Ghana, for instance, found that mothers were trying to find a balance on the higher cost of complementary foods (compared with breastfeeding) and concerns for their children's health on the one hand, but also on the convenience of preparation to reduce the demand on their time on the other (Pelto and Armar-Klemesu, 2011).

The concept of convenience includes the time and effort costs of purchasing, preparing, cooking and eating (Jackson and Viehoff, 2016). Time costs are both objective (hours spent on a task) and perceived (being rushed or feeling time-constrained) (Jabs and Devine, 2006). In the United States, higher consumption of fruit and vegetables was associated with more than two hours a day spent in preparing, cooking and cleaning up. Individuals who spent less than two hours a day on such tasks were 70 per cent more likely to eat at fast-food restaurants (Monsivais et al., 2014).

A New Zealand study found that healthier home-made and home-assembled meals were generally cheaper options than takeaways. When the cost of time was added, in most cases the home-made meal was the most expensive (Mackay et al., 2017).

In many LMICs, particularly in rural areas, obtaining fuel and water increases the time, effort and cost of food preparation among lower-income groups. In Malawi, women spent six to ten hours a week gathering fuelwood (Brouwer et al., 1997), and may respond to a fuelwood shortage by cooking cereals and beans less often (Brouwer et al., 1996). In India, families in urban areas who owned a pressure cooker were protected against severe food insecurity, even after controlling for household socio-economic factors (van Elsland et al., 2012).

The current levels of physical and economic access to food environments are conducive to the availability and affordability of UPFs. Being low-cost, highly palatable and convenient, UPFs offer a high desirability to consumers in the short term, but this has huge trade-offs for their long-term health (see box 4).

Marketing and promotion aspects

In addition to physical and economic food environments, there is convincing evidence that the marketing of unhealthy foods, in particular to children, affects their food and beverage preferences (Borzekowski and Robinson, 2001; Boyland et al., 2016, 2011; Kelly et al., 2015), their purchasing requests (Boyland et al., 2016; Buijzen and Valkenburg, 2003) and their food consumption (Boyland et al., 2016; Norman et al., 2018). A recent study found that the marketing of unhealthy food products was higher in Uganda than in Sweden, most likely because Sweden has regulations on marketing (Spires et al., 2020). The marketing of foods and beverages, including in LMICs, is predominantly for unhealthy foods, as shown in a recent multi-country study (Kelly et al., 2019). These foods are often found to be marketed extensively to children (Allemandi et al., 2018; Fagerberg et al., 2019; Gamboa- Gamboa et al., 2019; Mallarino et al., 2013; Pulker et al., 2018) and there is convincing evidence that this affects their food and beverage preferences (Boyland et al., 2016), their purchasing requests and their food consumption (Norman et al., 2018). In Chile – the country with the most comprehensive policy to restrict unhealthy food marketing to children – it was found that pre-school children's exposure to advertising for unhealthy foods and their consumption of unhealthy food products significantly decreased after the introduction of the policy (Jensen et al., 2020; Workicho et al., 2019).

3.2 Challenges in individual food choices for healthy diets

Research on the drivers of food choices is abundant for consumers in high-income and middle-income countries but much less so in low-income countries. Systematic mapping reviews of the determinants of dietary behaviour in low- and middle-income urban African populations has suggested that similar determinants play a role in food choices as in high-income countries – at the individual level (income, employment, education level, food knowledge, lifestyle, time), in the social environment (family and peer influence, cultural factors), the physical environment (food expenditure, lifestyle) and in the macroenvironment (Gissing et al., 2017; Osei-Kwasi et al., 2020; Yiga et al., 2020).

Taste is one of the individual key determinants and a key factor used by the food industry to influence consumers. Taste is often acquired and transmitted in a cultural setting, starting from birth (Montanari, 2006; Nicklaus and Schwartz, 2019). What is considered tasty in one culture is not always appreciated in another. Food demand is not governed just by taste and smell, but also by visual appeal and other attributes. The food industry has long known, for example, that attractive packaging increases demand for their products (e.g. Rundh, 2005). Price and convenience ("time is money") have been discussed in section 3.1. Price and affordability are considered the most important key factors for low-income consumers, who

are trying to survive and fulfil their basic needs. Yet research indicates that lower-income consumers also seek to fulfil higher-order needs, and have desires and aspirations to build social capital, for cultural reasons or to compensate for their limited means (Subrahmanyan and Gomez-Arias, 2008).

Understanding consumer choices is more complex than understanding drivers such as taste and cost. Food choices are influenced by multiple external (cultural and societal) factors, as well as internal (personal and psychological) ones (Frewer et al., 2001; Kotler and Armstrong, 2018). Cultural and societal factors include subculture, social class, family and other reference groups, role and social status. Personal and psychological factors, meanwhile – including income, education, lifestyle and profession, personality, motivation, perception, attitudes and beliefs, and learning (Frewer et al., 2001; Kotler and Armstrong, 2018) – will shape individual aspirations. The role of the food environment on consumer choices has been discussed in section 3.1.

The ways in which food is being produced, chosen, prepared, eaten and appreciated for its taste are all influenced and defined by culture (Montanari, 2006). Food habits, formed mainly early in life, are also culturally determined, though globalization has changed traditional food habits across the world for better and for worse (Kearney, 2010; Raschke and Cheema, 2008). Many different aspects of culture have been analysed, such as long-term versus short-term orientation, masculinity versus femininity, and individualism versus collectivism (Shavitt and Cho, 2016).

Social norms and values have a huge influence on individual food choices. A recent meta-analysis reported that descriptive social norms (i.e. what most other people do) were more effective in influencing behaviour than injunctive norms (i.e. what others approved of) (Melnyk et al., 2019). The study also found that the effects of social norms on behaviour were stronger when they came from groups that were close to the person and when sanctions were specified. Explicitly mentioning the rewards of the behaviour on the other hand did not add to the effectiveness of the message. Younger people are much more influenced by social norms than older people.

Box 4: Ultra processed foods: consumer trade-offs regarding convenience and taste versus health

Ultra-processed foods (UPFs)[3] and drinks have been characterized as hyper-palatable and quasi-addictive (because they are high in fat and sugar or salt). They are often ready to eat or ready to drink and thus highly convenient. UPFs are cheap and omnipresent, sold by street vendors, in supermarkets, and in school and work environments. Consumers appreciate UPFs for these reasons of low price, palatability and convenience, and many UPFs or fast foods are also sometimes considered to be a treat. Thanks to consumers' appreciation, ready-to-eat UPFs contribute to more than 50 per cent of the total energy intake in some high-income countries. In the United States and in Canada, for example, it accounts for up to 65 per cent of the total energy intake among children (Martínez Steele et al., 2016; Neri et al., 2019; Moubarac et al., 2013). The consumption of UPFs has been increasing rapidly in middle-income countries (Baker and Friel, 2016; Marrón-Ponce et al., 2018; Martins et al., 2013). Over the 15 years to 2016, UPF volume sales increased by over 67 per cent in South and South-East Asia and by over 57 per cent in North Africa and the Middle East, while volume sales for UPF drinks increased by 120 per cent in South and South-East Asia and by almost 71 per cent in Africa (Vandevijvere et al., 2019b). Although urbanization is a key driver of UPF consumption, these products have also become an important part of the rural diet. Several studies find that rural populations, while keeping some of their traditional food practices, are transitioning to a Western diet high in UPFs and non-local foods (Cattafesta et al., 2020; Fernández, 2020). Reardon and others (2014) found that highly processed foods constituted between 13 and 22 per cent of the total food expenditure in the rural households of four low- and middle-income Asian countries, compared with urban households spending between nearly 18 per cent and almost 37 per cent on them (Reardon et al., 2014). A Chilean study (Cediel et al., 2018) found that the energy contribution from UPFs was as high as 29 per cent in urban and 24 per cent in rural areas, after adjusting for sociodemographic factors.

[3] UPFs are defined as "not modified foods but formulations made mostly or entirely from substances derived from foods and additives with little if any intact food" (Monteiro et al., 2017).

