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EatSafe: Evidence and Action Towards Safe, Nutritious Food

Integrating Food Safety and Nutrition for Improved Health and Wellbeing:

A New Lens on Food System Frameworks

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This EatSafe report presents evidence that will help engage and empower consumers and market actors to better obtain safe nutritious food. It will be used to design and test consumer-centered food safety interventions in informal markets through the EatSafe program.

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ACRONYMS

Below is a list of all acronyms and abbreviations used in the report.

FAO	Food and Agriculture Organization
GAIN	Global Alliance for Improved Nutrition
LMIC	Low- and middle-income country
NCD	Non-communicable disease
RFS	(USAID Bureau for) Resilience and Food Security
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development

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EXECUTIVE SUMMARY

Food safety and nutrition are inextricably linked. To achieve optimal human health and wellbeing, people must be both well-nourished and free from foodborne disease—which requires that they have access to diverse foods, both staple foods and nutrient-dense non-staples, that are safe to eat. Despite these linkages, the connections between food safety and nutrition have been largely lacking from existing frameworks for nutrition or food safety and those for the food system overall. Existing frameworks for food systems tend to omit food safety or treat it superficially, as only one sub-component of one aspect of the framework, as opposed to integrated throughout. Similarly, few frameworks within the food safety field explicitly consider nutrition concerns or identify a conceptual framework for guiding policy linking the two. As a result, these frameworks are unable to highlight relevant pathways for integrated action and measurement related to food safety and nutrition.

This report looks at existing conceptual frameworks for food systems with a new lens that links food safety and nutrition and explores how such a perspective can be used to improve policy and programming. This new lens for viewing food safety frameworks was constructed following a review of the main prior conceptual frameworks for food safety and/or food systems/nutrition as well as of other analyses tackling the two topics jointly. It was also informed by an in-depth systematic review of research on linkages between food safety and nutrition as well as a virtual workshop with leading experts in food safety, nutrition, and related fields, including potential users.

First, we present a set of specific causal pathways through which food safety and nutrition are interlinked, grouped into the domains of health and physiology, consumer behavior, supply chains and markets, and policy and regulation. These linkages illustrate the direct ways in which food safety and foodborne diseases may impact nutrition outcomes—and vice versa. We also present underlying assumptions and qualitatively discuss the evidence associated with these pathways. At this stage we include both established and putative impact mechanisms, as input into a discussion on strength of evidence and knowledge gaps. We then build upon these underlying causal mechanisms to view food safety frameworks in a way that clearly elucidates the connections between food safety and nutrition at the level of the food system.

Our vision for the food system, when seen through this new lens, is that it aims to deliver healthy, balanced diets that provide sufficient amounts of necessary nutrients while also preventing foodborne diseases. Both food safety and nutrition are integrated throughout the different elements of this food system (food supply chains, food environments, and consumer behavior) and both are influenced by external drivers, suggesting potential levers for action. As a central part of this perspective, we note certain positive and negative feedback loops that operate to foster (or inhibit) the supply and consumption of safer, more nutritious food. We conclude by noting various ways in which this new lens on existing food system

frameworks can be used by different types of stakeholders to guide their decisions and actions. The contents of this document can be considered as a foundational step towards the development of actionable and validated implementation guidance and tools for better integrating food safety and nutrition within food systems interventions.

1. BACKGROUND AND MOTIVATION

Food safety is defined as the assurance that food will not cause harm (chronic or acute) to the consumer when it is prepared or eaten according to its intended use (1). Causes of unsafe food include viruses, bacteria, molds, protozoa, helminths (worms), mechanical/physical contaminants, and chemicals that enter the food supply at various stages, from production to home preparation. These contaminants are widespread in the food supply in low- and middle-income countries and can both cause acute illness or injury and raise the risk of long-term, chronic disease—for example, both aflatoxin and arsenic have been associated with cancer (2,3). Such illnesses can be particularly detrimental in settings like Sub-Saharan Africa, where the health system has limited capacity for diagnosis and treatment (4).

Foodborne disease is responsible for an estimated 600 million illnesses and 420,000 premature deaths annually (2010 est.) (5). Consumers living in low- and middle-income countries (LMICs) (6,7) experience the majority of foodborne disease, including about 75% of deaths from foodborne illness (despite comprising only 41% of the global population). This is particularly true for Africa, where the per-capita burden of foodborne disease is about 27 times that of Europe or North America (5). Young children are particularly susceptible, shouldering about 40% of the burden (5). In addition, immune system changes during pregnancy place women, fetuses, and newborns at increased risk of foodborne illness, which can lead to adverse pregnancy outcomes (8,9). Foodborne illnesses also entail economic costs, due to sickness and loss of life, workplace absences, treatment costs, and impacts on trade; the World Bank estimates these at about $20 billion USD per year (10).

Unhealthy diets – those lacking essential nutrients or with excess consumption of some – are an important cause of all forms of malnutrition. Malnutrition comprises both overweight/obesity and undernutrition, which can be further divided into the often-overlapping categories of micronutrient deficiencies and protein-energy undernutrition, which exists in both acute and chronic forms (11–13). The immediate causes of undernutrition include insufficient (micro- and/or macro-) nutrient intake, poor health, and inadequate care. Insufficient nutrient intake is driven by poor diets linked to insufficient access to affordable, safe, nutrient-rich foods, with poverty being an important root cause (14). Poor access to nutritious foods and readily available, inexpensive nutrient-dense 'junk' foods are linked to overweight/obesity (15,16); genetic factors and physical activity levels also play considerable roles in determining risk (15,17). Undernutrition can lead to poor growth, fatigue, and

conditions such as goiter or night-blindness and can weaken the immune response (18). Among children, it can lead to delayed physical and cognitive development (19–21). Maternal undernutrition, in particular, contributes to poor pregnancy outcomes, including fetal growth restriction, birth complications, and maternal mortality (22). The global burden of undernutrition remains large, with about 22.2% of children under age five stunted and 32.8% of women and adolescent girls affected by anemia (12). Poor diets and overweight/obesity are also major risk factors for non-communicable diseases, including cardiovascular disease, diabetes, and cancer (23–28). Overweight and obesity affect about 1.9 billion adults, and in 2017, diet-related risk factors were responsible for about 22% of all adult deaths (29). The cost of malnutrition in all its forms for the global economy is estimated as being as high as $3.5 trillion USD per year (30).

Within international development policy and programming, food safety and nutrition have usually been thought of as separate issues, with different solutions and approaches, and addressed by different types of organizations and experts. However, there is a strong argument for seeing them as connected. For example, about one third of diarrheal disease cases can be attributed to food (6), and diarrheal disease is a major determinant of undernutrition (31–36). There are also behavioral and dietary choice linkages. Many of the foods at highest risk of causing foodborne disease due to microbial or chemical hazards are also among the most nutritious (e.g., animal-source foods, fresh vegetables) (6). Food safety concerns could incentivize consumers to avoid or consume less of these highly nutritious foods if they are considered likely to be unsafe, to the potential detriment of nutrition (10,37,38). Conversely, campaigns to increase the consumption of nutritious, higher-risk foods could increase the health burden if food safety issues are not addressed. As the World Bank summarizes, 'Food and nutritional security are realized only when the essential elements of a healthy diet are safe to eat, and when consumers recognize this' ((10), p. xxi).

Despite these linkages, and as discussed in more depth in Section 3, most conceptual frameworks in the food and nutrition space do not articulate the multifaceted connections between food safety and nutrition or highlight relevant pathways for integration, action, and measurement.[1] However, there are a number of strong frameworks that already exist for viewing and understanding food systems. As such, this report uses those frameworks but looks at them with a new lens: one that links food safety and nutrition and recognizes that both are influenced by actions and processes throughout the food system.

This paper also explores how such a lens can be used to improve policy and programming in practice. The objective of the lens illustrated in this document is to guide approaches that can promote positive development outcomes such as improved health, wellbeing, cognitive

[1] For this document, and in the context of food systems, we define a framework as follows: A framework is a model that depicts a system, highlighting its key components and how they interact. A framework serves as the foundation for internal and external messaging, organizing priorities and initiatives into strategic drivers or pillars that ladder up to a high-level goal or purpose. A strong framework is aspirational, designed to inspire stakeholders and demonstrate how the organization engages them in working towards their vision, purpose, or goals.

capacity, and earning potential for consumers in low- and middle-income countries. Central to our perspective is the idea that both the safety and the nutrient content of the food supply are equally integral to achieving these positive outcomes. The next section describes the methods used to develop this new perspective. Box 1 defines key terms relevant to the content of this document.

Box 1. Key Terms (continued next page)

For the purposes of this report, we use the following working definitions.

Contaminant: Any substance not intentionally added to food, which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food or as a result of environmental contamination. The term does not include insect fragments, rodent hairs and other extraneous matter (39).

Developmental outcomes: Outcomes related to the growth of the human organism, from birth to adulthood, including physical and cognitive capacities (see also: Indicators of nutritional status).

Dietary exposure: For the purposes of risk assessment, measurement of the amount of a substance consumed by a person or animal in their diet that is intentionally added or unintentionally present (e.g. a nutrient, additive or pesticide) (40).

Diet-related noncommunicable diseases (NCDs): Non-infectious diseases for which unhealthy diets and poor nutrition are among the top risk factors; they include heart disease, stroke, diabetes and some cancers (41).

Foodborne disease: Any disease of an infectious or toxic nature caused by the consumption of food (42). This term is often used in the context of a population or generally to indicate all syndromes due to foodborne hazards.

Foodborne illness: Illness is defined as the lack of wellness, and hence includes physiological impacts, injury and individual perceptions of pain and distress. This term can be a synonym of foodborne disease, though more often it is applied to a specific outbreak or illness event.

Food safety: Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (43).

Food environment: The "interface that mediates people's food acquisition and consumption within the wider food system." Some definitions break this down into 'personal' and 'external' food environments. In this case, the *personal food environment* includes individual- or household-level aspects, such the accessibility, affordability, convenience, and desirability of food sources and products, and the *external food environment* includes dimensions that across all individuals within a community, such as food availability, food prices, vendor and product properties, and advertising and promotional information (44).

Box 1. Key Terms (continued)

Food system: A food system gathers all the elements (including environment, people, inputs, processes, infrastructures and institutions) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socioeconomic and environmental outcomes (45).

Hazard: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect (46). An agent that has the potential to cause adverse health effects in exposed populations (47).

Health outcomes: Measurable health states (positive or negative), including morbidity and mortality metrics.

Indicators of nutritional status: Anthropometric indicators (height and/or weight for a given age and sex) are commonly used to measure child growth and nutritional status. Indicators of undernutrition include stunting, wasting and underweight (48).

Malnutrition: Refers to "deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients." It encompasses undernutrition (including wasting (low weight-for-height), stunting (low height-for-age) and underweight (low weight-for-age)), micronutrient-related malnutrition (deficiencies or excesses of vitamins and minerals), and overweight, obesity and diet-related noncommunicable diseases (41).

Non-communicable diseases (NCDs) and **diet-related NCDs**: NCDs are non-infectious chronic diseases that last a long time, progress slowly, and are caused by a combination of modifiable and non-modifiable risk factors, including lifestyle/behavioral, environmental, physiological and genetic factors. Main types of NCDs include cardiovascular disease, diabetes, cancer, and chronic respiratory disease. Obesity is both a chronic disease and a risk factor for other NCDs. We refer to NCDs related to diet (or nutrition) as 'diet-related NCDs'. These mainly include obesity, cardiovascular disease, diabetes, and specific cancer types (45).

Nutritious food: A "nutritious" food is a food that in the context where it is consumed and by the individual that consumes it, provides beneficial nutrients (e.g., vitamins, major and trace minerals, essential amino acids, essential fatty acids, dietary fiber) and minimizes potentially harmful elements (e.g., anti-nutrients, quantities of saturated fats and sugars). This definition thus encompasses both foods that can contribute to preventing undernutrition as well as those that can help prevent overweight/obesity and diet-related NCDs (49).

Risk: A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food (46).

Stunting: Stunting refers to the impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation. The World Health Organization (WHO) defines childhood stunting (moderate and severe) as a length- or height-for-age z-score more than two standard deviations below the median of the WHO Child Growth Standards. Children who are stunted are also more likely to be wasted (45).

2. METHODS

To develop this new way of viewing food system frameworks, we first reviewed prominent frameworks in nutrition or food systems (e.g., (14,39–41)) and those in food safety to understand whether food safety was included in nutrition frameworks, and vice versa. We also searched for frameworks or other analyses examining both food safety and nutrition in an integrated manner (37,38,42,43) and noted their main points and gaps. The review did not intend to be systematic and cover all frameworks proposed on the topic, but rather focused on those that have been the most prominent, used, and/or influential.

Next, we commissioned a new literature review on evidence for linkages between food safety and nutrition, with focus on impact mechanisms and outcomes related to health and physiology. To this end a search of the peer-reviewed literature was conducted for work relevant to the intersection of food safety and nutrition outcomes, with a focus on LMICs, using a broad set of keywords. This search was complemented by a search for grey literature from selected organizations. Articles were filtered for relevance to the research questions, and data was extracted and summarized by type of impact pathway (44).

Based on this information, we discussed how food system frameworks would look if both food safety and nutrition were integrated within a common approach, among a cross-disciplinary team with expertise in nutrition and food safety, agriculture, public health, law, economics, program design and implementation, and monitoring and research.

We presented our draft thinking at a virtual workshop with over 30 experts in food safety and/or nutrition in October 2020. These experts were chosen based on depth and complementarity of expertise, experience in different organizational sectors, and geographical and gender balance. We also aimed to strike a balance between “evidence generators/synthesizers” (e.g., researchers and analysts) and “evidence users” (e.g., policy designers or program managers). We sought to represent various areas of expertise, including nutrition, food safety, international development programming and investment in food and agriculture, policy design and analysis, agricultural economics, regulatory impact analysis, food supply chains, epidemiology and risk analysis, medicine and physiology, and consumer and behavioral science. Over the course of the workshop, participants were asked to critique and comment on various aspects of our new perspective on food systems frameworks, in order to identify gaps, understand the strength of the assumptions, evidence, and consensus underlying its various aspects, and improve the presentation and usability. The feedback received through this workshop was used to devise a final (working) version, presented here. A summary of the workshop is provided in Appendix II.