Evidence suggests a strong relationship between the type, intensity and purpose of food processing, and the diet quality and human health (Monteiro et al., 2019). UPFs provide excessive nutrients of concern, including added sugar, sodium and saturated fats, are low in fibre, protein and micronutrients, and often contain a large number of additives. The consumption of UPFs has been associated with unhealthy dietary patterns (Adams and White, 2015; Batal et al., 2018; Bielemann et al., 2015; Cediel et al., 2020; Chen et al., 2018; Cornwell et al., 2018a; da Costa Louzada et al., 2018; Martínez Steele et al., 2017; Moubarac et al., 2017; Vandevijvere et al., 2019a), associated with lower intakes of most micronutrients (Cornwell et al., 2018b; Da Costa Louzada et al., 2018; da Costa Louzada et al., 2015), linked to overweight and obesity in studies conducted in high- and middle-income countries (Canella et al., 2014; Canhada et al., 2020; Mendonça et al., 2016; Monteiro et al., 2018; PAHO, 2015). A recent review found dietary UPF exposure was associated with at least one adverse health outcome in adults (overweight, obesity, cardio-metabolic risks, cancer, type 2 diabetes, cardiovascular diseases, irritable bowel syndrome, depression and frailty conditions, and all-cause mortality) and cardio-metabolic risks and asthma among children and adolescents (Elizabeth et al., 2020). In several prospective studies, a higher percentage of UPFs in the diet has been associated with an increased risk of depressive symptoms (Adjibade et al., 2019; Gómez-Donoso et al., 2020), with higher all-cause mortality (Blanco-Rojo et al., 2019), a higher cancer risk (Fiolet et al., 2018; Rico-Campà et al., 2019), raised blood lipid levels in children (Leffa et al., 2020), hypertension (Mendonça et al., 2017) and cardiovascular diseases (Srour et al., 2019).

Cognitive psychologists and behavioural economists have extensively described how psychological traits influence human behaviour: people do not like change (the status quo bias), do not like to lose anything (loss aversion), have a strong preference for “free” products, would rather not make a choice (the default bias), prefer immediate over long-term benefits (and so discount delayed events) and imitate others (“social proof”) (Ariely, 2010; Kahneman, 2011). The short-term pleasure of consuming an unhealthy food or meal thereby sometimes has more weight than the expected long-term benefit of a healthy diet. It is well known that humans are temporal discounters, seeing more value in the present than in an uncertain future (Cisneros and Silva, 2017).

Though most people like to see themselves as rational human beings making conscious choices, behaviour is driven, for 95 per cent of people, by subconscious determinants, which may favour impulsive alternatives that bring an immediate benefit (Logue, 1998; Zaltman, 2003). Subconscious motives include status, comfort, fear, disgust, attraction, love and play (Aunger and Curtis, 2013). To encourage behaviour change, therefore, it is insufficient to rely only on the planned, conscious and rational decisions of consumers. Instead, the emotional and subconscious motives that deliver more immediate, though not always rational, benefits should also be tapped into.

Within the framework of this paper, it is key to understand whether the other expected outcomes of food systems transformation (sustainability and inclusiveness) could be used to drive consumer food choices for a healthy diet. A study reported by Deloitte (2016) showed that a set of evolving value drivers (health and wellness, social impact, experience and transparency) had become meaningful for consumers in the United States and significantly influenced 50 per cent of their purchase decisions, with no difference across regions, age and income groups (Ringquist et al., 2016). Similarly, a European report indicated that sustainability was increasingly being mentioned as a motive by consumers who feared for the destruction of the planet and its resources (BEUC, 2020). How strong these drivers are in comparison with others, especially those of short-term benefits, is unknown. Little, too, is known about how consumers in low-income countries are influenced by these drivers. Box 5 illustrates some of the trade-offs between sustainability, cost and health in the example of ASFs. ASFs have an undisputable role in meeting the nutrient gaps in resource-poor households that consume below the recommended minimum levels, but the box also summarizes how ASFs should not be overconsumed; indeed, consumption needs to be reduced in high-income countries and in high-income settings in LMICs. Annex 2 summarizes the key potential compromises needed in the themes of nutrition, health, environment, social factors and economic sustainability to balance the risks and benefits of producing and consuming ASFs.

Consumer choices are triggered by distribution and marketing implemented by the food industry. This has contributed globally to consumers increasingly choosing processed food products, resulting in increasingly unhealthy diets over the past few decades, as demonstrated in Brazil, China, India, Mexico and the United States (Kearney, 2010). Evidence on what works to counteract this trend and make positive changes remains limited, especially for low- and middle-income consumers. A deep understanding of the multiple consumer motives and the determinants of choice is crucial to influence choices towards more healthy foods and diets (for examples, see section 4.1 on innovations in consumer behaviour for a healthy diet). There is no universal consumer, of course – drivers are not the same for each individual. Low-income populations are more price-sensitive than high-income populations, and adolescents are more easily influenced by the opinions of their peers than older people (Cislaghi and Heise, 2019). Creating awareness and filling an information gap will be insufficient to drive consumer choices in food systems transformation. Social and behaviour-change interventions must do more than rely only on the planned, conscious and rational decisions of consumers, and should understand and respond to the emotional and subconscious motives that deliver more immediate, though not always rational, benefits.

Box 5: Animal sourced foods: trade-offs between nutritional value, affordability and environmental sustainability

Animal sourced foods (ASFs) have high nutritional value (e.g. essential amino acids and fatty acids, bioavailable micronutrients such as vitamin B12 [which is available only from ASFs], zinc, iron, calcium and vitamin A). The World Health Organization identified ASFs as an optimal source of high-quality nutrients for children aged 6 to 23 months (WHO, 2009). The consumption of meat, dairy and eggs in young children is associated with improved linear growth and cognitive development (Grace et al., 2018). One of the contributing factors to the high levels of iron deficiency anaemia in women is low consumption of ASFs, together with high consumption of plant-based foods (rich in phytates, which reduce iron absorption) (Bailey et al., 2015; Kassebaum et al., 2014; Workicho et al., 2019). When consumed in excess, however, ASFs have potential negative effects on non-communicable diseases due to high levels of saturated fat, total energy, salt and additives, particularly in processed red meat (Micha et al., 2010; Pan et al., 2011).

ASFs are especially important for diet quality in low- and middle-income countries (LMICs), where diets often have important nutritional gaps and ASFs are less accessible (Dasi et al., 2019; Grace et al., 2018; Nordhagen et al., 2020). Low-income countries rely more on staple cereals and pulses than high-income countries, and less on nutrient-dense foods (ASFs, fruit and vegetables). This is because low-income countries face high market prices and demand that has a high price elasticity (as prices rise, people switch to other foods) (FAO et al., 2020; Green et al., 2013; Headey et al., 2017). There are variations in ASF consumption between rural and urban areas in LMICs, where the per capita consumption can be almost half that in urban areas. In Ethiopia, in 2010/11, the average consumption expenditure of rural and urban dwellers was 89.9 Ethiopian birr and 177.1 birr, respectively, likely due to disparities in incomes (Abegaz et al., 2018). Urbanization is a significant driver of ASF demand around the world, often promoting enhancement in infrastructure, like cold chains. On the other hand, ASF consumption also varies with production system and livelihood. Communities such as pastoralists who rely predominantly on livestock would consume more ASFs, as seen in the Afar and Somali regions of Ethiopia. In general, however, ASFs are costly and unaffordable for poor households, predisposing them to malnutrition (Abegaz et al., 2018).

Moreover, the environmental footprint of livestock is at the heart of heated debates encouraging an important move towards plant-based diets, particularly in high-income countries (Chai et al., 2019; Willett et al., 2019). ASF products (i.e. eggs, dairy, poultry, red meat and fish) have a heterogeneity, though, in their nutrient contribution and in their respective production systems and value chains, and an environmental impact that needs consideration.

Trade-offs related to the production of ASFs between the sustainability and affordability of moderate consumption versus the environmental burden and profitability of production are very context-specific (Willett et al., 2019). A key challenge will be to ensure regenerative production practices that promote environmental sustainability, and to ensure ASFs benefit and are accessible to the most nutritionally vulnerable. It is equally challenging to reduce the consumption of ASFs, in particular that of ruminant meat and milk, where it is excessive, while increasing the consumption in undernourished populations,

which brings up important considerations for production. Annex 2 summarizes the key potential compromises in balancing the risks and benefits of ASFs.