The next section describes the results of the review of prior frameworks, before presenting a new food safety- and nutrition-sensitive perspective on these frameworks. In addition,

Appendix III presents a review of food safety measures and performance indicators, to complement the food safety perspective presented here.

3. FOOD SAFETY & NUTRITION WITHIN PAST FRAMEWORKS

3.1. Food Safety within Nutrition and Food Systems Frameworks

Within the major existing frameworks for nutrition and/or food systems, food safety may appear, but its connection to malnutrition is rarely explained and made explicit. In the domain of nutrition frameworks, for instance, the influential United Nations Children's Fund (UNICEF) undernutrition framework does not explicitly mention food safety (14). While safety is included in the classic 1996 definition of food security, it is often omitted or under-discussed in actual applications of the food security concept (e.g., (45)). The conceptual pathways document refined by the USAID Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project, which is widely used to design integrated interventions in nutrition and agriculture, does mention food safety in its framing and policy principles but omits it from its causal pathways (46).

Within the domain of food systems frameworks, a particularly influential framework was included in the High-Level Panel of Experts (HLPE) "Food Systems" report (see Figure 4 in the Appendix I). It acknowledges that food safety and nutrition are inextricably linked and situates 'safety' in two parts of its framework: food environments and diets. However, the explicit linkages between the two are not covered in depth (40). The UNICEF-GAIN *Innocenti* Framework on food systems for children and adolescents, developed in 2019, is centered on delivering "nutritious, safe, affordable, and sustainable diets" and food safety is mentioned several times in its background document; however, within the framework, "food safety" appears only as one of four sub-categories of "influencers" within the external food environments (which, in this framework, is separate from the "personal food environment" and refers to, e.g., markets, shops, and schools; see Box 1) and is not reflected in other areas, such as food supply chains, personal food environments, or caregiver/child behavior (39). The more recent USAID Bureau for Resilience and Food Security (RFS) Food Systems Conceptual Framework (41), shown in Figure 5 in Appendix I, takes a similar approach, situating food safety as one element of the food environment but not explicitly focusing on its links to nutrition or its role in other components of the food system. We consider the USAID food system framework as a key reference in this discussion; we combined its structure and main components with those of the HLPE framework and then viewed that 'food system' through a lens that made the food safety aspects as explicit as the nutrition and food security aspects.

The 2013 "State of Food and Agriculture" report of the UN Food and Agriculture Organization (FAO) was a key comprehensive document and turning point for galvanizing global thinking on malnutrition to consider the entire food system, beyond agricultural production alone. That report did not present a framework *per se* but did conceptualize of the food system as

consisting of production (up to the farm gate), the post-harvest supply chain, and consumers (including advertising, labelling, education, and safety nets). “Food safety” was noted as essential to nutritious diets and noted as an opportunity for intervention within the supply chain (47). Subsequent FAO guidance on “nutrition-sensitive food systems” and “food systems for healthy diets” mentions safety as a cross-cutting theme, but does not go into details on the linkages between it and nutrition (48,49). An FAO “concept and framework” for “sustainable food systems” also includes only passing reference to food safety (50).

Other food systems conceptions akin to frameworks have been proposed, though not as widely adopted as those named above. For example, a group of experts convened by the U.S. Institute of Medicine and the U.S. National Research Council developed an analytical framework to assess the “health, environmental, and social effects (positive and negative) associated with the ways in which food is grown, processed, distributed, marketed, retailed, and consumed,” with a focus on the U.S. food system (51). This framework consists of six steps: “(1) identify the problem; (2) define the scope of the problem; (3) identify the scenarios; (4) conduct the analysis; (5) synthesize the results; and (6) report the findings” (51). Within this framework, food safety and nutrition both appear as aspects of food quality. Sobal et al. (1998) developed an early “food and nutrition system” framework, divided into three subsystems: producer, consumer, and nutrition (52); food safety is not considered explicitly within this framework.[2] Ericksen et al. (2008) developed a framework for studying interactions of food systems with global environmental change; food safety and nutrition both appear as aspects of food utilization (a sub-aspect of “food security”) and are not explicitly discussed in other aspects of the system: “drivers” and “activities” (53). Ecker and Breisinger (2012), of the International Food Policy Research Institute, developed a “food security system” framework seeking to integrate macro-level dimensions of food and nutrition security alongside micro-level ones and to include the impact of external shocks and stresses. Within that framework, food safety appears again as a sub-aspect of utilization and is not clearly reflected in other parts of the framework (54). Kanter et al. (2015) develop a framework depicting key relationships among the food system, agriculture, nutrition, and public health (55). In this approach, food safety (divided into livestock and vector-borne diseases and food/water-borne diseases) appears as linked to markets, food environments, and health outcomes (morbidity and mortality), the latter of which is linked to nutritional status (55). However, food safety is not given any in-depth treatment within the rest of the framework or supporting text. A 2018 Wageningen University report again mentions safety as a theme but does not go into detail on the linkages between it and nutrition (56).

There are also some conceptual approaches that are not frameworks *per se* but do link the two topics. Häsler et al. developed a conceptual approach to linking food safety with nutrition outcomes but focused explicitly on livestock and fish value chains. While very practical and containing useful insights, this specific focus limits some of its applicability to the broader

[2] The authors also note this existence of over 70 different diagrams presenting various depictions of the food and nutrition system, which are not covered here as they have largely been supplanted by more recent work.

context (37). Vipham et al. review of lessons from livestock-related research draws on prior literature and experience from the USAID Feed the Future Innovation Lab for Livestock Systems to identify the interconnected elements of food safety and food and nutrition security, though without presenting a broader approach for viewing them jointly (42). Similarly, Walls et al. discuss complementarities and tensions between food safety, healthy nutrition, and food security, but without presenting them within a wider framework.

Finally, two influential recent global reports on sustainable food systems make little or no mention of food safety (57,58), and a recent USAID-commissioned review of research on food systems identified food safety as an important research gap (59). Within the field of nutrition and food systems, it is clear that food safety has received insufficient attention, particularly in terms of how it links to nutrition.

3.2. Nutrition within Food Safety Frameworks

Within food safety, there are fewer examples of "conceptual frameworks" *per se;* instead, comprehensive discussions on food safety systems often take the form of strategic action plans, policy frameworks, comprehensive sets of standards or guidelines, or methodological approaches to risk assessment or management. While these do not usually seek explicitly to understand linkages within a system, they do illuminate some thinking about main priorities and concerns. Within these approaches, nutrition considerations are often lacking or included only marginally. However, nutrition and food quality may be an integral part of the discussion leading to a policy.

In general, food safety policies and regulations, as well as industry standards, work within existing supply chains and products to maintain or improve the safety of existing food commodities. As such, food safety policies and practices in general do not include statements on the nutritional quality of foods or their appropriate level of consumption. In some situations, nutrition concerns have been a key aspect of opposition to food safety practices and their codification into a legal framework.[3] There is thus a need to encompass nutrition and food safety goals within policy frameworks and underlying analyses.

At the international level, the Codex Alimentarius[4] standards and guidelines constitutes the main food safety framework that many LMICs (and high-income countries) reference and adopt (62), with the twin goals of protecting consumer health and ensuring fair trade practices. Codex provides both general standards (principles and guidance over broad topics, which can be used as guidance for countries to develop their own standards) and commodity-

[3] For example, in the U.S. following a number of high profile outbreaks, mandatory preventive control systems for juice frequently include pasteurization of commercial fruit juices, to ensure food safety and prolong shelf life (60). Unpasteurized juices must carry a safety warning label. While guidelines were based on food safety considerations, some civil society level concerns have discussed the potential nutrient loss due to pasteurization. A similar discussion has occurred in the U.S. for milk and milk products, where pasteurization is a mandatory requirement to ship product across state lines (61). The policy for milk pasteurization was adopted in the 1930s to address illnesses and outbreaks linked to unpasteurized milk.

[4] The Codex Alimentarius Commission (Codex) is an international standard-setting organization established by the World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO).

specific standards, which serve as a reference for national government food safety operations and outcomes. The work of Codex overall includes nutrition, through committees on “Food labelling” and “Nutrition and Foods for Special Dietary Uses” (63), though the standards and guidelines do not generally integrate food safety and nutrition. In Codex commodity standards, nutrition criteria are generally not mentioned explicitly. However, several quality specifications based on sensory criteria may be relevant to the nutritional quality of the product. For example, standards for tomatoes and other fresh fruits and vegetables specify quality requirements for different product categories, including requirements to be “fresh in appearance” and “healthy” (64). The contribution of the Codex framework to nutrition is highlighted in the Codex Strategic Plan for 2020–2025, which highlights Codex’s role on developing standards related to Nutrient Reference Values, foods for special dietary uses, and labelling standards (65). However, while Codex’s scope includes nutrition, it has not explicitly integrated its approach to tackling food safety and nutrition jointly.

At the national level, most food safety policy frameworks under development do not explicitly include nutrition criteria, as seen in examples from Kenya and Vietnam (66). However, food law and policies in several countries or regional bodies encompass both food safety and nutrition.

At the regional scale, in 2020 the WHO Office for South-East Asia developed a “Framework for action on food safety in the WHO South-East Asia Region” (67), built upon the previous Regional Food Safety Strategy of 2014–2018. This framework mentions nutrition as part of its context and goal statements, for instance recognizing the key role of food safety in achieving the UN Sustainable Development Goals, which also include nutrition and food security (68). The framework recognizes the contribution of other sectors and domains to food safety and consumer health protection, and *vice versa* (67), stating: “Food safety is a shared responsibility and implementation of the Framework should be coordinated with various health-related programmes in WHO, such as nutrition...” (67). While the detailed discussion of needs, standards, and implementation does not include nutrition criteria, or how food safety and nutrition outcomes could be jointly pursued, the framework mentions its alignment with other health-related strategic plans, including those focused on nutrition (69). It also highlights its support for nutrition-relevant programmes, including initiatives on regulation of healthy diet (e.g., labelling, marketing to children, and health claims); risk-based inspection to manage foodborne risks, particularly to reduce infections contributing to malnutrition; and a consumer awareness programme to promote food safety, labelling awareness, and healthy and balanced diets.

An integrated approach that explicitly ties food safety and nutrition is illustrated in the pathways diagram developed in 2016 by Grace (38). This figure (See Figure 1 in the Appendix) begins by aiming to examine the role of food safety in creating a healthy food environment, elucidating three pathways through which food safety can affect health: causing disease, causing people to change their food consumption behavior, and causing control of unsafe

food (disease control). It also notes that the first pathway is likely to be most influential in lower-income countries and the second pathway ('food fears') likely to be most influential in higher-income countries. This is probably the most developed framework to date and is very useful for considering interactions between food safety and nutrition. A framework also by Grace et al. (2018) (70), focused on livestock and child nutrition and health in the first 1000 days of life, follows a similar approach highlighting cause-and-effect mechanisms associated with health, dietary and behavioral choices, and broader socio-economic and food system factors such as labor and income, land use, and environmental contamination.

However, the Grace (2016) (38) pathways diagram and accompanying discussion take a somewhat different approach, focused on causal mechanisms, compared to broader food systems frameworks that guide the work of many policies and programs in nutrition (e.g., those of USAID) and has certain gaps, particularly related to dynamics operating among vendors and within the market. Moreover, it takes an explicit negative framing (how 'unsafe food could lead to worse nutrition and health'), thus perhaps underrepresenting potentially positive linkages. (See Figure 1, Appendix I.)

Building upon existing frameworks but viewing them in a way that more comprehensively and clearly links food safety and nutrition throughout the food system, can help inform better-designed and better-implemented policy and programming and evaluate its outcomes with the dual goals of better nutrition and improved food safety in mind. It could also assist in the prioritization of new topics for research to fill gaps in information.

4. EXISTING FRAMEWORKS THROUGH A NEW LENS

4.1 Important Framing Concepts

There are many different types of food safety risks, caused by diverse types of contaminants. They can arise throughout the supply chain, as well as in the home. Some are the result of accidental contamination, whereas others may result from deliberate adulteration. Some types of foodborne illness are acute (e.g., diarrheal diseases) whereas others are chronic (e.g., cancer). This distinction is important, as consumers may be more concerned about one or the other (in some settings, serious chronic effects have been noted by experts as eliciting most concern). However, chronic effects are largely imperceptible to consumers and thus may be less likely to lead to behavior change (e.g., avoiding a specific food or vendor) in the absence of deliberate and trusted communication on that risk and how it can be avoided. In the discussion below, we aim to encompass these varied types of risks and illnesses, flagging where relevant whether something is particularly applicable to some risks and illnesses more than others (e.g., acute as opposed to chronic).

In addition, food safety is not binary: that is, food can rarely be seen as clearly 'safe' or 'unsafe'. Instead, food safety is a continuum spanning many different levels of safety. The aim of policies and programs should be to prevent hazards from entering the food supply in order to reduce risk and harm along this continuum. It is rare (particularly in LMIC settings) that the 'perfect' goal of safe food can be achieved, given the trade-offs associated with doing so, such as increasing cost and decreasing affordability for consumers.[5] Where we refer to 'safe' or 'unsafe' or 'risky' or 'less risky' throughout this discussion, it should be seen as shorthand for an increase or reduction of risk along this continuum.

Finally, there are different types of food systems, many of which mix formal and informal sources (72), and consumers in LMICs can patronize both formal and informal sources when buying their food. Registered or branded food products can be marketed in the informal sector, and products from the formal sector can be diverted to the informal sector based on quality concerns. Food safety concerns and dynamics differ across formal and informal sources, and the ability to control and regulate food safety also varies widely. For example, in informal systems, regulations and standards tend to be weak, and recalls may be rare. Linking a particular food with a specific illness can be extremely challenging, so consumers may be less likely to avoid certain foods or vendors based on food safety reasons. This may make it less likely that feedback from consumers will reshape actions in the supply chain. In more formal systems, in contrast, surveillance and food tracing systems can be stronger, and

[5] An FAO/WHO expert committee has recently issued guidance specifying two different thresholds for tropane alkaloids in grain: one for routine settings, one for emergency settings. The latter is higher, tolerating some health effects given the need to address acute hunger (71).

consumers may have greater recourse to report problems. Market signals also may not operate as smoothly in informal settings. In informal channels, trust in official regulation and control may be weak, and personal trust can be more important than institutional trust (i.e., in regulation and control systems).[6] Consumers in informal markets may select vendors whom they trust and buy potentially risky products from them even if they are more generally concerned about the safety of those products. In formal systems, trust may instead be placed in brands and institutions. Moreover, those living in formal, modern supply chains may take food safety less seriously because they assume that food is already safe—thus perhaps exposing themselves to greater risks. Our discussion aims to encompass both informal and formal systems/sources but notes where the distinction is relevant.

4.2. Linking Nutrition and Food Safety

Bringing a 'food safety and nutrition' perspective to view existing frameworks is motivated by the central idea that food safety and nutrition are interlinked, with causal pathways running in both directions. Food safety issues influence nutrition, and nutrition issues influence food safety, both in terms of processes and outcomes. Both interact in determining health outcomes, as well as impacting livelihoods and other aspects of society. Figure 2 offers a visual summary of these linkages, not weighted by impact or strength of evidence. We categorize these linkages into four types: health and physiology, consumer behavior, supply chains and markets, and policy and regulation. The selection included below is illustrative and non-exhaustive; some linkages are discussed in the text but not noted in the figure, and additional linkages likely do exist.

Here we briefly summarize each of these types of linkages and explain their importance. In the next subsection (Section 4.2), we use these different linkages as the foundation for applying a 'food safety and nutrition' lens to view existing food systems frameworks so that food safety and nutrition are considered in an integrated manner. With the partial exception of physiological impacts of food safety and foodborne disease on nutrition and developmental outcomes, some of which are fairly well studied and have been reviewed elsewhere (44), other impact mechanisms are largely putative or based on limited or anecdotal evidence. We present them to illustrate a broad range of potential mechanisms and foster discussion, recognizing that many assumptions and hypotheses still need to be tested. There is thus an important research agenda in examining these different linkages in more detail and testing which ones are substantiated (e.g., in terms of their frequency of occurrence and population-level impact), as well as their main directionality and relative impact.

[6] Recent data shows that consumers worldwide tend to trust personal connections, like family and friends, more than any other source of food safety information; reliance on food safety authorities is particularly low in low- and lower-middle-income countries (73).

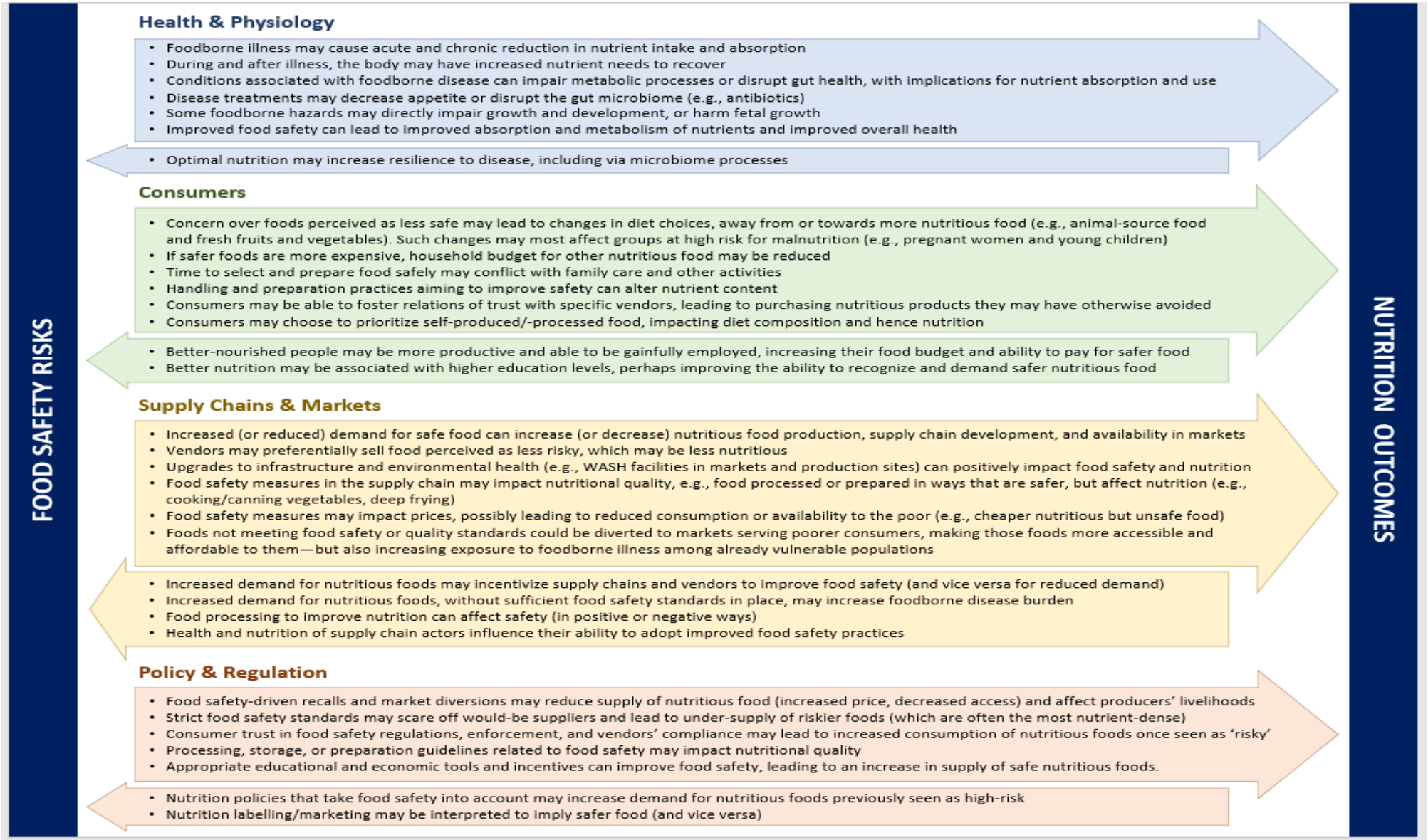


Figure 1. Bidirectional impact mechanisms between food safety and nutrition

Health and Physiology

The most obvious linkages between food safety and nutrition are physiological ones—which exist in addition to numerous other negative physiological and health consequences of foodborne disease (both chronic and acute). Eating unsafe food can lead to disease, which can be defined as adverse health impacts caused by an external agent (usually excluding injuries caused by physical agents such as glass or metal fragments). Foodborne disease can be caused by microbial, chemical, or radiological hazards. While several foodborne diseases do not affect nutrient intake or metabolism (e.g., ocular toxoplasmosis), many others do. Specifically:

- Many foodborne diseases involve acute gastrointestinal distress, including reduced appetite, vomiting, and/or diarrhea. Diarrhea and other acute gastrointestinal disease mechanisms can lead to decreased nutrient absorption, either acute or chronic.
- For foodborne as well as for other infections, during or following acute illness, the organism may have increased nutrient needs to recover.
- Foodborne exposure to some hazards can impair metabolic processes (acute or chronic) needed for the organism to properly utilize nutrients.
- Disease and sub-clinical chronic exposure to microbes may also disrupt the gut health and gut microbiome composition, with potential implications for longer-term nutrient absorption and use, as well as disruption of nutrient production by the gut microbial community.
- Pharmaceuticals used to treat foodborne infections may decrease appetite and disrupt the gut microbiome; they could also adversely impact nutrient intake, absorption, or metabolism.

In all these cases, the main impact on nutrition would be to increase the risk of undernutrition; temporary decreases in nutrient intake/absorption due to acute illness could temporarily reduce overweight/obesity but would likely have little long-term impact. Framed more positively, improved food safety can lead to improved absorption of nutrients and improve overall health.

It is important to note that, in addition to the impact of foodborne disease on nutrient intake or absorption, foodborne diseases and malnutrition can both contribute to longer-term developmental outcomes. For example, some foodborne toxins (e.g., aflatoxins) may directly harm growth, though this is disputed, and certain diseases (e.g., listeriosis, toxoplasmosis) during pregnancy may impair fetal growth and result in reduced birthweight.

At the same time, nutrition also has physiological impacts on foodborne disease burden: with optimal nutrition in the longer term, overall resilience to diseases (likely including foodborne infectious diseases) is enhanced, including via microbiome processes and gut health, which

impact the immune system. Hence, improving nutrition could be important in reducing foodborne disease.

Box 2. Highly Nutritious Foods, Staple Foods, and Foodborne Disease Risk

Many linkages between food safety and nutrition are amplified by the fact that many of the most nutrient-dense foods, which contribute to optimal nutrition, also pose higher food safety risks in some contexts. For example, animal-source foods such as meat, milk, and eggs are excellent sources of many vitamins and minerals, such as iron, zinc, and B vitamins, but are often vulnerable to contamination by pathogenic bacteria, protozoa, and helminths. Fresh fruits and vegetables are dense in vitamins (such as vitamins A and C) but may be contaminated with pathogens and pesticide residues. We refer to these as 'nutritious, high-risk foods.' In contrast, packaged, highly processed foods are typically thought to pose a lower safety risk (though they can also be unsafe, e.g., if poorly processed, packaged, or stored)—but tend to have a negative nutritional impact, increasing risk of overweight/obesity and diet-related NCDs. There are, of course, examples of less nutrient-dense foods that also pose food safety risks (e.g., aflatoxin in maize) and highly nutritious foods that are relatively low risk (e.g., tree nuts). Processed foods can also make important contributions to diets and improve food safety, representing a 'double win.' Food safety is not a safe/unsafe binary, but a continuum dependent on context. Overall, however, there is currently a correlation between nutrient-dense foods and food safety risk.

Main staple foods (e.g., rice, maize, wheat) are also essential parts of diets, central to ensuring food security, and their safety is also crucial. While they tend to be less vulnerable to contamination than the foods cited above, they are eaten in large quantities and by all members of a population, so even a relatively low level of contamination can have a large aggregate impact. Both these staple foods and the nutrient-dense foods named above, in both raw and processed forms, thus need to be considered when discussing linkages between food safety and nutrition and when viewing food systems through an integrated 'food safety and nutrition' lens.

Consumer Behaviour

Food safety and nutrition are also linked through consumer behavior. Unlike health and physiology, consumer behavior (and, as covered in the next section, the behavior of supply chain actors) is malleable: it is shaped, dominated, and modifiable by consumers' and supply chain actors' own perceptions. Consumers are regularly trading off concerns like safety with other characteristics, such as affordability, tradition, and convenience; these trade-offs vary in the short and long term and may depend on other constraints. These linkages should thus be seen as more dynamic and flexible that those noted above.

The most obvious pathway within this category is that fear of food being potentially unsafe can lead to the avoidance of nutritious food; this is particularly relevant because some of the most nutritious foods are also those that pose the greatest food safety risk (e.g., animal-source foods, fresh vegetables—see Box 1). This effect could be particularly important for groups at high risk of malnutrition, such as pregnant women and young children, who may be particularly vulnerable to foodborne disease (and, if aware of that fact, averse to taking such risks). Food fears can arise either directly, through illness of oneself or a personal contact, or through media coverage of foodborne disease outbreaks. The negative association with getting sick from food could also lead to a longtime aversion to that specific food, particularly if an exposure or event happened during a formative period for food preferences, such as childhood or adolescence. This is more likely to operate for acute illness, as the effects of chronic illness are not as perceivable to consumers (unless clearly communicated to them by a trusted source). This aversion can be weakened as it is difficult to associate a disease with its source, as traceability systems may be weak or non-existent, particularly in informal settings. It can also be weakened by a lack of purchasing power: poor consumers may be less able to afford to change their diets and food sources, weakening the extent to which food safety can influence their decisions. Avoidance of particular foods can lead to substitution with less nutritious ones.

Other behavioral linkages between food safety and nutrition are less obvious. For example:

- If consumers feel a need to pay more for safer food (i.e., they feel the lower-priced options are less safe), this will impact the relative amount of money they have available for other foods. This may shift diets towards the more affordable foods—which are sometimes of lower nutritional value. This is particularly relevant for increasing the risk of micronutrient deficiencies and overweight/obesity, as the cheapest foods are often main staples and/or highly processed packaged or fast/street foods, with limited micronutrient content but high in starches, sugars, and fats. In contrast, if the healthiest foods for optimal nutrition are also both affordable and perceived as safer, consumers do not face this constraint.
- Similarly, if consumers perceive many foods as potentially less safe, they may increase the amount of time they spend making food choices or preparing/cooking food to improve safety – this may explain why raw vegetables consumption is rare among low-

income populations in resource poor environments. This reduces the time available for other activities—including maintaining one's health, making a living, and/or caring for young children. And caregiver health, income, and practices are both important determinants for child nutrition—marking an indirect, cross-generational pathway that is likely to be particularly relevant for women, who often play a major role in purchasing and preparing food and caring for children.

- Handling, cooking, or processing practices aiming to improve safety may also directly alter nutrient content, as when foods are fermented, treated at high heat, dried, or preserved with added salt. These can have either positive or negative consequences for nutrition. For example, fermentation may decrease the nutritional value of vegetables, compared to their fresh form. However, fermentation can also increase nutrient value, e.g., by reducing the effect of phytates on nutrient bioavailability, or by supporting a healthy gut microbial community.
- Consumers in informal traditional markets who have general fears about potentially risky products may be able to foster relations of trust with specific vendors, thus encouraging them to purchase safe nutrient-dense products they may have otherwise avoided.
- Finally, consumers who mistrust the safety of the foods available in the market, and who can do so, may choose to prioritize self-produced or self-processed food. The effects of this on nutrition are ambiguous: if it leads to greater consumption of nutrient-dense, minimally processed foods, it could be a positive effect. If it leads to the opposite, or if it leads to consumers not consuming fortified foods that could meet nutrient gaps in their diets, it could have a negative effect on nutrition.

Nutrition may also impact food safety issues through consumer behavior. Better-nourished, healthier consumers are likely to have more physical and mental energy to spend in food procurement and preparation. As a result, they may be better able to make optimal choices regarding food safety. They may also be more economically productive and thus face fewer constraints to purchasing safer foods. Over the long term, better nutrition in early life is associated with higher cognitive levels and educational attainment; this may lead to better informed, more literate consumers, with the income and ability to recognize and demand safer foods. These 'nutrition to food safety' pathways relate to both acute and chronic illness but may be more important in the case of chronic illness or where acute illness is particularly frequent.