4. Food systems innovations towards healthy diets

Chapter 3 focused on a better understanding of the determinants of the food environment and consumer food choices. This is necessary to identify and implement effective interventions across food systems that lead to healthy and sustainable diets. The trends towards unhealthy and unsustainable diets must be reversed by transforming the food systems, using an approach that starts with an analysis of which consumer behaviours need to be modified and which food environment interventions are needed to achieve this change, depending on the food systems context in which the transformation should take place.

This chapter highlights some of the opportunities and innovations that have proven or shown the potential to motivate consumers to make healthier food choices. In turn it asks how a shift in consumer demand towards healthier foods may drive changes in the market and in the supply side of the food systems (the built and cultivated food environment). Rather than starting from the perspective of the producer, we propose starting with innovations at the consumer level, followed by innovations in markets where consumers purchase foods, before finally looking at innovations at the producer level.

Several nudging strategies are discussed, which have, on average, resulted in increasing healthy food choices by 15 per cent, according to a meta-analysis of studies in high-income countries (Arno and Thomas, 2016). These strategies include providing information (social media, labelling etc.), leveraging social norms, changing default choices, and changing the physical environment (Bauer and Reisch, 2019). There is some overlap between what can be considered a consumer-oriented versus a market-oriented innovation. Nudge-style interventions are discussed in section 4.1 when they directly influence consumer behaviours. Nudge interventions are also discussed in market-oriented interventions (section 4.2) as approaches to specifically change the way in which actors within food markets behave, such as in labelling food products.

In LMICs, the innovations and interventions seem to be more focused on the supply and producer side and, for the moment, less on the consumer and market. Evidence for the impact of these interventions on driving healthy and sustainable diets remains thin and disconnected.

4.1 Consumer-oriented innovations towards healthy diets

Nutrition-focused social and behaviour change communication (SBCC),[4] while no longer an innovation, have ample evidence for their effectiveness in LMICs, especially to improve feeding practices for infants and young children. Several reviews have identified the positive impact of behaviour-change interventions on breastfeeding practices and, to a lesser extent, on complementary feeding (Benedict et al., 2018; Lamstein et al., 2014; Webb Girard et al., 2020). A systematic review of mass media and nutrition education for improving infant and young child feeding in LMICs showed the effectiveness of the interventions but indicated that there were few common elements in their design, thus hampering their replicability (Graziose et al., 2018). Few SBCC programmes, however, have demonstrated impact when implemented on a large scale. The well-studied Alive and Thrive programme[5] has demonstrated the large-scale impact of implementation in Bangladesh, Ethiopia and Viet Nam using a combination of communication channels and of individual, household and community approaches (e.g. interpersonal communication, mass media and social mobilization), and focusing on a limited number of actionable messages (Kim et al., 2020; Menon et al., 2016).

[4] SBCC interventions can be categorized into three areas: interpersonal communication, the use of media and community/social mobilization.

[5] See https://www.aliveandthrive.org.

A particularly successful example of an SBCC intervention is a television advertisement in Viet Nam in which two babies deliver the key message that an exclusively breastfed child does not need additional water.[6] In East Java, Indonesia, the adoption of a set of behaviour-change interventions (TV advertisement and behaviour demonstrations) that incorporated emotive, interactive and surprising ways of improving child feeding was tested as part of an integrated nutrition, hygiene and health intervention programme showed evidence of significant effects on infant and child feeding outcomes (Keats et al., 2019). Much less is known about influencing the healthy diet choices of other population groups (households, women, adolescents) in LMICs. The bulk of the evidence on the impact of consumer motives, individual behaviour and social norms on diet and nutrition comes from high-income countries in the global North. Most innovative approaches make use of nudges,[7] such as by leveraging social norms, digital technology and social media, which complement more traditional interpersonal and mass-media behaviour-change approaches.

Leveraging social norms to motivate healthy diets

Social norms around healthy eating, defined by culture and context, may influence an individual's food choice by implying that a code exists for appropriate behaviour. There are well-known social norms and taboos in LMICs around, for instance, nutrition for young children (avoiding eggs), and pregnant and lactating women.[8] Social norms can be asserted by key influencers, including parents and family, friends and peers, health care professionals, schoolteachers, older people, and traditional and religious leaders. Influencers may also be role models in society, such as singers and actors, or leaders on social media (Instagram, YouTube, blogs). In studies in high-income countries, family traditions and the way parents talk about food, cook meals and eat together have been demonstrated to have a huge influence on the healthy eating habits developed by a child (Walton et al., 2018; Weinstein, 2005).

A review of 15 experimental studies in high-income countries found consistent evidence that norms influenced food choices. Participants receiving information that people not known to them (e.g. "other students" and "other people in the United Kingdom") made low- or high-energy food choices were significantly more likely to make similar choices (Robinson et al., 2014b). In an experimental setting, messages containing reference to the consumption of fruit and vegetables by peers have also proved to be more effective than a general statement of health benefit (Robinson et al., 2014a). Draper and others (2015) reviewed 30 studies for the impact of social norms and social support on the diet, physical activity and sedentary behaviour of adolescents, and found sufficient evidence for parental influences, especially on diet, but much less conclusive evidence for peer influences (Draper et al., 2015).

Although we found no literature to describe the use of social norms to influence healthy eating in consumer behaviour in low-income populations, a large body of literature describes the importance in low-income countries of cultural preferences and taboos and of the use of "positive deviance" to influence nutrition behaviour (D'Alimonte et al., 2016; Fowles et al., 2005). Albanna and Heeks (2019) suggest that big data (for instance, mobile phone records, social media, remote sensing data) might be used to overcome a number of challenges in the positive deviance[9] identification (time, cost, sample size, complexity), as long as access to these data and their use protects the privacy of the data owners (Albanna and Heeks, 2019). A study in Canada, for example, demonstrated that social media discussions could be used to gain insights on nutrition-related issues and social norms, and as a tool to improve nutrition-related activities, nutrition literacy and food environments (Lynch and Mah, 2020).

The use of social norms to motivate healthy eating behaviour can be applied in every population group (urban and rural) and every communication channel, whether it is in interpersonal communication, mass media, social and digital media, or mobile technology. A mass-media and community-based behaviour-

[6] See the advertisement at YouTube: https://www.youtube.com/watch?v=-wIWFlr3xNE.

[7] Nudges are any aspect of choice architecture altering behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. To be considered a mere nudge, the intervention must be easy and cheap to avoid, and not mandatory (Thaler and Sunstein, 2008).

[8] See https://sightandlife.org/wp-content/uploads/2017/02/Food-Taboos-infographic.pdf.

[9] In the framework of nutrition and health, positive deviants are well-nourished children living in disadvantaged contexts. The positive deviant approach tries to understand and identify local nutrition, health and growth-promoting behaviours leading to well-nourished children in a situation where undernutrition prevails.

change campaign in Indonesia made use of the concept of gossip (reflecting social pressure) to reinforce appropriate infant feeding practices and successfully impact dietary diversity (vegetable intake) and breastfeeding, but not influence snacking behaviour (White et al., 2016). The power of cooking together has been demonstrated to lead to improved attitudes, self-efficacy and a healthier dietary intake in adults and children in studies in high-income countries, though we know of no examples in LMICs (Hasan et al., 2019).

Digital interventions and social media

Digital interventions have become mainstream in the global North for lifestyle behaviour change regarding healthy eating, physical activity and quitting smoking. One review of online interventions has indicated that these are most successful in achieving dietary behaviour change using techniques such as goal setting, self-monitoring and providing instructions and feedback. The quality of the studies in the review was in general moderate, however, with relatively small sample sizes, a lack of effective engagement measures, and not all studies reporting attrition rates (Young et al., 2019). Another review provided modest evidence that app-based interventions to improve diet, physical activity and sedentary behaviours could be effective, especially when apps were used in conjunction with other intervention strategies, such as counselling sessions, motivational emails and pedometer use. These combined interventions appear to be more effective than stand-alone app interventions (Schoeppe et al., 2016). A systematic review in *The Lancet* on the use of social media for the delivery of health promotion on smoking, nutrition (weight loss but not healthy diet) and physical activity concluded that there was insufficient quality evidence to establish whether health promotion delivered using social media was effective in improving health (Johns et al., 2017).