Supply Chains and Markets

Food safety and nutrition may also impact one another through dynamics within the supply chain and within markets. For example:

- If consumers demand that the safety of a food commodity is improved, market vendors may respond to this demand, either by improving the safety of a commodity at retail stage (i.e., with actions under their control), or by sourcing safer products.
- If this demand for safer foods were communicated to producers and processors, in a sustained way over time, the supply chain may have incentives to increasingly invest in these foods products, including in their safety. It may be important to distinguish demand for increased safety of a food (i.e., a feature of a product) from increased demand for a food that is already perceived as fairly safe (i.e., a product). In either case, increased supply chain investments may lead to greater availability, accessibility, quality, or affordability of the food product. The reverse would be true if fears of a food being less safe led to less demand or investment.
- Vendors may choose to sell the foods that they perceive as posing a lower food safety risk, without considering its nutrition value, to avoid the reputational or legal harm that could result from an adverse food safety event, such as a foodborne illness outbreak or recall of unsafe food. Over time, this could reduce the overall availability of highly nutritious foods for consumers. As these less-risky foods are likely to include shelf-stable staples and highly processed foods, this could also lead to their increased availability, accessibility, quality, or affordability. That could, in turn, increase consumption, with potentially negative effects on nutrition. For this pathway to operate, there would need to be at least a minimum awareness of relative food safety risks among vendors and either awareness among consumers or adequate regulation and enforcement. This mechanism is more likely to operate with foods causing acute illness, as that can be more clearly connected with a given food type or source than can chronic illness. This dynamic may also play out in the short-term following food safety scares or detected foodborne illness outbreaks, when either consumers may reduce their demand for the product involved in the outbreak, or vendor may choose to temporarily discontinue the product. This mechanism can be weakened by the fact that it can be difficult to associate a disease with its source.
- Upgrades to community market infrastructure and efforts to improve environmental health (e.g., installing improved WASH facilities in markets) can positively impact both food safety and nutrition.

Food safety concerns may also impact supply chain actions with implications for nutrition. Some potential mechanisms include:

- Storage and handling practices within a value chain, aimed to improve safety, could affect nutrient levels—positively or negatively.
- Vendors of ready-to-eat foods and processors may process or prepare foods (e.g., deep frying, salting) in ways that may be safer, but adversely affect nutritional content; on the other hand, other processes that are beneficial for food safety (e.g., fermentation) may have positive effects on nutrition.

- Food safety measures in the supply chain may increase prices, perhaps leading to reduced consumption of certain foods. Where the foods affected are highly nutritious, this would lead to an adverse effect on nutrition; where they are less nutritious, higher prices leading to lower consumption could have a positive impact on nutrition. In contrast, some food safety measures could be low-cost, or even lead to reduced costs in the long term (due to greater production efficiency or less waste), leading to lower prices and incentivizing greater consumption.
- Nutritious foods known to be contaminated could be diverted to markets serving poorer consumers, making those foods more accessible and affordable to them—but also less safe.
- Wider supply-and-demand dynamics could have price or availability affects: for example, increased demand for foods that are seen as safer could increase short-term prices (or decrease availability), affecting what consumers (particularly lower-income ones) can purchase; in the long run, however, the market would likely respond—perhaps even being able to offer such foods for lower prices, due to greater efficiencies of scale in production of larger volumes of foods under higher safety standards.

Considering linkages in the other direction:

- As mentioned above, increased demand for nutritious foods could incentivize supply chain actors to improve food safety (and vice versa for reduced demand). While in the short-term increased consumption of high-risk nutritious foods could lead to an increase in (primarily acute) foodborne disease burden and avoidance of certain foods, over time foodborne illnesses and outbreaks (primarily acute ones) may trigger increased awareness and demand for food safety, leading to longer-term and more widespread food safety controls.
- However, if increased demand for nutritious but more risky foods is not accompanied by improved food safety, this could increase the foodborne disease burden. If this burden is not reported or attributed (e.g., due to the limited capacity of a surveillance system, or due to the chronic nature of the foodborne disease in question hindering attribution), demand for food safety and resulting interventions are unlikely to be triggered.
- Food processing aimed at improving nutrition (e.g., fortification) could, if done poorly, have negative implications for the safety of the food in question; however, such processing for nutritional goals could offer an easy in-road to improve food safety at the same time (e.g., through installation of improved equipment and upgrading of processes).
- Finally, as with consumers, the health and nutrition of supply chain actors influences their energy and (in the long term) cognitive capacity/education, perhaps affecting

their ability to adopt improved practices related to food safety. This is likely to be more important in the case of chronic illness or where acute illness is particularly frequent.

Policy, Regulation, and Incentives

At the higher level of policy and regulation, there are numerous potential linkages between food safety and nutrition. Some policy and regulation impact mechanisms include:

- Safety-driven market recalls and diversion of food products (e.g., condemnation of products, or culls of live animals) could lead to food loss and waste as well as increased price and decreased access to the foods in question. These potential impact mechanisms are more likely to apply to formal food systems and the suppliers within them. Also, in many cases diverted product can be reprocessed to be made safe (e.g., sold cooked instead of raw) instead of destroyed, thus limiting losses. Recalls and market diversions may also affect the livelihoods of those whose product is rejected, with implications for their own and their families' food security and nutrition.
- In contrast, food safety certifications that allow producers and vendors to sell 'certified safe' products at a premium, or to access export markets, could improve livelihoods, with positive nutrition implications for producers and vendors.
- Strict food safety standards could also lead to reduced supply of the foods in question if producers decide to produce less of those products or switch to products that pose lower regulatory or financial hurdles (assuming such a switch is feasible and economically beneficial). Context-appropriate and achievable standards could, in contrast, incentivize greater supply of nutritious foods.
- Consumers' trust in food safety regulations, enforcement, and vendors' compliance could make them more willing to consume foods that were previously considered at higher risk, likely leading to improved dietary quality. This is more likely to operate in more formal and upper-middle-income country contexts, where national food safety systems are more developed and trust in them is higher.
- Processing, storage, or preparation guidelines put in place for food safety reasons, may also alter nutrient content for the better or worse.
- Beyond regulations and policies, appropriate educational and economic tools and incentives can also serve to improve food safety, leading to an increase in supply of nutritious foods.

Considering linkages from nutrition to food safety, nutrition-related policies and programmes that take food safety into account could increase demand for safer food, improving incentives for supply chains to provide it (and regulators to enforce appropriate safety standards). Certain nutrition-related policies could have negative impacts on food safety. For example, increasing the demand for a food (or a way of consuming a food, e.g., raw vegetables) that is currently high-risk could increase the foodborne disease burden in a population, unless

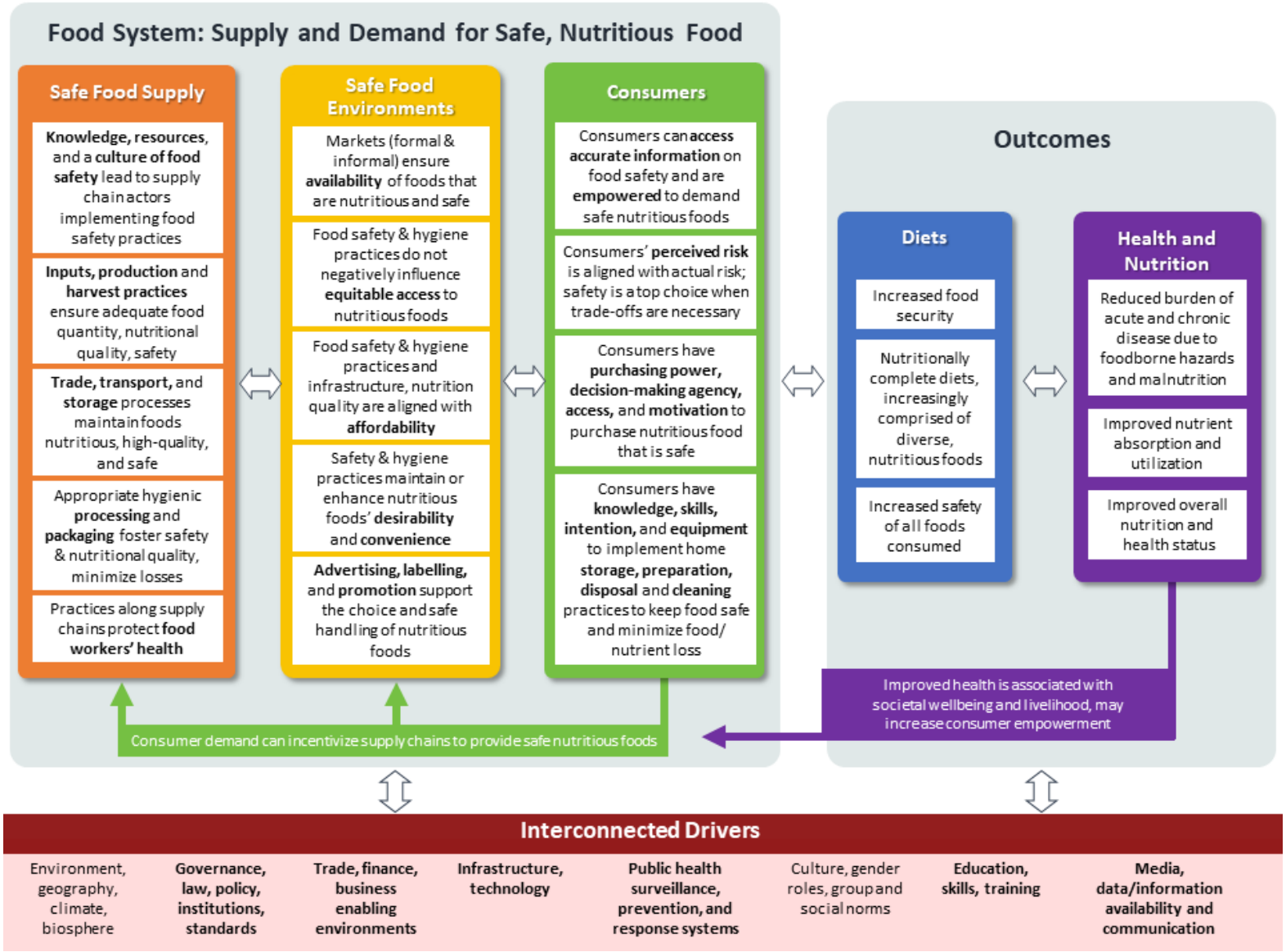
appropriate food safety measures are also put in place at the production and retail levels. In addition, mandated or voluntary nutrition labelling or certain types of marketing may be misinterpreted by consumers to imply safer food, when it in fact only relates to nutrient content and provides no information on foodborne hazards; this could lead to effects on the behavior of supply-chain actors and consumers (e.g., less careful cleaning and processing).

4.3. Food Safety and Nutrition within the Food System

These interlinkages between food safety and nutrition support taking a novel view of food systems through an integrated 'food safety and nutrition' lens. Figure 3 presents this lens, as applied to an existing food system model derived from the USAID Bureau for Resilience and Food Security Food Systems conceptual framework (41) and the HLPE framework (40), both included in the Appendix. The model food systems framework lens envisions how the food system appears when food safety and nutrition are considered explicitly throughout.

Food system frameworks, and our lens, seek to represent all actors and activities that play a role in production, processing, distribution, preparation, and consumption of food, directly or indirectly. The main components of the food system include food supply chains (from inputs to retail), food environments (places where consumers interact with food), and consumer behaviors, as well as external drivers (higher-level and more diffuse forces that influence the system). The food system influences diets—which influence human health and other development outcomes. 'Levers' or opportunities for action have also been included in some frameworks but are not here. While the food system is much more complex, Figure 3 necessarily amplifies certain food safety and nutrition aspects while providing less detail on the links and feedback mechanisms. The Figure also does not provide an exhaustive listing of the elements of the food supply chain, food environment, consumer behaviors, and outcomes.

From the perspective of human health, the goal of the food system is to provide safe, healthy, balanced diets that provide sufficient amounts of necessary nutrients to sustain health, and do not contain unsafe levels of contaminants that can cause foodborne illness. This, in turn, can lead to positive health, developmental, and societal outcomes such as improved health, wellbeing, optimal cognitive capacity, and earning potential. The food system seen through our lens provides aspirational goals for these outcomes and shows the different food system components as directional—i.e., they are framed in terms of positive actions and outputs, as opposed to neutral components. While most food system frameworks use neutral, nondirectional terms, we choose this aspirational, positive-outcome-oriented framing to highlight the potential for positive action in support of safe and nutritious diets throughout the food system. This does not, mean, however, that negative outputs, outcomes, and impacts are not possible: Figure 3 could be negatively framed to show the potential harms related to food safety and nutrition throughout the food system.



Bold: drivers more likely to be modifiable by interventions.

Figure 2. The food system through an integrated "food safety and nutrition" lens

Figure 3, and our discussion here, focus the scope and system boundaries on outcomes and processes related to health. However, other outcomes, such as improved livelihoods, reduced environmental impacts, greater biodiversity, changes in gender dynamics, and increased trade in both informal and formal markets, also emerge from food systems. Food systems should be seen not only from the perspective of human health but also of One Health (integrating human, animal, and environmental health) as well as Planetary Health (more broadly encompassing ecosystem health and resilience). The One Health perspective highlights and accounts for connections and feedback loops that clearly impact food safety and human health, and that could be missed if taking a narrower perspective. Zoonotic pathogens, which cause the large majority of foodborne disease burden worldwide, are an example of an issue that can be effectively tackled only with a One Health integrated plan of action. These additional lenses could be added, though they are not our focus here (see Section 4.5 for a discussion of certain additional outcomes).

Likewise, the boundaries of the food system lens were set, consistently with the frameworks used as a reference, to encompass activities that involve food directly. Other relevant processes, such as production of agricultural processing equipment, waste management, and water quality and treatment are not explicitly included, although many are related to or implicitly included in the drivers.

As shown in Figure 3, this new lens makes it clear that nutrition and food safety are intricately linked throughout each of the food system components. Within the food supply chain[7], primary production inputs and production and harvest practices, as well as processing, transport, storage, and trade processes, must ensure that nutritious foods are produced in sufficient amounts and with adequate controls on their quality and safety—and that both safety and nutrition are retained throughout the post-harvest stages. Processing and packaging are often important to improve or retain nutritional quality—while also ensuring safety and reducing loss. At this stage, it is essential to ensure that nutrition-related processes (e.g., fortification) maintain or enhance safety (as opposed to, for example, introducing contaminants or toxicity) and that safety-related processes (e.g., canning) do not reduce the content of beneficial nutrients (e.g., temperature-sensitive vitamins) or increase that of potentially harmful ones (e.g., sodium).