Several studies in high-income countries have reported on the influence of social media on both positive and negative dietary habits of adolescents and young adults (Chau et al., 2018; Fleming-Milici and Harris, 2020; Hsu et al., 2018). A randomized trial demonstrated that British children who were shown social media influencers with unhealthy snacks had significantly increased overall intake, especially of unhealthy snacks, compared with children who viewed influencers with non-food products (Coates et al., 2019). Conversely, viewing influencers with healthy snacks did not significantly affect the intake of these. We found no literature with evidence for low-income countries, although there are examples of social media being used in interventions. The International Crops Research Institute for the Semi-Arid Tropics started the Smart Food campaign[10] in 2017, using multiple social media and mass media channels, with the support of a Senegalese chef, among others. This approach aims to promote the use of nutritious local staples such as millets and pulses to contribute to the three goals of sustainable food systems: good for people, planet and farmer.

Social media and digital services, such as the mNutrition services described in the next section, are relevant for both urban and rural consumers in most LMICs, but need customization to the local context and innovation to also reach women and the very poor, for whom accessibility and connectivity remain key challenges.

mNutrition services

Over the past five to 10 years, the use of mobile phone technology targeting behaviour change has increased globally, with expectations to facilitate the adoption and long-term maintenance of new behaviours. A summary of mNutrition and mAgri services identified a number of challenges and limitations, such as modest evidence for the impact of mNutrition on behaviour change, a lack of sustainable business models and an ineffectiveness of push messages (Barnett et al., 2016).

A review of 15 mHealth studies in Asian and Latin American countries showed that 50 per cent of the eHealth and mHealth interventions were effective in increasing physical activity, and 70 per cent of the identified interventions were effective in improving diet quality (Müller et al., 2016). An evaluation of mNutrition services in Ghana and Tanzania, however, found that such services did not always reach very poor households or women and had a limited effect on nutrition behaviours on a large scale, although active users reported some behavioural change. Stand-alone mobile phone nutrition services may be insufficient to motivate behavioural change, but may be more effective if combined with in-person support (Barnett et

[10] See https://www.smartfood.org.

al., 2020). Girl Effect has set up a global mobile platform, Springster,[11] to empower adolescent girls to get informed about difficult and intimate issues regarding their body, their education and their relationships. Nutrition International partnered with Girl Effect to develop dedicated gender-sensitive nutrition content, NLIFT,[12] targeting media-savvy adolescent girls in Indonesia.

There still is an important coverage gap (people living in an area with no coverage of mobile broadband) and usage gap (people living in an area covered by mobile broadband, but not using it) in mobile connectivity in the global South. These gaps are highest in sub-Saharan Africa, where 31 and 45 per cent of the population experience a coverage and usage gap, respectively, compared with 10 and 43 per cent of the global population (GSMA, 2019). Significant investments and innovations in technology as well as business models aim to rapidly close these gaps.

Social marketing by the private sector

There is evidence of the success of social marketing advertisements on healthy eating (Abril and Dempsey, 2019). Campaigns with both stop and go outcomes (such as swapping one food for another) and generic outcomes (such as calling a coach) were more successful than campaigns with simple stop or go outcomes. The length of campaigns (longer than six months) was also identified as a critical success factor. Private-sector food companies are nowadays also investing in healthy-choice campaigns, not only in high-income countries (for example, the Eat More Veg campaign in the Netherlands or Cheat on Meat campaign in the United Kingdom), but also in LMICs (Green Food Steps in Nigeria, NutriMenu in Indonesia). Although the impact of such interventions is rarely assessed, a study in Nigeria seemed to indicate that the Green Food Steps behaviour-change programme increased the amount of green leafy vegetables added to stews, and iron-fortified cubes added to soups (Lion et al., 2018).

With the objectives of a food systems transition towards a healthy diet, of a healthy planet and of healthy livelihoods for workers along the food value chain, it is key to take consumer motives, including psychological and emotional traits, and social norms into consideration to create demand for healthier food options and to inform the redesign of the food environment and food supply side to meet the changing demand. The above-mentioned innovations and approaches, for which evidence is drawn mainly from the global North, offer good entry points to develop context-specific innovations in the global South, for both urban and rural populations. Rural areas in LMICs are increasingly connected through mobile and digital technologies, and packaged and processed foods are increasingly part of the rural diet. Consumers should be considered as active drivers in the food systems transition and not only as passive recipients at the end of the food value chain.

4.2 Market-oriented innovation pathways towards healthy diets

The food environment plays a central role in connecting food supply systems with consumers, and determining the availability, accessibility and affordability of healthy and unhealthy diets. In this section, we discuss ways that interventions in the food environment can play a role in encouraging healthier diets. Four types of market-oriented intervention are described: (i) food labelling interventions, which regulate the way that food can be presented to consumers; (ii) regulation of advertising; (iii) interventions to restrict choices in certain contexts to attempt to induce healthier eating; and (iv) taxes and subsidies.

Food labelling interventions

Providing nutrition information on packaged food products is mandatory in most high-income countries, but this requirement is not as common in LMICs. There are two ways such labels can potentially affect health – directly, by affecting consumer demand for less healthy products, or indirectly, by influencing manufacturers or restaurants to reformulate their products to look better when labelled.

There are a few different ways that labelling can be implemented. Labelling may be mandatory, which means that all packaged foods need to provide nutritional information. Labels usually list calories, fat and

[11] See https://www.girleffect.org/what-we-do/mobile-platforms/springster.
[12] See https://www.nutritionintl.org/what-we-do/nlift.

protein content, and some micronutrients, usually in a table on the back of the pack.[13] In Latin America, however, several countries have introduced a traffic light system, which is required to be shown on the front of packaging. Other examples include front-of-pack labelling, first introduced in Thailand in 2011, followed by the introduction of a warning statement in Indonesia and a red label for soft drinks containing high sugar in Sri Lanka.

Labelling can also be voluntary, which enables a supplier to provide a signal for foods that are healthier when the food product has met standards set by an external agency. Several Asian countries use health logos such as the healthier choice symbol (Malaysia and Thailand), the Wise Eat logo (the Philippines) or a logo based on the Healthy Choices system initially developed for the United States but adapted by many countries, including some LMICs. South Africa introduced a voluntary traffic light label for per-serving energy, total sugar, fat, saturated fat and total salt or equivalent. It is not clear if companies using such voluntary labelling systems are motivated by public health concerns, or see the opportunity for a form of advertisement.

While there is no evidence on the impact of these voluntary labelling efforts on public health and diets, there is evidence, in high-income countries, on the mandatory front-of-package labelling or the labelling on restaurant menus. A meta-analysis on the impact of food labels on choice and calorific intake in high-income countries concluded that front-of-pack food labels would increase the percentage of people selecting a healthier food product by about 18 per cent, but the impact on energy intake reduction was not statistically significant (Cecchini and Warin, 2016). The same study indicated that interpretive traffic light labels seem to be slightly more effective than guidelines on daily amounts or other types of front-of-pack labels. A more recent meta-analysis suggested that labelling reduced energy and fat intakes among consumers, and increased vegetable intakes (Shangguan et al., 2019). Restaurant labelling may be less effective though. Long and others (2015), for example, found that the labelling calories on menus appeared to lead to an average decline of 18 calories in the total calories ordered. The researchers pointed to significant heterogeneity across the studies, however (Long et al., 2015).

Several Latin American countries have also recently developed mandatory front-of-pack labelling. This movement, led by Chile, consisted of implementing labels that look like black stop signs for foods that are high in salt, added sugar, calories or saturated fats (Reyes et al., 2019). Kanter and others (2019) found little evidence of product reformulation there, although demand did appear to shift in some product categories (Kanter et al., 2019). Araya and others (2020) use supermarket loyalty club data and differences in the timing of product introduction in advance of the label introduction to identify impacts on demand for food in three product categories: breakfast cereal, chocolate and cookies (Araya et al., 2020). They found that consumers tended to substitute away from breakfast cereals with labels (towards those without labels), but found no effects on purchases of chocolate or cookies. Since almost all chocolate or cookies have labels, consumers do not have options to substitute within these food categories. But for breakfast cereals, there are several choices within the category, and it appears that the labelling pushes consumers to shift to healthier options. There are no studies on the longer-term or health impacts of food labelling, but some evidence shows that sweetened beverage demand has fallen following labelling (Taillie et al., 2020). The Chilean-style labels have since been adapted by Ecuador, Mexico and Peru and are being considered in other countries. In Mexico, Vargas-Meza and others (2019) studied the level of understanding of nutrition labels in low- and middle-income consumers. Their study demonstrated that directive and semi-directive labels – such as warning labels, health star ratings or multiple traffic lights – may be better at helping people of low- and middle incomes to make healthier food choices than non-directive, front-of-pack labelling, such as to give guideline daily amounts (Vargas-Meza et al., 2019).

Beyond findings in high-income countries and the recent evidence from Latin America, further evidence of the impact of labelling on healthy food choices remains limited. A review of nutrition labelling studies in the global South indicates that consumers like to have nutrition labelling on pre-packaged foods, but the use

[13] Back-of-pack labelling is a nutrition declaration on pre-packed foods that must provide the energy value, amounts of fat, saturates, carbohydrate, sugars, protein and salt per 100 g or per 100 ml of the food, in a legible tabular format or, when space does not permit that, in linear format. Front-of-pack nutrition labelling is simplified nutrition information aiming to help consumers with their food choices.

and comprehension of these labels is low (Mandle et al., 2015). The same review concluded that government-endorsed nutrition information that was clear, easily visible, standardized and included symbols or pictures was positively received by consumers. A qualitative study in South Africa found that food prices remained a more significant consideration among South African consumers when selecting food products than quality and nutritional value (Koen et al., 2018). The list of ingredients, nutrient content claims and specific health-endorsement logos were considered important, but consumers did not easily understand the information on the labels, specifically that in the nutrition information table.

Regulation of advertising

Rather than trying to induce increased consumption, countries can instead regulate either food advertising or packaging. By limiting the advertising of junk foods, the goal is to reduce the consumption of these foods. Since obesity in children is positively correlated with several negative health outcomes in childhood and later in life, many argue that the most important type of food advertising to regulate is that directed to children. As a consequence, several countries have limited or banned junk-food advertising to children. Since the WHO issued a report on the marketing of food and non-alcoholic beverages to children in 2006, the industry has attempted to self-regulate such advertisements to stave off actual regulation – with limited effect (WHO, 2006).

The evidence is mixed on the effectiveness of bans, but it suggests that mandatory bans could be more effective than self-regulation. Quebec banned such advertising between 1984 and 1992; Dhar and Baylis (2011) compare households in Quebec and neighbouring parts of Ontario, and find that the ban on advertising targeted to children decreased the propensity of consumers to purchase fast food, as documented using household expenditure data (Dhar and Baylis, 2011). The mechanism, however, by which fast-food purchases are reduced is unclear. Huang and Yang (2013) used data on advertising by chocolate manufacturers to argue that children saw ads targeted towards adults anyway, and so bans on advertising to children alone might not be effective (Huang and Yang, 2013). A review of evidence on self-regulation shows it is often quite vague, permissive and likely ineffective (Ronit and Jensen, 2014). A systematic review combining studies on the regulation of food advertising to children suggested that more actual regulation rather than self-regulation would reduce children's exposure and had more potential for health effects (Chambers et al., 2015).

Choice restrictions: changing default options and the physical environment

As people are in general risk averse and prefer the status quo, the default option is an important element of decision-making (Ariely, 2010; Kahneman, 2011). Setting healthy options as the default in food choices may work well in, for example, fast-food and institutional restaurants (in workplaces and schools). Proposing a healthier side dish or drink as the default option, or making a smaller portion size or smaller plate the default has proven to have a positive effect (Anzman-Frasca et al., 2015; Thorndike et al., 2012). Similarly, proposing fortified foods as the default option in school meals, at the workplace and in modern markets may work in developing country settings. Governments may use public procurement schemes, such as home-grown school feeding programmes, where the regular food basket is complemented with fresh food, such as vegetables and eggs, purchased from local smallholder farmers (Masset and Gelli, 2013). Another example is Tuskys, a leading retailer in Kenya and Uganda, which has developed a successful bakery product line based on the use of orange-flesh sweet potato paste (MQSUN+, 2018).

Changes in the positioning and presentation of the product, and enhancing convenience, availability and attractiveness to the consumer also have positive effects on their food choices. The food and retail industries apply these principles for both healthy and unhealthy food products. There is evidence that the in-store placement on a mid-shelf or at the checkout, the size of dishware, visual cues, or suggestive names (such as "grande" and "tall") influence food choices (Sigurdsson et al. 2009, Sigurdsson et al. 2014, Bauer and Reisch 2019).

The proximity of healthy foods also encourages their consumption by low-income populations, who do not always have the time to prepare healthy dishes or do not have the refrigeration to store and preserve healthy perishable foods. In Madagascar, "baby restaurants" promote and sell nutritious locally made complementary foods for children over 6 months of age, and mobile food vendors sell these healthy porridges at the household doorstep (MQSUN+, 2018). Similarly, fruit and vegetable cart interventions have

been attempted in contexts as varied as New York City and Nigeria. In New York City, a mobile vending initiative was associated with an increase in the number of establishments selling fruit and vegetables in intervention neighbourhoods relative to control neighbourhoods (Farley et al., 2015). In Ibadan, Nigeria, a vegetable-on-wheels intervention has similarly attempted to increase availability and convenience by setting up carts that offer ready-to-cook vegetables. In both cases, the interventions were simply proof-of-concept (e.g. to test if they were potentially profitable), so there is no robust evidence that they would actually affect diets.

Further innovations also relate to making healthy foods more convenient. Milk-vending machines in Kenya reach a growing market segment of consumers, allowing them to buy the exact amount of milk they need, when they need it and at a much lower cost than for processed packaged milk (Ayuya et al., 2020; MQSUN+, 2018). The combination of affordability, convenience and time-saving benefits is an even more attractive choice for consumers in the case of the pre-cooked, dehydrated beans that are sold in small, affordable packages by Smart Logistics Solutions, a Kenyan aggregator and marketer of cereals and pulses (MQSUN+, 2018). These options, which can potentially be used in both urban and rural areas, provide economic opportunities for the often female entrepreneur, and health benefits for consumers.

Taxes and subsidies

Governments can intervene in markets in ways that can lower the prices of healthier foods relative to those that are consumed sufficiently or in excess. For example, it is possible to subsidize the production of nutrient-dense crops, either directly or, through their value chains, indirectly. Conversely, the prices of overconsumed unhealthy foods can be increased by imposing a tax on the unhealthy component, taxing sugar or unhealthy fat, for example. The outcomes of such interventions for different groups of consumers should be considered carefully to determine the direct and indirect effects, such as substitution and economic effects (Jensen and Smed, 2018). A careful combination of taxes and subsidies is perhaps the most effective option (Redondo et al., 2018).

The most common recent policy innovation, implemented in 42 countries and eight localities around the world, is taxes on sweetened beverages (Global Food Research Program, 2020). The goal of such taxes is to reduce demand for these products, as they have no obvious nutritional benefits, and to generate revenue. Underlying the former goal is a hope that reduced consumption will lead to lower rates of overweight and obesity, or a slowing of these rates.

Much of the evidence on the effects of sugary drink taxes comes from Mexico, which was a leader in implementing such a tax. Evidence suggests the taxes reduce demand. Colchero and others (2017) showed that sales of taxed sugar sweetened beverages fell in Mexico by 5.5 per cent in 2014 and by 9.7 per cent in 2015 relative to 2012/13, while the sales of non-taxed beverages increased by 4 per cent (Colchero et al., 2017). Simulation evidence suggests that impacts of this size could reduce the cases of type 2 diabetes by about 190,000 over 10 years (Sánchez-Romero et al., 2016). The thinking has evolved from whether such taxes are helpful at reducing demand to improving the design of these taxes to achieve a greater impact. Taxing the weight of added sugar in grams rather than taxing the volume could also trigger demand shifts and even support product reformulation, thus further benefiting consumer health; a sugar tax rather than a volume tax can reduce diabetes incidence by a further 0.7 per cent per year (Grummon et al., 2019).

Another frontier for potential taxes would be on UPFs, since they are associated with negative health effects (Pagliai et al., 2020). Some countries, including Brazil (Bortolini et al., 2019), Canada (Government of Canada, 2020), and Uruguay (Ministerio de Salud, 2018), include the concept of UPFs in their food-based dietary guidelines. Taxes on UPFs could reduce demand through price effects; such taxes could also lead to reformulation. So far, however, there has been no uptake of the concept of UPFs in specific national government policies.