Once safe and nutritious foods reach markets, they must be maintained until they reach consumers. Similarly, to other steps in the supply chain, this means food markets must implement food storage, preparation, and disposal practices and infrastructure (including sufficient cleaning and cold storage) to keep food safe and minimize food and nutrient loss. Within the food environment, nutritious and safe foods must be available, affordable, and accessible—and safety and/or nutrition considerations must be perceived as an affordable

[7] In line with existing frameworks (40), the term "supply chain" is used here to refer to the steps from primary production up to and including retail. It is distinguished from the external food environment, wherein consumers acquire food, and the consumer stage, which includes consumer choices and behaviors.

value addition, not negatively influence their accessibility or affordability (or, alternatively, consumers must be willing to pay a premium for safety, possibly in association with other desirable features of the food). Storage and handling practices (e.g., sorting, cleaning, cutting, and refreshing food, vendors' displays, and cooking in the case of food sold ready-to-eat) should maintain or enhance safety and nutrient content as well as the foods' desirability and convenience. In addition, advertising, labelling, and promotion information within the food environment must support the choice *and proper handling* of safe, nutritious foods—such as by giving clear information on safety standards, safe cooking practices, and nutrient content.

External food environments include both formal retail outlets, such as supermarkets, and informal traditional marketplaces, such as open-air wet markets. It is common for at least part of the population in LMICs to acquire food from both, likely for different reasons. Hence, the different food safety practices adopted in each setting and the interplay between formal and informal markets should be kept in mind when considering food safety and consumer choices—bearing in mind that food from formal markets is not necessarily safer.

At the consumer level, consumers must have the information, purchasing power (i.e., income or social support), decision-making power (e.g., based on gender and social norms), access, and motivation to purchase safe nutritious food. When consumers are making choices within the market, it is essential that the choice of a nutritious food does not conflict with the choice of a safe food (and vice versa). Potential trade-offs with food safety are a particular concern for factors such as price and affordability, convenience (e.g., longer shelf life, easier preparation), desirability, and other characteristics. In addition, consumers (and other supply chain actors) usually cannot easily identify whether a particular food is unsafe, as contamination is often not perceivable via sight or smell. The relative importance of food safety among desired food features, and how consumers make these trade-off decisions, is still a significant knowledge gap.

Once consumers bring food home, they must either consume the food (if already ready-to-eat) quickly or clean, separate, and cool the food to keep it safe and minimize food and nutrient loss. Providing information on safe food handling is important to engage and inform consumers to do their part to keep food they have purchased safe and nutritious. Fundamental to ensuring both nutrition and food safety, consumers must be able to access accurate information (e.g., the safety record of vendors in their local markets, the nutrient content of processed foods, best food safety practices) and be empowered to identify and demand safe nutritious foods.

With these processes in place, positive outcomes can be achieved in the form of improved diets meeting the three goals outlined earlier in this section. This would entail an increased proportion of the diet being comprised of safe and nutritious foods, including both staples and nutrient-dense foods such as vegetables, and a decreased proportion of the diet being comprised of foods that are either unsafe or not nutritious. The result is a varied, nutritionally complete diet in sufficient quantity. When such diets are consumed regularly, this will help

lead to achievement of the ultimate outcomes: improved nutrient absorption and utilization, leading to lower levels of undernutrition and micronutrient deficiency, and reduced disease, both acute and chronic, due to foodborne hazards and malnutrition. This, in turn, can lead to other positive outcomes that support overall development goals, such as improved overall health, wellbeing, cognitive capacity, and earning potential, as well as improved mental and physical development in children. The safety and adequate nutrient content of the food supply are equally integral to achieving these positive outcomes.

4.4. Feedback loops, drivers, and levers

Feedback loops

Consumer demand feedback loop. In bringing a food safety and nutrition lens to the food system, it becomes clear that several relevant feedback mechanisms are involved, which are central to indicating where to intervene for maximum effect. Of high importance among these is consumer communication to the actors of the food supply chain and the food environment. Consumer demand for safe, nutritious food incentivizes supply chain actors to provide it—that is, to prioritize more nutritious foods; to invest in the processes to keep them safe throughout their supply chain; and to find ways to signal that safety to consumers. Without this incentive, there is no 'carrot' to motivate the choices of food supply chain actors in the absence of a 'stick' in the form of regulation and sufficient enforcement (rare in many LMIC informal market contexts). If one of these signals is stronger than the other, e.g., safe food is seen by consumers as a more essential demand than nutritious food, this will steer the food supply chain actors in one direction more than the other—with implications for diets and health/nutrition outcomes. Consumers' preferences also have an influence; for example, in many regions, consumer prefer to purchase meat from wet markets despite the potential risk from such markets, which are frequently subject to less regulation.

Consumer demand for both safe and nutritious food is a result of consumers' awareness, which depends on other factors, such as risk communication, empowerment, and access to purchasing and decision-making power. Consumer feedback can take a positive form (e.g., a food product, vendor, or market being preferred by consumers), leading to higher sales. It can also take a negative form, such as if consumers (rightly or in error) believe food from a vendor has caused disease or has not met their quality expectations, they can not only stop purchasing from that vendor but also communicate their negative assessment to other consumers, jeopardizing the vendor's reputation. If consumers cannot identify safe food or cannot trace adverse health outcomes to a food, this feedback loop may be very weak. In addition, the decision-making power of consumers can only be fully exercised if they have limited power or there is sufficient choice; for example, food-insecure settings and food deserts do not allow for unfettered decision making. As noted in Section 4.1, this feedback loop may be stronger for certain types of food systems/sectors: in modern, formal food

systems, traceability is often better and consumers may have more treatment options and recourse to report; however, in more informal food systems, consumers more often have personal relationships with vendors that could allow for more direct communication and pressure. Because the effects are more readily apparent, this feedback loop may also be more functional for acute, as opposed to chronic, foodborne illness.

More broadly, consumers as citizens, or as individuals and groups with creative agency, play a role in shaping the food system and food system transformations; while this is not explicitly shown in the diagram in the interest of simplicity, leadership and policy are influenced by consumers as citizens (at least within democratic states); citizens also influence other drivers (e.g., social norms) in less direct and more long-term ways.

Another important aspect that drives awareness is the linkage between appropriate advertising, labelling, and promotion within the food environment to consumer access to accurate information: consumers who can access some viable information on food safety and/or nutrition will be more empowered to demand more of it or to seek it out where it exists.

Societal wellbeing and livelihood feedback loop. Improved health and nutrition and overall wellbeing of a population can also impact consumers' choices and their participation in positively shaping the food system: as health and nutritional status improve, consumers may have more energy and capacity (perhaps including greater purchasing power, due to increased work productivity) to make optimal choices related to food safety and nutrition. Illness and malnutrition, in contrast, can sap both mental and physical energy for work and decision-making, potentially feeding a negative cycle. While there is limited direct information of such linkages occurring, they are plausible. For example, there is evidence of both acute and long-term secondary effects of foodborne disease in terms of fatigue, lost productivity, or reduced mobility, which can impact an individual's ability to participate in many civil society activities. These feedback loops echo certain of the more detailed pathways linking food safety and nutrition discussed in Section 4.2: it is these pathways that form the bi-directional mechanisms through which feedbacks at the system level occur.

Drivers

The bottom of Figure 3 depicts several categories of food system drivers (and of health and nutrition, through domains other than the food system)—i.e., external forces that (positively or negatively) affect, and can be affected by, the food system. These are drawn from prior frameworks (40,41) and are not chosen to be exhaustive but rather to highlight the *main* drivers of the food system in terms of its ability to enable consumers to access safe and nutritious foods. Drivers do not act in isolation but rather are interconnected and interacting (for example, policy influences trade, which can influence the business environment and technology). Some drivers may also affect health outcomes directly. In Figure 3, we use only a general bidirectional arrow for simplicity, to highlight overall connections to the food system

and the considered outcomes, but we recognize the complexity not represented here. They include a mix of contextual factors that shape food system characteristics as well as factors that can directly facilitate change. They also range from those that are more amenable to intervention to those that are less flexible and can practically be considered as fixed constraints; we discuss these two groups separately here. In Figure 3, these more modifiable, potential key actionable drivers of food safety improvements are shown in bold text.

Contextual and Less Flexible Drivers

Environment, geography, and climate are important drivers of sustainable food systems—but difficult to modify, at least in the short term. They define the types of foods that can be produced and influence the risk of food contamination. Geography of a region, for instance, determines what food can be produced and where; water available for producing food; feasibility of distancing food animals from wildlife; potential spread of hazards through the landscape; and the feasibility of food preservation. Weather and climate patterns significantly affect food safety, in addition to determining what food can be produced and hence risks due to food-specific production and consumption practices. For example, rainfall and other weather factors have been linked to increased bacterial contamination in produce fields (74,75). Increased temperature or humidity can in some cases lead to faster growth of bacteria in food, leading (in the absence of control measures) to increased risk of foodborne diseases. Climate shocks and climate change can also drive disruptions to the food supply chain and exacerbate ill health and malnutrition. Climate change is estimated to increase food contamination by foodborne pathogens and chemical hazards and shift such pathogens' occurrence patterns (76–79). Severe storms can result in water and food contamination as well as disruption of the transport, or storage conditions needed to ensure safety (80).

However, some aspects of the environment and natural resources are modifiable. For instance, while overall rainfall and water availability may be a fixed constraint, the construction of water management infrastructure such as dams, ponds, and aqueducts can make water available where and when needed. Baseline water quality and the ability to treat water can affect the quality of water used for food production. The development of sanitation and waste management systems affects environmental contamination, including of preharvest agricultural environments. Clear-cutting forests can lead to destructive runoff and landslides that could be avoided. The extent to which natural resources can be modified and managed depends on the level of technology and skills available, among other factors.

Within the area of culture and social norms, there are numerous important drivers; while all of these are modifiable at a societal level and in the long term, they are hard to shift, particularly in the short term. These include food preferences and food cultures—such as how a given food is expected to be served (e.g., a preference for raw or cooked vegetables, or for certain cuts of meat or offal). They also include social norms about how people acquire food and how they interact with the markets and vendors that bring it to them: in settings where people are accustomed to close interpersonal interaction with a known vendor, for example,

food safety and nutritional content may be directly communicated. There are also social norms about handwashing and cleanliness that may shape food safety. Finally, gender norms and roles are essential drivers of the food system (and of health and nutrition in their own right). Gender norms and roles can shape who plays what role within the food supply chain, and their access to technology and financing, within implications for food safety (81). Gender norms can also influence decisions around who acquires and prepares food, and how much purchasing and decision-making power they have to do that—thereby profoundly influencing access to nutritious, safe food and the extent to which consumer demand can drive a safer food supply. Finally, gender norms influence consumers' access to information and their empowerment when it comes to using it to demand safe, nutritious foods.

Modifiable Drivers & Key Facilitators of Change

Governance, policy, institutions, and standards and regulatory guidelines are essential modifiable drivers of the food system's ability to deliver safe and nutritious foods. In particular, food safety regulations and their enforcement, if successful in ensuring food safety, can increase consumer trust in nutritious food and increase its consumption. In some situations, non-compliance with food safety requirements would lead food products to be discarded or reprocessed, for example following a violation or a recall. Such events can be costly for the producer, in particular small producers, but are usually small-scale and do not lead to reduced availability of a product category (i.e., to food security issues). However, some critics of specific food safety regulations have highlighted how the costs and efforts of compliance with regulatory requirements (e.g., the need to produce extensive documentation, acquire certifications, or perform tests) can be prohibitive for small businesses and hence hinder their survival and thriving, which in turn could lead to lower food availability. While there is little or no evidence that food safety regulations have been the cause of business failures, offsetting the cost of compliance (e.g., via extension services or requirements tailored to business scale), is an important consideration in policy design, food safety and otherwise. In addition, the interaction and different standards applied in formal and informal traditional markets can have both food safety and nutrition implications; for example, food not meeting food safety standards may be rejected by formal food retailers and redirected into informal markets where low-income people shop. This could lead to increased foodborne exposure in these groups. In LMICs, attention to promoting food safety interventions and regulations commensurate with the capacity of small businesses to sustainably implement them is key, both for successful food safety outcomes and to ensure food and nutrition security. In general, food safety concerns or regulations are not a significant cause of food loss or waste relative to other causes. However, at the retail stage food "sell by" labels, which may be partially directed to food safety, may contribute to food waste (82).

For nutrition, governance, institutions, standards or guidelines, and policy help shape outcomes such as nutrition labelling requirements, the structure of school meal and food aid

programs, and food fortification. Perhaps most importantly, for the system to operate optimally in achieving dual goals of safe food and nutritious food, such policies and regulations must be aligned—with food safety-related regulations considering their potential effects on nutrition and vice-versa.

Within trade, finance, and income, numerous additional drivers operate, most of which are modifiable and important levers of change. Trade flows and regulations can influence local regulations and enforcement of food safety standards, as well as those for nutrition labelling and fortification, and a country's supply of safe, nutritious food. In some countries, for example, the safest foods are exported to higher-income countries. In addition, instances of sending out-of-date food to LMICs for sale have raised concerns of unfair trade practices. As with many other drivers, trade can also be influenced by food safety: unsafe food can act as a barrier to trade, whereas a reputation for safe food can be a facilitator of trade. Financing systems and availability strongly affect how farmers and food-related businesses can function and grow, including in the creation of more nutritious or safer products (83). The incomes shaped by these economic drivers influence consumers ability to demand and purchase safe, nutritious foods—as well as services like improved sanitation and food disposal, which impact their ability to keep food safety within the household.

Infrastructure and technology play a key role in enabling the production and distribution, and access to safe, nutritious foods. For example, roads and cold chain and shipping technologies help move nutritious foods more quickly and safely, reducing nutrient loss and contamination. Water, sanitation, and hygiene infrastructure make it easier for both food supply chain actors and consumers to keep foods free from contamination; they also influence health outcomes independent of the food system, through broader hygiene and sanitation practices and influencing exposure to disease. Electricity is an important enabler of refrigeration and other technologies central to keeping food safe—and often absent or unreliable in remote LMIC settings. Technologies can be used to increase or retain nutrient content of foods, enhance shelf life, and improve safety—as well as to improve their desirability and convenience. Technologies for improving traceability throughout supply chains can be particularly important for preventing and addressing contamination of foods.

Media (including news media, social media, and entertainment) and communication also play a role in shaping food systems with regard to food safety. Media largely shape the ways in which people think about food safety, and how they perceive it as a threat/risk relative to others within their lives. This can perpetuate false information and food scares—but it can also be leveraged as a positive tool for risk communication and for motivating action through compelling communication.

Public health surveillance, prevention, and response systems play an important role in shaping population awareness about food safety and nutrition, in tracking foodborne disease outbreaks, and in treating foodborne illness and malnutrition. This category of drivers is somewhat unique in that it directly influences health outcomes independent of the food

system—e.g., by facilitating access to treatment for foodborne illness. They are modifiable but tend to affect change not on their own but rather in how they shape governance and policy. Effective surveillance systems can also play a role in citizen perceptions of food safety and the effectiveness of government systems in protecting citizens' health and wellbeing. Media often carry stories about public health events, such as foodborne illness outbreaks, and these can influence how citizens act as consumers and value chain actors, and in pressuring government for action. Well-functioning surveillance and response systems can provide the information needed to motivate concern and action. As with other aspects of policy, aligning these goals across food safety and nutrition is important to drive the food system to meet both goals.

Levers

While the USAID RFS food systems framework (41) explicitly includes investment levers, these are not included in this perspective on frameworks (in line with the HLPE framework, which does not separate these out (40)). However, most of the levers identified by RFS are equally applicable here and can be used in specific ways to achieve the twin goals of safe food and nutritious food. Research and technology development, for example, can focus on understanding consumer and vendor behavior as it relates to food safety and nutrition (including how these goals are traded-off) or in developing technologies to improve food safety or increase nutrient content. Education and behavior change could be used to improve awareness (among both consumers and supply chain actors) of food safety and nutrition and of best practices to keep nutritious foods safe. Improving information access and connectivity could help to spread such information and support better supply chain traceability. Indeed, most of the 'drivers' mentioned above can also serve as levers for intervention.

4.5. Other outcomes

Simplicity is a necessary characteristic of a useable framework, so in the interest of retaining a targeted focus on food safety and nutrition, certain other key outcomes and goals of the food system were omitted from this examination of the food system through a food safety and nutrition lens. These include, most notably, environmental sustainability, resilience, and income and livelihoods; also omitted are animal health and welfare and issues related to human rights, equity, and welfare beyond health and nutrition. This omission should not be seen to indicate that these outcomes are not important, nor that these outcomes (e.g., sustainability or livelihoods) have no interactions with food safety and nutrition. Rather, each of these outcomes can be used as an additional lens for viewing this framework and its implications.

For example, when considering environmental sustainability as an *outcome* of the food system (as compared to environmental drivers of the food system, which are discussed above), certain tradeoffs and win-wins between actions to improve food safety/nutrition and those to improve environmental sustainability can be seen. Improving food safety along the

supply chain, for example, can avoid the need to cull animals or recall or destroy food, leading to a reduction in food loss and waste—which places a major burden on environmental sustainability. Increased use of cold chain technologies could increase the supply of nutritious, safe foods—but also increase energy use, unless green energy is used. Improved processing and packaging can be used to enhance safety and/or nutrient content but could have negative environmental affects, depending on the processes and packaging used. Advertising, promotion, and labelling, as well as informational campaigns, offer an opportunity to share information about food's environmental footprint (in addition to its safety and nutrient content), but there may be a limit to how many of these goals food producers or consumers can target, requiring them to trade off amongst them. Within livelihoods, aiming to improve food safety and increase the supply of nutritious foods can open up new income-earning opportunities throughout the supply chain and can improve the quality of workers' livelihoods, perhaps reducing their exposure to illness—but may also harm certain actors, such as producers who do not have the resources to comply with new food safety regulations.

5. USE OF THIS LENS AND IMPLICATIONS FOR POLICY AND PROGRAMMING

We envision that this nutrition- and food safety-centered lens on food systems can be used by different types of stakeholders to guide various types of decisions and action. For policymakers and donors, it can help to identify levers among the food system drivers and envision how shifting those (e.g., by implementing new regulations, or supporting a particular program) might influence food safety as well as nutrition. For those designing and implementing development programs, the detailed linkages between food safety and nutrition (Figure 2) and those among supply chains, food environments, and consumers will be of interest to identify new programmatic approaches and areas for intervening. For both groups, the lens presented here can be used, first and foremost, to identify and enhance synergies as well as to identify and mitigate tradeoffs. In the former category, this would include identifying positive feedbacks between food safety and nutrition and using them to amplify intervention impacts by creating multiplier effects—such as using training, technology, or legislation that can enhance both the nutritional content of food products and the safety of food processing. In the latter category, this would include identifying and avoiding or mitigating negative feedback loops—such as promoting food safety standards that inadvertently discourage the production or sale of highly nutritious foods. Providing the bidirectional linkages between food safety and nutrition gives policymakers and program designers a tool to consider how their actions affect both, so they can avoid actions that aim to positively impact one—but might negatively affect the other. Synergies and tradeoffs between different components of the food system can also be highlighted for leverage—such as communicating on risk and educating and empowering consumers to demand safer food, which could in turn increase supply and lead to greater awareness of food safety.

For researchers, we expect this lens to be useful for highlighting potential new areas for exploring, such as probing the assumptions and pathways within Figure 2 that have less supporting evidence or gauging the scale of the feedback loops across the different parts of Figure 3. Both researchers and those involved in monitoring and evaluation of development programs and policies can use this new lens to identify indicators that capture joint impacts on food safety and on nutrition and to assess progress to achieving both goals simultaneously.

For all stakeholders, we expect that the use of this lens can improve discussion among groups that do not often interact, such as experts in food safety and those in public health nutrition. By beginning with a shared foundation, within which the end goals of each group are made equally paramount, a solid path for fruitful discussion will be laid.

6. CONCLUSION

Achieving optimal human health and wellbeing requires people to be both well-nourished and free from foodborne disease. The food system that can achieve these dual goals will deliver healthy, balanced diets comprised of essential staples and nutrient-dense foods that provide sufficient amounts of necessary nutrients—without containing food safety hazards. Supporting healthy food systems requires recognizing the numerous interlinkages between food safety and nutrition, the feedback mechanisms between them, and the drivers and levers that affect them both.

At such, this report has presented a new lens for viewing the food system in a way that more explicitly recognizes the connections between food safety and nutrition. We first presented a set of impact mechanisms through which food safety and nutrition can impact one another, grouped into the domains of health and physiology, consumer behavior, supply chains and markets, and policy and regulation. These linkages show the direct pathways through which foodborne diseases and food safety processes may impact nutrition outcomes—and vice versa. Based on these underlying linkages we then crafted a new lens onto existing food systems frameworks that highlights the role of food safety and the connections between food safety and nutrition within a food system. Within the different elements of a food system (food supply chains, food environments, and consumer behavior), food safety and nutrition are explicitly integrated, highlighting that achieving optimal health and wellbeing requires paying attention to both goals when considering actions and interventions throughout the food system. There are also several positive and negative feedback loops that operate to foster (or inhibit) the supply and consumption of safer, more nutritious food. Both safety and nutrition are shown to be influenced by shared external drivers, which suggest levers for action. The analysis was grounded in an understanding of both food safety and nutritiousness as being a continuum, not a binary concept, and of food systems as being diverse and comprised of both formal and informal food supply chains and food environments.

This perspective on the food system is programmatically broad and non-technical, intended to cater to a range of stakeholders who could use a roadmap to support their decision-making. For policymakers and donors, it can help identify areas for high-level intervention to influence food safety and nutrition. For program designers and implementers, it can be used to identify new programmatic approaches and areas for intervention, while identifying synergies and tradeoffs between levers in their joint impacts on food safety and nutrition. For researchers and research funders, the resources and considerations presented here can help highlight areas where more evidence is needed, illustrate how processes in different domains are connected, and identify indicators that can track joint impacts on food safety and nutrition. For all stakeholders, a lens that allows for interpreting the food system with both nutrition and food safety front of mind can create a common foundation for dialogue, based on shared goals.

Box 3. Recommendations for Intervention Design and Future Studies under EatSafe

The joint food safety and nutrition lens on food systems presented here is intended as both the foundation for developing global guidance, and for practical applications in individual countries. As such, it is highly relevant to EatSafe programming:

- EatSafe has the opportunity to be a model program for designing interventions based on both food safety and nutrition goals. Keeping a strong focus on nutritious foods will help leverage this opportunity.
- The design of food safety interventions should consider potential nutrition impacts, e.g., how an intervention may modify perceptions around a food and effect its consumption, affect prices or availability, etc., as well as changes in actual risk.
- Impact mechanisms linking food safety and nutrition vary over time with the level of maturity of food systems, and between formal and informal sectors. In the informal sector, consumer demand and preferences, supply chain infrastructure, market and supply chain power dynamics, and overall population health levels could play a key role in determining the success of an intervention.
- A better understanding of foodborne risk perceptions and other factors affecting consumer choices are needed to predict joint food safety-nutrition impacts. EatSafe is designed to fill some key gaps in this area.
- When discussing desired or anticipated EatSafe program impacts, potential nutrition impacts of food safety interventions should be explicitly anticipated and discussed, including the impact of uncertainty or evidence gaps.
- The food safety and nutrition lens developed here, and any further customization, can serve as a road map to pinpoint where a project sits within a food system, to map direct and indirect connections with other system components, and to estimate impact pathways of interventions including trade-offs.
- Indicators: while EatSafe will not directly track nutrition outcomes, it will propose and test a set of food safety indicators appropriate for Feed the Future efforts and other joint food safety-nutrition programs in LMICs.
- As both food safety and nutrition outcomes develop over years or decades, relatively short interventions (e.g., 1-2 years) may not be able to detect significant changes in the ultimate health outcomes. Impact assessment should focus on intermediate outcomes with known or likely links to health and nutrition outcomes. EatSafe might also identify promising interventions with established impact pathways but requiring longer impact timeframes.
- Coordination between programs in nutrition and food safety is needed, including an effort to share information across projects to better evaluate food safety and nutrition progress jointly.

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APPENDIX I - FOOD SYSTEM FRAMEWORK DIAGRAMS

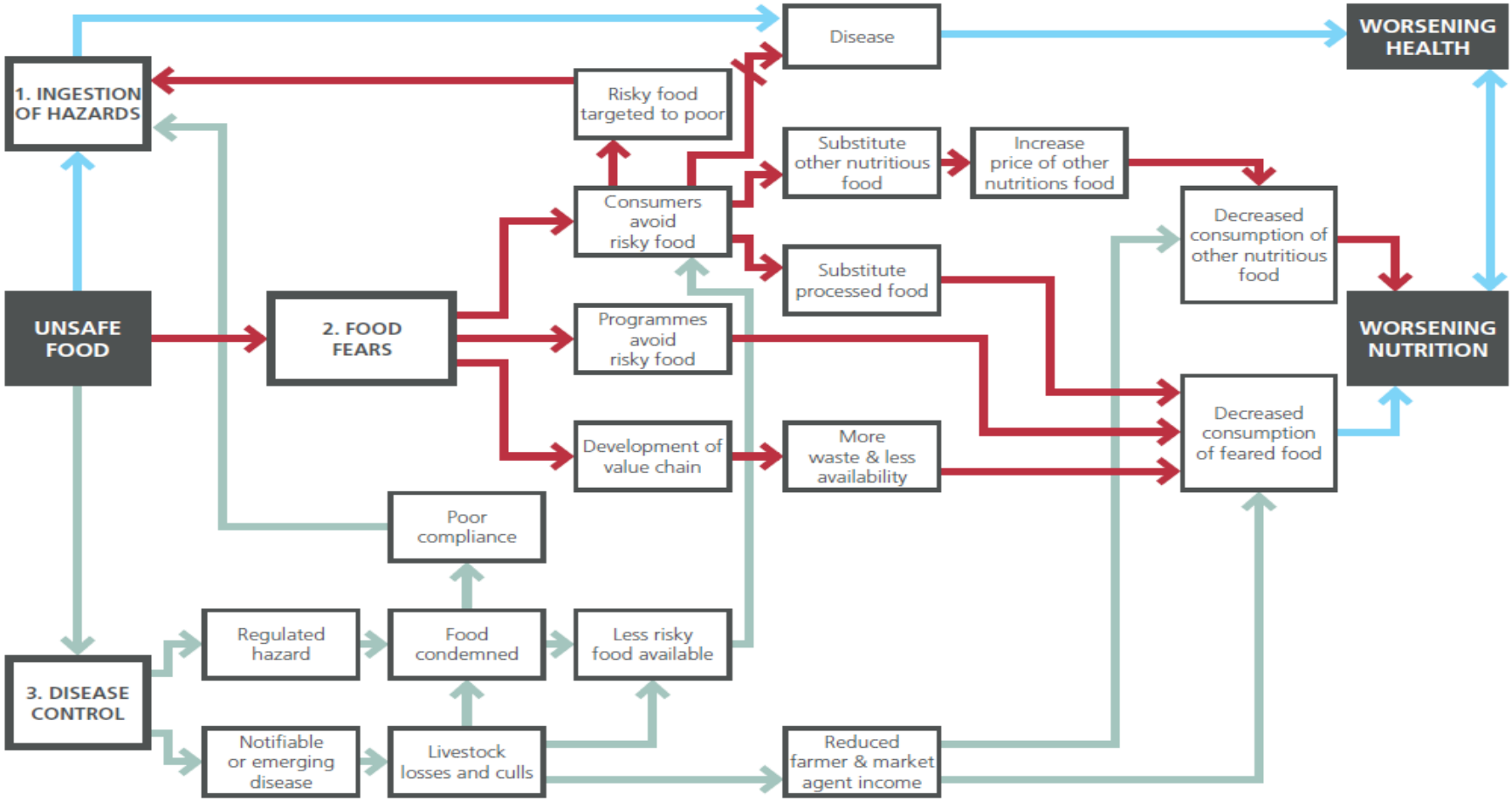

Figure 3. Pathways through which unsafe food could lead to worse nutrition and health. Reproduced from (38)