Consumption subsidies for healthy foods are another option that has been used mostly in the form of vouchers for fruit and vegetables. There are voucher programmes targeted to low-income consumers in Canada and the United States – the vouchers can be used at farmers' markets for fruit and vegetables (e.g. Byker et al., 2013; Downs and Fanzo, 2016). There is little evidence about their effectiveness in increasing fruit and vegetable intakes, though, likely due to the lack of studies rather than a lack of impacts. An

exception is from Olsho and others (2016), who randomly selected 7,500 recipients of the Supplemental Nutrition Assistance Program in Hampden County, Massachusetts, to receive a 30 per cent rebate on targeted fruit and vegetables, purchased with benefits from the programme. Using phone surveys, they found an increase of 0.32 cup/day in fruit and vegetable intake in the previous 24 hours, which appeared to totally offset refined grain intakes (Olsho et al., 2016). Ridberg and others (2019) studied an alternative – prescriptions for low-income households for fruit and vegetables for children. They found these increased food security among participant households, but the intervention was not randomized (Ridberg et al., 2019). These examples, while providing limited evidence, demonstrate that distributing such coupons could lead to increased fruit and vegetable intakes and could be an effective type of intervention worth testing in a developing country setting, where incomes are low and the lack of affordability is a major barrier to consumption. In countries with strong administrative capacities, this type of intervention using vouchers could increase the consumption of fruit and vegetables more than, for example, cash transfers of the same size.

Last, cash transfers (whether conditional or unconditional) can help to improve diets among poor people by increasing their purchasing power. A recent review focusing on sub-Saharan Africa demonstrated that such transfers typically improved dietary diversity among young children (de Groot et al., 2017). There are three potential concerns with using direct cash transfers to improve dietary diversity, though. First, targeting such programmes is challenging (Hanna and Olken, 2018, describe the trade-offs between using statistical targeting and making universal transfers). Second, when transfers are targeted, they can have negative impacts on the nutritional status of non-beneficiaries through price increases for more nutrient-rich foods (Filmer et al., 2018). Third, the income elasticity of overweight and/or obesity status is also positive, so overweight and obesity status can also potentially rise through transfers (e.g. Ruel and Alderman, 2013). To design transfers to improve diets, then, careful policy design is needed to minimize any possible negative effects; targeted coupons may be preferable to cash transfers.

4.3 Supply-oriented innovations towards healthy diets

Interventions to improve the impact of agriculture investments on diets and nutrition (nutrition-sensitive agriculture) to support poor rural (smallholder) households, especially those living far away from markets, are reviewed elsewhere (Ruel et al., 2018). In summary, nutrition-sensitive agricultural programmes improve dietary outcomes in both mothers and children and are more effective when they incorporate nutrition and health behaviour change communication and women's empowerment interventions, although there are still important knowledge gaps concerning sustainability, scale-up and cost-effectiveness (Ruel et al., 2018). In this section, our focus is on improving the global supply of nutrient-rich foods, as this supply is lower than needed to provide the world's population with a healthy diet. It is estimated that the global supply of fruit and vegetables, for example, is 22 per cent lower than what would be needed to ensure global adequate intakes (Siegel et al., 2014). The supply lag is a direct consequence of biased past investments in agricultural research and development that favoured the production of starchy staple crops over more nutritious crops (Pingali, 2015). Increased investment in research and development on more nutrient-rich crops and agricultural products could improve their productivity, particularly if higher-yielding varieties of those crops and/or products were developed and adopted.

Broadly, there are two ways to increase the supply of nutritious foods – either directly, by increasing their production, or indirectly, especially for perishable products, by increasing efficiency in the middle of the value chain to reduce handling, transportation and distribution costs and food waste to reduce nutrient losses and the overall cost of the products. Direct changes can occur, either within a specific crop or product, by intensifying or expanding production and/or productivity, or through crop diversification, by increasing the production of biofortified staples or of indigenous foods.

The challenge to any of these strategies is for them to occur on a large scale. Interventions that attempt to improve the efficiency of value chains for nutritious products have the best chance at scaling up, and many of these are reviewed elsewhere (e.g. Allen and de Brauw, 2018; Barrett et al., 2020). It is worth discussing one of these types of win-win intervention models briefly here though – interventions that take place in the middle of the value chain to improve efficiency. For example, the increased availability of cold chains can expand both the longevity and safety of perishables, as well as the transportation distance between

production and sale around urban areas. In fact, supermarkets often require cold chains for their produce (e.g. Neven and Reardon, 2012). Using information and communication technologies such as blockchain is another approach, and it can improve the tracking of products through the value chain, potentially leading to reduced transaction costs and increased traceability to move products faster and reduce food safety-related risks (e.g. Nakasone et al., 2014). Finally, interventions in the middle of the value chain for perishables to make them more efficient could reduce post-harvest losses, which are as high as 30 per cent (FAO, 2019).

In newly participating in value chains for more nutritious foods, farmers need not switch the bulk of their production from staples to more nutrient-rich crops. Rather, they can diversify some of their land to more nutrient-rich crops and products if there are markets for these products. Modelling suggests that there are potential methods for farmers to diversify their production without negatively affecting livelihoods. For example, Timler and colleagues modelled how farms in both Kenya and Viet Nam could improve their resource management and supply of nutritious diets by planting different crops without harming their incomes (Timler et al., 2020). However, in both countries, there would be a substantial need for integrated agriculture-nutrition extension to make the intervention these authors suggested work. Agriculture-nutrition interventions can be particularly expensive and do not necessarily yield significant benefits; for example, an intervention in Burkina Faso that was meant to increase chicken production and improve nutrition among producer households did not yield any additional profits relative to a control group (Leight et al., 2020).

Another option is to breed staples that are more micronutrient-rich (e.g. Bouis et al., 2011). The biofortification organization HarvestPlus has worked both on the production of micronutrient-rich staples in developing markets (e.g. orange-fleshed sweet potatoes and iron-rich beans), including methods of processing. However, one concern is that if diets will increasingly include processed foods, even among relatively poor people (as claimed by Tschirley et al., 2015), it will be crucial that they do not lose nutritional value in processing; orange sweet potato, for example, can lose its vitamin A content during processing (Bechoff et al., 2009).

Livestock is a rich source of bioavailable nutrients. Evidence on the impacts of livestock interventions on diets in developing countries, however, is somewhat mixed. One reason is that rural smallholder livestock owners tend to sell the large livestock rather than to consume it, and slaughter animals for consumption only on rare occasions, although they can eventually purchase meat with the cash obtained by selling. For milk and eggs, the own-consumption pathway to nutrition may be more enhanced, but in instances where the production and commercialization is enhanced by development institutions, there is a risk of shifting away from the own-consumption pathway (Dominguez-Salas et al., 2019a). A livestock distribution programme in Nepal, for instance, demonstrated positive impacts on livestock ownership and child anthropometrics in one region, but not in others (Miller et al., 2014). Among pastoralists in northern Senegal who received micronutrient fortified yogurt in return for reliable milk delivery, anaemia reduced among all participants, and haemoglobin levels increased in children who received yogurt (Le Port et al., 2017). None of these interventions, though, was large enough to increase the supply sufficiently to change prices.

Even if a large number of farmers could be convinced to grow more nutrient-rich crops or produce more livestock profitably, prices would invariably be affected. Since many such crops are perishable, prices are more likely to be set by local conditions than by international markets. If production increases, prices will fall, which is good for consumers but not producers. If those price changes would make growing nutrient-rich products less profitable than other crops, farmers would not switch. This effect can limit the growth of nutrient-rich food production, especially if value chains are weak or have high transaction costs associated with them.

Finally, for each approach, whether at the consumer or the producer level, there will be trade-offs for different outcomes and food systems actors. Trade-offs could occur, for example, between the healthy diet goal and other food systems outcomes, such as environmental sustainability or inclusion. Trade- offs may also occur between types of interventions; for example, if public funds are invested in food-environment interventions, they cannot be invested in other value-chain interventions that may have larger positive effects on diet quality. Evidence on the impacts of such interventions can help with making informed decisions about how to use scarce resources most effectively. One individual approach will likely not suffice, and levers must be pulled across various food system components. Connecting the various

components and perspectives of the multiple actors in the food system requires a reverse analysis of what is needed for a healthy and sustainable diet from consumers, the food environment and producers.

5. Discussion

This paper has argued that taking a healthy-diet perspective towards food systems transformation is essential to identify and address bottlenecks and to avoid further deterioration of the nutrition and health status of populations globally. Business as usual in nutrition, health and food system policies and programmes has not been successful at preventing or attenuating the nutrition transition, first mentioned more than 25 years ago by Popkin (1993). The main focus of most agricultural investments and food system transformations has been on increasing food production and producers' income, strengthening agrifood supply chains and markets, focusing on increasing income and access to single foods or food groups, especially staple cereals and oil crops (Khoury et al., 2014). Until recently, the food environment, consumers' preferences and dietary needs, the whole-of-diet approach and the affordability of healthy diets were all generally neglected in international reports on agriculture and food system strategies (Brouwer et al., 2020). Though the importance of healthy food environments to reduce obesity was highlighted in 2013 by the International Network for Food and Obesity/Non-communicable Diseases Research, Monitoring and Action Support (INFORMAS; Swinburn et al., 2013), a healthy and sustainable diet was not seen as an explicit goal of global food systems until the publication of a 2017 report by the High-Level Panel of Experts on Food Security and Nutrition (HLPE, 2017) and more recent reports, the State of Food Security and Nutrition in the World (SOFI) report (FAO et al., 2020) and a report from the Global Panel on Agriculture and Food Systems for Nutrition (GLOPAN, 2020). Likewise, the information and insights on diets, consumer choices and food environment have not been included in most food systems analyses, except for some covered in this paper.

There is large heterogeneity between regions and countries and many have multiple food system types that are not delineated only by the countries' or regions' averages, and these are dynamic and rapidly evolving. There is thus no one-size-fits-all solution. We compared food system types as identified by the Food Systems Dashboard (Fanzo et al., 2020) to offer insights on trends in dietary changes and subsequent health risks, when food systems transition along the continuum from rural and traditional to more urbanized and industrialized. Diets become healthier in some aspects, but also unhealthier in others: the consumption of nutrient-rich foods, especially animal-sourced foods, increases, whereas the intake of fruit and vegetables, dairy, nuts and seeds, and pulses remains insufficient in the most urbanized food systems. The consumption of high-calorie, non-nutritious UPFs increases most sharply in the emerging/diversifying food systems but also in the rural and traditional food systems. These changes are not static, nor distinct, but represent a dynamic continuum in which food systems evolve, and adopt certain characteristics of more complex food system types, with concomitant dietary changes.

We need a deeper understanding of consumer food choices and the food environment to inform transformative food system strategies, especially in traditional, rural and emerging food systems. In food systems analysis, it is often assumed that when foods are available and accessible, populations will consume them. This assumption, however, is too simplistic. This paper has therefore put specific emphasis on the importance of understanding the determinants and key challenges related to consumer food choices and the food environment. There is good evidence that consumers living in urbanized and complex food systems in high- and middle-income countries can be nudged into healthier choices by changing social norms, using digital applications, mHealth services, product labelling, sugar taxes, or making healthy food the default choice. Yet there is limited to no evidence on whether such interventions will work in different food systems, or how they would need to be adapted for instance to the more traditional, rural or emerging contexts. Similarly, there is little evidence regarding the potential or the challenges of scaling up these innovations in different contexts. Furthermore, most interventions targeting the consumer, food environment or the supply of nutritious foods are developed as stand-alone ones focusing on a single component of the food system. Though such interventions may be effective within their particular food system component, there is no alignment, cohesion or connectedness of interventions across food system components so that they work in tandem towards desired impacts. While consumer and food environment interventions are developed mainly for more complex food systems, nutrition-sensitive agricultural interventions are directed

more to the rural/traditional and informal/expanding food systems. There is as of yet no effort to develop, nor evidence of the design of, coherent and connected interventions or simultaneous implementation across the complex food systems to create a multiplier effect on desired health and environment outcomes of the food systems at large scale.

To ensure that food systems transformations will deliver better health and nutrition within planetary boundaries, we recommend that food systems analyses and the design of interventions incorporate healthy diet considerations from the start, to: (i) inform the objectives for food systems transformation towards a healthy diet; and (ii) guide food systems analysis in identifying potential bottlenecks and enablers in the various components, actors and drivers of food systems that prohibit or promote the achievement of the healthy-diet target. Contrary to the traditional supply- and market-oriented food systems analysis, such reverse analyses aim to assess the potential impact of any change or intervention in any given food system component on the expected healthy diet outcome.

We have formulated the following recommendations to ensure that a healthy-diet perspective is taken into consideration in food systems transformation and to overcome the current weaknesses in food systems analyses, intervention design and policy development.

1. Food systems analysis should be used to create a more in-depth understanding of how different food system types affect the availability, accessibility and affordability of healthy diets in different countries, and to inform decision-making regarding context-specific food system policies and interventions. Food systems are dynamic, evolving and interrelated, meaning that traditional, rural populations are exposed to the built food environment in urban centres (exposure to UPFs), and, vice versa, rural producers with market access may contribute to increasing availability of nutritious foods (e.g. fruit and vegetables, dairy, eggs) for populations living in urban, built environments.

2. Food systems analysis should identify potentially conflicting objectives across, or trade-offs between, the multiple food systems actors, drivers and food systems outcomes. Whereas the healthy-diets objective seems well aligned with achieving the environmental sustainability of food systems, there may be other trade-offs between the desired healthy diet for consumers, the economic objectives of producers (e.g. farmers, food processors, traders, and food and beverage companies) and the social objectives of governments, which all need to be weighed and managed carefully.

3. Food systems analysis needs to include the formulation of pertinent questions that challenge intrinsic assumptions regarding the relationship between the multiple food system components. A specific intervention in one of the food system components may have unintended consequences in another. These assumptions and consequences should be well understood and made explicit. The following are two examples.

    a. If behaviour-change interventions are successfully catalysing demand for fruit and vegetables, aggregate demand for these foods will increase. In the absence of increased supply, prices will increase in response, with potentially negative effects on the accessibility of these healthy foods for poorer or other disadvantaged populations. If, instead, supply increases in response, there could be environmental consequences due to an increase in pesticide and herbicide use for fruit and vegetable production, which in turn may have negative health effects on producers or people living downstream of them.

    b. Agricultural food subsidies will impact the production of specific foods and therefore their availability, accessibility and price (and so affordability), which in turn will influence consumer food choices and ultimately food consumption and nutrition indicators. Intrinsic assumptions about the objectives of specific stakeholders must, however, be questioned. For example, the assumption that the availability and affordability of healthy foods would automatically lead to consumers choosing a healthy diet must be challenged. Consumers' choices are driven not just by conscious, rational motives (for long-term health) but also – or perhaps more so – by subconscious, emotional motives. Consumers often make the "unhealthy" choice because they seek short-term pleasure, consolation, status or peer affiliation.

4. Investments in research should be made in low-and middle-income countries to test interventions that have proven impactful in one food system type, for adoption and effectiveness in another food system typology. Nudges to drive healthier consumer choices, food environment adaptations, and effective interventions to increase the supply and affordability of healthy foods should be adapted to and tested in countries characterized by a rural, traditional and emerging food system typology.

To ensure coherence and connectedness, we would need to encourage governments to develop and implement a national food system strategy and action plan. These should address desired health, environmental and inclusivity outcomes through cohesive, interconnected interventions across all food system components. Such action should include the development or revision of national food-based dietary guidelines so that they consider not only the health impact of recommended diets but also the environmental impact and sustainable food production. These guidelines can facilitate the formulation of dietary targets to be taken into account in strategies and action plans.

Finally, the transformation of complex food systems involving multiple actors, activities and outcomes asks for strong food system governance and political will to provide direction and incentives to explicitly manage potential trade-offs, conflicts and unintended consequences (Brouwer et al., 2020). It asks for the courage to challenge and discuss well-established food policy strategies, such as subsidies for staple foods or intensive livestock production, and needs interventions that address the power balances – the connections between formal and informal systems – and address the role of marginalized groups (Dunning et al., 2015; Mancini, 2019). The proposed paradigm shift in taking a dietary perspective to food system transformation provides a tool that allows governments and experts to ask the crucial systemic questions – for food system transformations that achieve healthy diets, sustainable food production and that are inclusive of vulnerable, marginalized population groups.