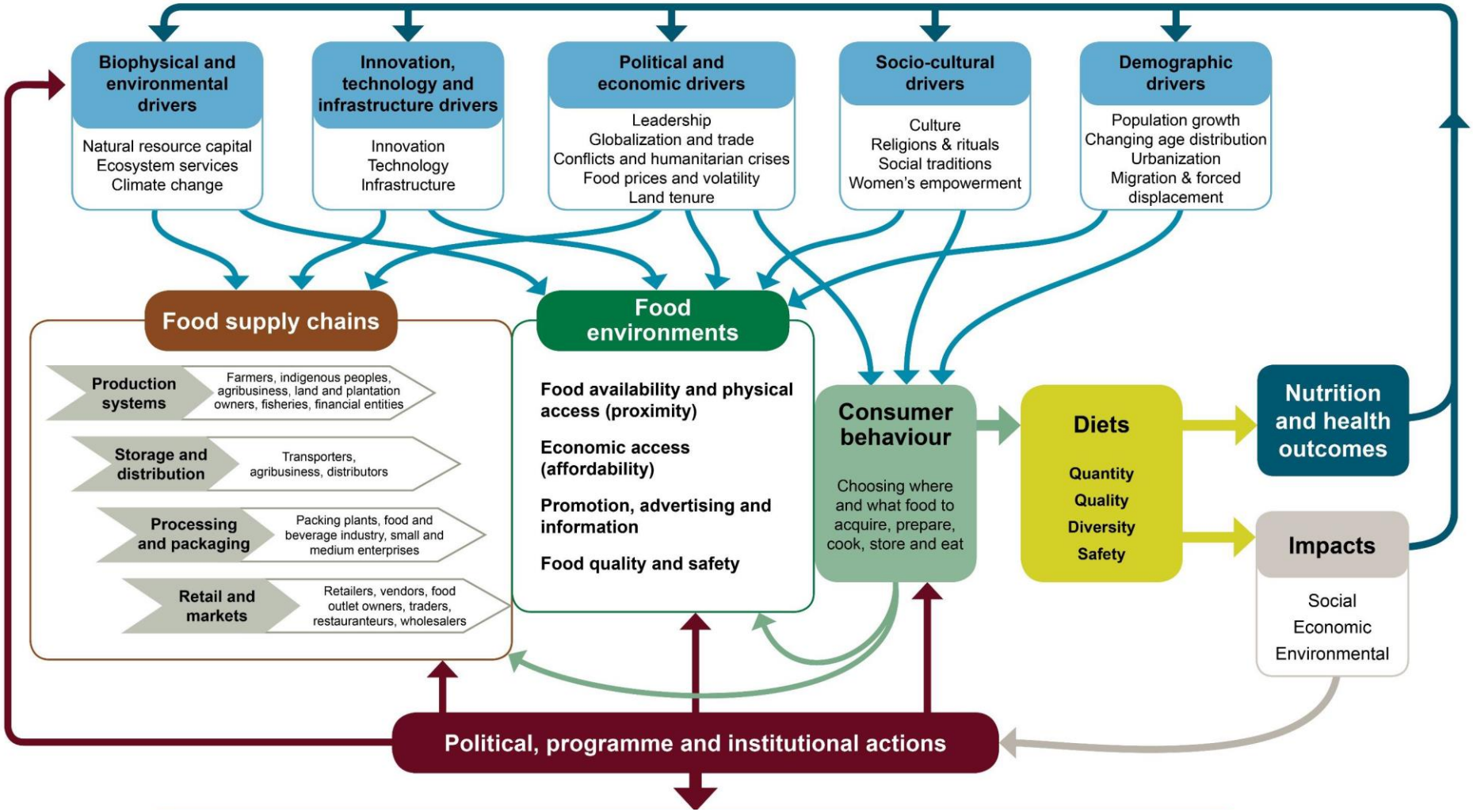

Figure 4. High-level Panel of Experts Food Systems Framework. Source: (40)

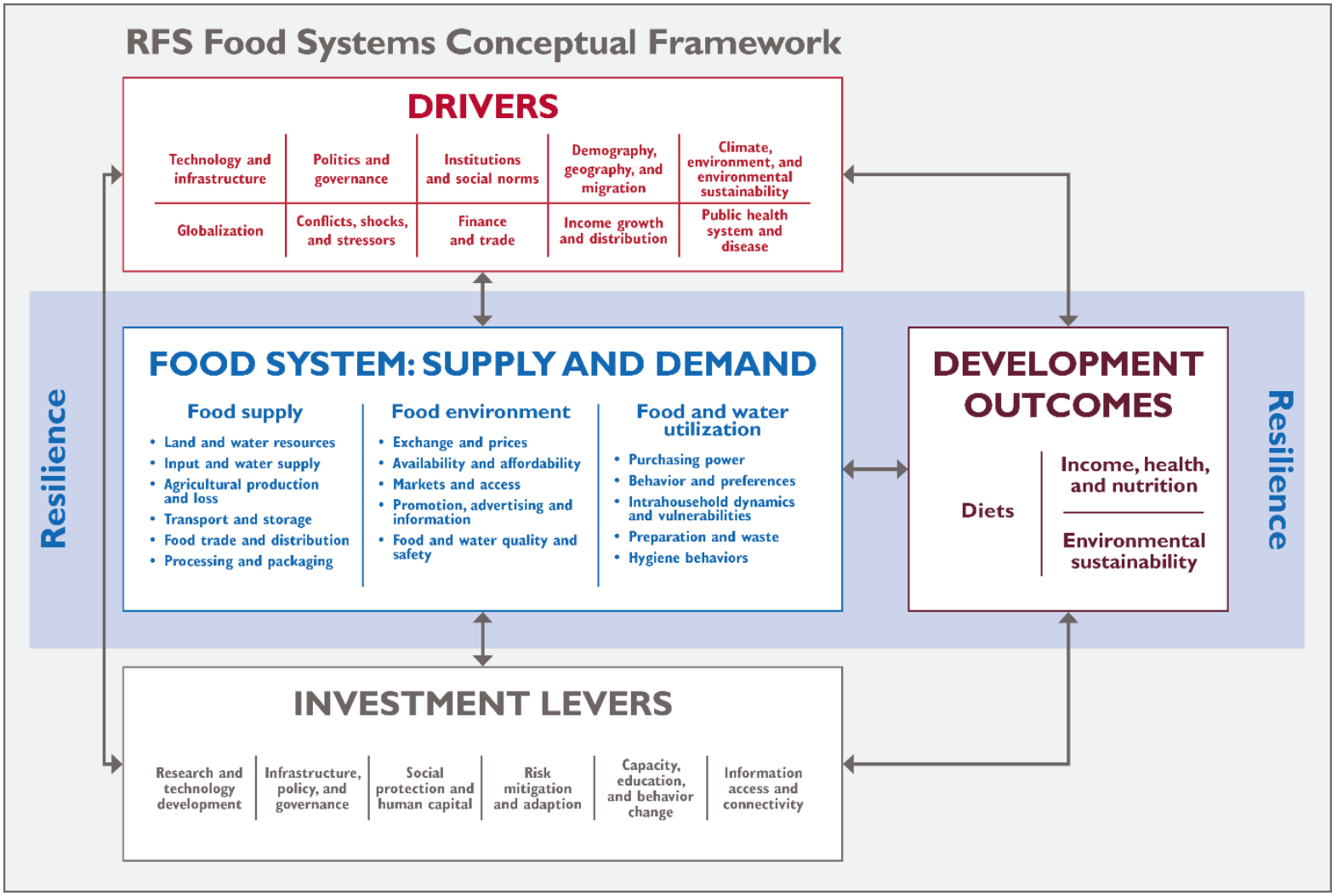

Figure 5. USAID Bureau for Resilience and Food Security Conceptual Framework. Source: (41)

APPENDIX II. EXPERT WORKSHOP SUMMARY

1. STRUCTURE AND PURPOSE OF THE WORKSHOP

This appendix summarizes the expert consultation ("workshop") organized by GAIN on October 22nd and 23rd, 2020, as part of the development of the new lens on food systems presented in the main report. The workshop was held virtually via a videoconference. Participants are listed in the Acknowledgements on page 4 of this report.

This expert consultation presented research and synthesis conducted by GAIN thus far and elicited expert input on the foundational components of the new perspective on food systems that links food safety and nutrition. The consultation aimed to ensure that a broad set of stakeholder perspectives, expertise, and needs were taken into account in refining this lens on food systems frameworks.

More than 25 experts joined the discussion, including several USAID representatives. The experts group covers a broad range of expertise in food safety, nutrition, and food systems, while also representing both "evidence generators" (e.g., researchers, technical experts) and "evidence users" (e.g., program officers and decision makers). All participants had worked on one or multiple areas relevant to food systems, nutrition, and food safety, in different world regions. In addition, the session served to foster connections among experts for future collaborations.

The consultation took place over two days, for a total of six hours. On Day 1, experts had the opportunity to comment on the importance of impact mechanisms linking food safety and nutrition, grouped into the domains of: health and physiology, consumer behavior, supply chains and markets, and policy and regulations (see Figure 2 in the body of the report), as well as discussing the quality of supporting evidence. The new lens on food systems frameworks, linking and highlighting food safety and nutrition, was then presented, and participants discussed the causal mechanisms and assumptions behind it. On Day 2, participants critically evaluated the proposed lens on food systems frameworks in more in detail, focusing on each component as well as its overall utility for informing existing initiatives and investments. Input and feedback received was synthesized by GAIN and used to refine the proposed framework lens presented in this document.

2. DAY 1: BIDIRECTIONAL IMPACT PATHWAYS LINKING FOOD SAFETY AND NUTRITION

The overall objective of Day 1 was to familiarize participants with the topic of frameworks, identify the importance of linking food safety and nutrition within a food system to achieve food security objectives, and introduce two new products: the bidirectional impact mechanism diagram and the new lens on food systems frameworks.

2.1 Definition of a framework

During Day 1 of the workshop, a working definition of a framework – for the purposes of this discussion- was presented to the participants as: "*A framework is a model that depicts a system, highlighting its key components and how they interact. A framework serves as the foundation for*

internal and external messaging, organizing priorities and initiatives into strategic drivers or pillars that ladder up to a high-level goal or purpose. A strong framework is aspirational, designed to inspire stakeholders and demonstrate how the organization engages them in working towards their vision, purpose, or goals".

It was specified that this effort does not aim to develop a new framework, but leverages existing food system frameworks, in particular the framework included in the High-Level Panel of Experts (HLPE) "Food Systems" report (40) and the recent USAID Bureau for Resilience and Food Security (RFS) Food Systems Conceptual Framework (41), and adds a new lens to highlight the role and goals of food safety and nutrition within the context of food systems.

2.2 Discussion of bidirectional impact mechanisms

The discussion on Day 1 focused on the mechanisms though which foodborne diseases and food safety practices impact nutrition processes and outcomes, and vice versa. A bidirectional diagram (Figure 2 in the main text) summarizing these impact mechanisms was presented and used to guide the discussion. The data and evidence supporting this image were, in part, compiled in the EatSafe product "Literature Review Linking Food Safety and Nutrition", which focuses on links related to health and physiology (84).

The discussion took place in a plenary session, moving though impact pathways grouped into four domains: Healthy & Physiology, Consumers, Supply Chains & Markets, and Policy & Regulation. Each of these four categories was presented in detail, followed by discussion. Participants discussed both in voice and via chat; records of both, as well as notes taken by the organizers, were archived for reference.

GAIN started the discussion by asking whether participants agreed with the categorization of impacts; whether any key impact or link was missing; and whether links are always bidirectional or not. Highlights of comments from the participants include:

- On the consumer side, labelled foods (e.g., organic foods) or foods seen as safe might lead to less careful cleaning and thus in fact pose more risk. Also, conventionally and non-conventionally produced foods (e.g., organics) often have different risks.
- The consumer category is different from all others in that is shaped, dominated, and modifiable by perceptions (and changes therein); the other factors are more hard-coded (e.g., physiology, market mechanics).
- Most of the impacts from food safety towards nutrition are phrased as negative. We need to supplement with some positive links.
- This work should also take into account that some nutrition policies have negative impacts on food safety.
- If a food is not safe, it is not nutritious. That does not seem to clearly be reflected.
- There is a challenge with Policy and Regulations in Sub-Saharan African countries, as regulations and regulatory enforcement are lacking.

- We also should consider how food safety issues affect farm workers themselves (e.g., pickers and those engaged with processing). They can be at higher risk of exposure (e.g., to pesticides). Depending on the location/country, this is a significant portion of the population.

- There needs to be new thinking about how to conduct research to study the links between food safety and nutrition. If there are long-term effects, as suggested, then there need to be longer-term surveillance programs to study the issues. We need to develop new tools and metrics (even intermediate and proxy metrics) that can be tracked over time. We need develop research designs that can provide information using short-term studies and determine how to do randomized control trials to show impacts of different interventions related to food safety on nutritional status, possibly focused on children where changes can be measured more quickly than adults.

With the aim of directing the discussions for Day 2, GAIN reminded attendees that that the draft lens presented was not meant only for the informal sector, but rather it is meant as a global framework lens, encompassing both formal and informal supply chains and markets. The EatSafe program focuses on traditional/informal markets, but this work is intended not only meant for that program.

In the last hour of Day 1, Lourdes Romero Martinez (USAID) presented information on USAID's work on their novel food system framework, and on why a perspective that links nutrition and food safety is important to USAID. In preparation for Day 2 discussions, GAIN presented the guiding diagram on the framework lens (Figure 3 in the main report) and outlined the agenda for Day 2.

3. DAY II: FRAMEWORK LENS DISCUSSION

The second day of the workshop was characterized by breakout groups discussing the five components of the proposed food safety and nutrition framework lens: Safe Food Supply; Safe Food Environments; Consumers; Outcomes; and Drivers. The five groups were selected based on the expertise of participants; each group included a GAIN moderator and a reporter. To start the discussion, groups were given four questions to guide their discussions. The questions were the following:

1. Considering the purpose of this framework, and focusing on the [GROUP'S TOPIC] portion, have we captured the appropriate level of detail?
2. Are we missing any boxes or text within the boxes?
3. Considering the [GROUP'S TOPIC], are the arrows/linkages and assumptions behind them correct? Are we missing any?
4. Where are gaps in knowledge within this portion of the framework?
   (If time allows) Outside of the [GROUP'S TOPIC] portion, is the overall framework construct comprehensive? Are we missing any boxes or text within the boxes?