Annex 1. Description of selected indicators to illustrate dietary transitions

*Indicator**	*Description*	*Data sources used*
Share of dietary energy from cereals, roots, and tubers	The proportion of dietary energy available in a country's food supply that is derived from cereals, roots, and tubers (often referred to as staple foods). This indicator is based on national-level data from FAO's Food Balance Sheets.	National-level data from FAO's Food Balance Sheets.
Adults (age 25+ years): Estimated per capita fruit consumption	Estimated mean daily consumption of fruits (fresh, frozen, cooked, canned, or dried fruits, excluding fruit juices and salted or pickled fruits)	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/
Adults (age 25+ years): Estimated per capita vegetable consumption	Estimated mean daily consumption of vegetables (fresh, frozen, cooked, canned, or dried vegetables, excluding legumes and salted or pickled vegetables, juices, nuts, seeds, and starchy vegetables such as potatoes or corn)	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/
Adults (age 25+ years): Estimated per capita whole grains consumption	"Estimated mean daily consumption of whole grains (bran, germ, and endosperm in their natural proportion from breakfast cereals, bread, rice, pasta, biscuits, muffins, tortillas, pancakes, and other sources)"	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/
Adults (age 25+ years): Estimated per capita red meat consumption	"Estimated mean daily consumption of red meat (beef, pork, lamb, and goat, but excluding poultry, fish, eggs, and all processed meats)"	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/
Adults (age 25+ years): Estimated per capita processed meat consumption	"Estimated mean daily consumption (g/day) of meat preserved by smoking, curing, salting, or addition of chemical preservatives"	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/
Adults (age 25+ years): Estimated per capita sugar sweetened beverages consumption	"Estimated mean daily consumption of beverages with ≥50 kcal per 226·8 serving, including carbonated beverages, sodas, energy drinks, fruit drinks, but excluding 100% fruit and vegetable juice"	Global Burden of Disease, the Institute for Health Metrics and Evaluation http://ghdx.healthdata.org/

* For levels and range of acceptable intake, see table 1 in the main text.
Source: Food Systems Dashboard, available at https://foodsystemsdashboard.org/. Accessed 15 July 2020.

Annex 2. The role of animal sourced foods and their production: benefits and risks

Areas	*Benefits*	*Risks*	*Comments*
Nutrition	• High-quality proteins, with adequate combinations of all 9 essential amino acids (higher biological value) (Semba et al., 2016), with vegetarian/vegan diets requiring careful combination of foods to achieve protein adequacy (Mariotti and Gardner, 2019) • High contribution to essential micronutrient intake: high nutrient density, with higher bioavailability (e.g. iron, zinc, calcium and vitamin A) thus important in preventing micronutrient deficiencies like Anaemia that is disproportionately affecting women of reproductive age and adolescent girls in LMICs (Grace et al., 2018; WHO, 2008) • Only dietary sources of vitamin B12 and D (GAIN, 2020), with vegetarian, and especially vegan consumers, showing high deficiency prevalence (Pawlak et al., 2016) • Animal proteins are 20–30% more digestible than plant proteins (96–98% vs. 65–70%) (Murphy and Allen, 2003) • ASF contain bioavailable compounds like iron and preformed Vitamin A; Iron helps with blood formation while Vitamin A is important in cognitive and physical development of children (GAIN, 2020; Murphy and Allen, 2003) • Evidence of milk and eggs improving linear growth in young children if provided regularly and in appropriate amounts; and meat improving cognitive development (Grace et al., 2018). Supplementing usual diet with dairy products, benefits by approximately 0.4cm per annum additional growth per 245 mL of milk consumed daily (de Beer, 2012)	• Contribution to Non-Communicable Diseases: evidence very heterogeneous among ASF, and for dairy, eggs and fish, and poultry, the effect is neutral to preventive. There is strong evidence of an increased risk of consumption of processed red meat, most of it is related to the use of preservatives (Anand et al., 2015; IARC Monographs, 2018; Rouhani et al., 2014). Although associations of unprocessed red meat consumption with NCD have been observed, evidence is not equally conclusive (Ekmekcioglu et al., 2018; Micha et al., 2010) • High ASF consumption may result in excess protein and fat intake • Competition of livestock with humans for crops and water	• Moderate consumption of ASF should be recommended, which for an important part of the poorest population means increasing their current intake. • This requires supporting sustainable and affordable production and consumption for LMICs rural and peri-urban poor population whose diets are limited in ASF- cheap diets, poor in quality

Health	• ASF proteins promote lean mass and cell repair after extreme physical activity and in elderly individuals (Paddon-Jones and Rasmussen, 2009)	• The global burden of foodborne diseases is comparable to some of the key infectious diseases such as malaria, HIV/AIDS or tuberculosis and comes mostly from ASF and • fresh produce. This burden falls mostly on • nutritionally vulnerable populations such as pregnant women, immune-supressed or children under 5 of LMICs (Havelaar 2015) • ASF adulteration (e.g. milk dilution) • Particular production practices such as mass administration of antibiotics or hormones can result in the presence of unwished components in ASF, contributing to antimicrobial resistances or endocrine disruption (Kimera et al., 2020) • Zoonotic diseases in livestock producer households such as Campylobacter, due to poor livestock handling practices (Lowenstein et al., 2016) Occupational injuries from animals	• Governments and other actors need to consider how to improve ASF safety affordably, including for supply to the rural and urban poor
Environmental sustainability	• Ruminant can convert biomass unsuitable for consumption into high quality food, so not all the land use is in competition with crop production. Can also use lands unsuitable for crop production like in mountainous, in water bodies • Large part of livestock´s environmental footprint stems from feed production, but LMICs extensive systems use grass, crop residues or scavenged plans • Manure from livestock can be cycled back to crop production reducing the need for chemical fertilizers • Provision of draft power, and fuel for subsistence agriculture	• Use of 30-40% of global land and 80% of agricultural land; use of 8-10% of global fresh water (Herrero et al., 2015) • Contribution to up to 15% of global anthropogenic greenhouse gas emissions, but this varies largely by ASF (Godfray et al., 2018) • Evidence on the environmental footprint of livestock, including overgrazing with land and forest degradation, and subsequent carbon losses (e.g. contribution to Amazon deforestation) (De Sy et al., 2015) • Air, land and water pollution. • Livestock roaming, environmental contamination, noise and wastage • Potential negative impact on wildlife and biodiversity	• Evidence frequently based on research from intensive production systems of developed countries, notwithstanding that there is a wide variety of food production systems, some of which rely on feed resources that would go unused otherwise, and transform those into high quality food • Livestock is crucial in isolated areas where the arid conditions do not permit other forms of agriculture to ensure food security and livelihoods, as well as the contribution of ASF to total intake of protein and other key micronutrients, as is the case in the Sahel and Horn of Africa
Economic sustainability	• Role in rural poverty alleviation: Income, jobs, livelihoods (livestock-keeping represents the main livelihoods for around 1.3 billion people worldwide, that rely on livestock for income for education, health care, etc.) (FAO, 2020)	• Volatility of food markets • Social and environmental externalities not priced	

	• Cash/bank functions – financial security for health, education, etc.	
Social sustainability	• Cultural beliefs, values and norms => celebrations, sense of belonging, tendency to ASF in many cultures • Woman empowerment- Women are more likely control the milk and the eggs economy, and obtain income and assets, which are more likely to result in nutrition benefits for the family • ASF and animals are frequently a mark of social status • Ethnic minorities are often more livestock-dependent than other majority cultures • Milk is a culturally valued component of many diets in LMICs • Many derived psycho-social benefits from ownership of livestock	• Intra-household allocation practices may impair consumption by the most vulnerable (i.e. pregnant women and young children) (FAO, 2020) • Women disempowerment when women do the job, but men own the animals • Land issues can cause distress and conflict between neighbours • As valuable mobile assets, cattle are an incentive for raiding in some cultures • Fear- ASF, including milk, are often subject to dietary taboos, which cause distress if transgressed
Other aspects	• Desired taste • Emotional comfort • Convenience	• Poor animal welfare causes concerns • Long cooking to avoid food safety issues requires fuel, which is sometimes a limitation • (Dominguez-Salas et al., 2019a)

Based on and expanded from (Dominguez-Salas et al., 2019b)

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