The following sections present highlights of this discussion.

3.1 Drivers

Drivers, in the context of food systems and this discussion in particular, are defined as contextual or large-scale factors that are outside of food systems, but that influence them. In the draft framework lens diagram used to guide the discussion, these were classified into six categories, although it is recognized that additional factors exist:

1. Environment, geography, and climate
2. Governance, institutions, and policy
3. Culture, gender, and social norms
4. Trade, finance, and income
5. Public health goals and systems
6. Infrastructure and technology

Below is a summary of main ideas from the "Drivers" group:

- The diagram captures most categories of drivers, but there is a need for more detailed discussion in the document to understand what impacts what, and different degrees of influence.
- Make the diagram three dimensional (online): it would be useful to have a version where you can click on a driver and you can see details and examples.
- Make it clear that drivers are interconnected and interact with each other, they are not siloed.
- The category of information is missing, e.g., media, dissemination, consumer behavior around use and consumption of information.
- What about industry as driver, or consumer behavior as driver? Solution: make everything bidirectional so that there is also a flow from food system back to drivers.
- Drivers look different in informal and formal sectors. It is a key distinction, although covered in general terms under "governance". This point should be discussed in the narrative.
- Infrastructure, such as electricity and power, should be highlighted.

3.2 Supply Chains

The supply chains group shared the following feedback:

- The group discussed differences between formal and informal supply chains. It was suggested to explicitly mention informal and formal sectors in the diagram and discuss in the narrative.
- Consider revising processing and packaging to '*proper* packaging, handling, & processing'
- The focus of the main boxes is a mix between actions and functions (e.g., consumers are actors; supply is functions): consider harmonizing.
- The feedback loop from consumers (green arrow on bottom) is justified, but it would also be warranted to include more arrows connecting to drivers and showing interactions among them.
- Arrows showing interactions between consumers, FE, and supply chain should be bidirectional.
- Trade-offs among objectives were discussed: if we improve one thing, might we be harming another outcome?
- There is evidence from implementation science behind all of this.
- A good implementation example is East-West Seed and their work on incentives and best approaches/best practices, especially in working with middlemen.
- Evidence related to processing and packaged food: there are trade-offs between shelf life vs. nutrition vs. food safety.

3.3 Food Environment (FE)

The discussion in the FE group included the following comments:

- Food safety in existing frameworks (HLPE, etc.) is mentioned only within the FE box; this lens unpacks many aspects of food safety to show its role across different parts of the food system.

- The definition of FE was discussed; many versions exist, which can create confusion; consider renaming FE 'Food Acquisition Setting' to highlight the focus on the external, not personal, FE (aspects of the personal FE are covered under "Consumer").
- Some elements of FE should be highlighted more clearly; for instance, physical access and affordability should not be bundled together.
- Outlets also include school programs, companies' or school canteens, and other types of distribution.
- Need to include sanitary and environmental health characteristics of markets and other FE (e.g., water availability), in addition to the food itself.
- There is a feedback loop between consumers and the FE (especially information content) as well as the supply chain.
- How much power do consumers have in influencing the FE and food supply? It was noted that this varies a lot by context: power is stronger in some places, but very weak in extremely fragmented systems. We need to make these distinctions by food safety lifecycle (e.g., related to a food system's degree of formality).

3.4 Consumers

The consumers group gathered the following ideas and suggestions:

- Last box ('…accurate info') should go first. We need to think about whether/how consumers can get information. Consumers will never be able to know whether food is truly safe. Suggested to strike the word "identify" in "Can access accurate info about food safety and are empowered… "
- Box 2: add point about prioritizing food safety. How to help consumers prioritize it in decision making? Is that even realistic?
- Food safety is a continuum, and consumers often do not understand this well, e.g., they may be more concerned about pesticides than microbial contamination, even if the latter is associated with much higher risk.
- Consumers may choose certain vendors based on safety.
- The current second box needs rewording: it does not align with integrated behavior change model (e.g., intention versus motivation); access to tools is also important
- Suggest rewording next box to: Cleaning, sanitizing, and storage separation
- Add box on: "Consumers' perceived risk is aligned with actual risk".
- Suggest adding more emphasis on risk perception and risk communication.
- On the arrow from consumer box to FE and food supply chain: it is difficult for consumers to directly influence the FE or supply; this usually happens via policies, government, regulation, and through increased demand over time.
- The relative importance of drivers is not equal; we should make sure this is conveyed, in diagram or narrative.
- Arrow from consumers to better nutrition and foodborne disease: link to better health and reduced chronic disease; this, in turn, helps consumers better act and influence the food system.
- Gap between industry and consumers; we need more clarity on how/whether consumers can provide feedback to industry. Note that there is an assumption that consumers have the ability to report issues.
- We do not have good knowledge on what drives consumers' reporting on food safety.
- There is not a very robust literature about how consumers actually make decisions about food safety; we need to be not just looking at stated choices, but rather real actual choices/actions.
- It is not always true that more educated consumers make better choices.
- We need to include more considerations about peer effects and social norms.

- There is a large research gap related to the burden of disease, especially on severity of disease; current figures represent a lower bound.
- There is also currently data gap around risk assessment, and data needed for risk assessments.
- Culture of food safety was discussed: how can companies be made to take on food safety as a core part of their mission?
- What type of information is effective at changing consumer behavior?

3.5 Outcomes

In addition to the four questions listed above, the outcomes group had two additional questions:

1. What are your impressions? [Start with evidence gaps question for this group]

2. Do we have the right metrics to measure these outcomes?

Key points discussed or recommended by this group include:

- The group appreciated that outcomes are focused on diets and nutrition, not levels of food safety, as it maps well with USAID Bureau of Resilience and Food Security framework.
- The group also appreciated that the diagram makes a clear statement that food is not nutritious if it is not safe.
- Food safety is often a barrier to nutrition and trade (seen as hurdle to overcome, not outcome in itself). As such, it can be challenging to phrase food safety outcomes positively.
- Trade is a potential outcome, not just a driver.
- The framework is aspirational; in the next steps there is a need to make it more concrete and measurable.
- Food security needs to be more explicitly mentioned, integrating quantity, safety, and nutrition.
- Not every driver is equal; we need to show how some are more malleable than others (e.g., markets and trade can be changes more easily than geography and culture).
- We also need to show how the drivers interact with one another.
- Standards and metrics need to be reasonable for informal markets; HACPP is too stringent and expensive for informal markets.
- Capability of measuring food safety will largely depend on surveillance capability in a country, but currently data is severely lacking, which will make tracking progress on food safety very difficult.
- Indicators: Important to focus on governance structures and use system-level indicators.
- Other ideas on specific phrasing were suggested, e.g., “Reduced Foodborne Disease” should go to top, which would improve nutrient absorption; add a box on reducing chronic disease; add a box on reduced diarrheal disease.

3.6 Summary feedback for framework lens improvement

After discussions in groups, a plenary session was held during which each group reported to the workshop participants. Additional plenary discussion followed. A GAIN representative summarized the main actionable feedback for the immediate next steps in the framework lens development (diagrams and supporting document presented here) as follows:

1. A figure can only display so much; the underlying resources and discussion in the document are key to interpret the impact mechanisms and framework lens.

2. Discussion on the directionality of arrows points to the underlying complexity: we need to account for flows of information, etc. (without taking it all the way to complex systems dynamics models).
3. Phrasing matters: we need to be consistent (e.g., actors vs. actions).
4. The figure is currently somewhat flat: everything seems to have equal weight, but it does not – especially with drivers. Some are just context, not amenable to change, while others are key levers. We should highlight the different "elasticity" of drivers and levers and consider an online figure where additional detail and context can "pop up."
5. Food that is not safe is not nutritious underscores the issues with food security. For example, the FAO definition of food security embeds safe, nutritious, and sufficient.
6. We need to ensure language is inclusive of all different types of food.
7. A higher level of context specificity may be needed when interpreting or using the framework lens. An example is the distinction between informal and formal contexts.
8. Data/systems/surveillance: we need not only metrics, but the systems that will enable tracking them. We should use metrics that are responsive to change and are measurable.

4. CONCLUSION AND NEXT STEPS

Over the two days, GAIN/EatSafe received very rich feedback from the experts participating in the workshop, spanning multiple disciplines and organizational perspectives. The input and feedback received during this event were synthesized by GAIN and used to refine the proposed framework lens and associated supporting materials, as presented in the main body of this report, and to inform subsequent EatSafe activities. Highlights from the concluding participant remarks during the final plenary discussion include:

- More important than making it perfect, this framework lens should be operationalizable, to help steer interventions and decisions. Prioritize the components and factors that are most amenable to intervention (e.g., policy) and de-emphasize others (e.g., climate); highlight the distinction between the two.
- More explicitly highlight the points where it is easiest to intervene, particularly in the short term (e.g., surveillance is valuable, but current models may take a long time to build).
- Food safety needs to be seen through a One Health lens covering human, food, livestock, wildlife, and environmental factors. One Health prevents us from missing out on important links and impacts and can highlight key places to intervene.
- The recent food safety lifecycle concept can also enrich this discussion.
- We should look at interventions that can have positive impacts on both nutrition and food safety jointly, acting together on both fronts (e.g., hygiene measures, which cover both infrastructure and practices). We need to reinforce the message on both topics.
- The framework lens needs to capture trade-offs, in addition to synergies.
- Some of the pathways discussed are assumptions and hypotheses. Additional evidence and validation are needed.

The following documents and materials related to the workshop are available upon request:

1. Concept Note
2. Workshop Agenda
4. Attendance List
5. Discussion Comments and Questions-Day I, Day II
6. Workshop Breakout Groups – Master List
7. Workshop Presentations
9. Workshop Recordings

APPENDIX III. INDICATORS OF FOOD SAFETY PERFORMANCE

Indicators are measuring tools that are used to monitor the performance of a system or its components. Food safety indicators can span a broad range of scales and are used in multiple ways throughout the food supply chain. For example, food buyers use them to evaluate the quality, efficiency, or cost of their suppliers and to assess whether the food they are purchasing is safe. Governments use them to assess hygiene levels in food businesses throughout the supply chain to protect the health of consumers. In any context, developing a framework that clearly defines food safety objectives is an important step in developing effective indicators to measure performance along the supply chain.

A review of food safety measures and indicators was conducted by GAIN and is available as a separate report (85). The referenced document, summarized in this Appendix, provides an overview of the use of indicators use in multiple contexts and world regions, as well as a summary of the normative food safety standards and guidelines adopted by the Codex Alimentarius Commission (Codex), an international standard setting organization established by the World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO). This analysis is an important building block for EatSafe's efforts to develop a conceptual framework lens and indices linking food safety and nutrition. Specifically, a categorized review of food safety indicators can serve as a "menu" to help develop a custom set of indicators for new programs in nutrition and food safety (considered individually and jointly).

A broad range of indicators was reviewed and categorized as follows: indicators for public health (the burden of foodborne disease); the demand side (indicators of consumer and vendor knowledge, attitudes, and practices including individuals and organizations); the supply side (food hazard standards and indicators; food industry performance indicators); core competencies of national food safety systems and indicators of their performance; and the enabling environment including broader natural and societal contexts. While not exhaustive, this review provides a reference to discuss future efforts to develop harmonized indicators for food safety. Food safety and healthy nutrition are dependent on each other, and EatSafe's future work will review the interactions and impact pathways between the two domains and work towards synergistic and integrated indicators that are relevant for food safety and nutrition.

1. Public health: Indicators of Foodborne Disease Burden

Quantifying the burden of FBD is key in selecting, implementing, and tracking the success of interventions to reduce it. Indicators of FBD burden, and the associated data, are mainly derived from disease surveillance programs at different geographical scales (e.g., local, regional, or national). They are widely used in most countries and are aggregated at international level, e.g., by WHO. The basic units of measurement commonly used to assess FBD burden include incidence of morbidity and mortality (number of illness cases and deaths per year in a defined population), and disability-adjusted life years (DALY), for a specific hazard or aggregated over hazards, and summarized at different geographical scales (86).

The ability to collect, analyze, and disseminate FBD occurrence data relies on an effective reporting and surveillance system, as well as effective outbreak investigation capabilities. These functions are

usually carried out by government as part of national public health and food safety systems and include laboratory as well and data analysis capabilities (see Section 5 below). Indicators of the degree of development and effectiveness of these national systems also exist, for example metric of timeliness of outbreak investigation (87,88) and the Benchmark tool that is part of the WHO's International Health Regulations (IHR) toolbox (89,90).

2. Indicators Related to Knowledge, Attitude and Practices (KAP) of Consumers and Retail Food Service Workers

Individual and group actions by consumers, as well as other actors in the supply chain, can have a significant impact on food safety, for example because food handling at retail and at home can exacerbate hazards that enter earlier in the supply chain and introduce new hazards. Choices made at the retail and consumer level more generally have been a major driver of safer food in middle- and high-income countries (91–93). These actions are determined by a range of underlying factors that can be broadly categorized as knowledge, attitudes, and practices (KAPs).

Variables to measure and assess KAPs have been developed and applied, mainly in research settings. However, this type of metrics is rarely codified as indicators of food system performance and included in national or international assessments. Some notable exceptions exist and show promise. For example, the U.S. Healthy People 2030 food safety targets, a selected set of priority indicators tailored to the current needs of the national food safety system, include consumer behavior indicators ("Increase the proportion of people who wash their hands and surfaces often when preparing food", "Increase the proportion of people who cook food to a safe temperature", and "Increase the proportion of people who refrigerate food within 2 hours after cooking") as well as indicators of retail worker behavior (e.g., "Increase the proportion of delis where employees wash their hands properly", "Increase the proportion of delis where surfaces that touch food are properly cleaned and sanitized") (94).

3. Food Hazard Standards and Indicators

Key to managing foodborne risks is knowing the common food/hazard combinations, where hazards are introduced or spread in the production or supply chain, and whether their level is acceptable to protect public health. Indicators and standards of foodborne hazard occurrence aim to measure the degree and patterns of specific hazards' presence in specific food commodities and supply chains, contributing to managing risk by controlling exposure. Hazard indicators can help assess food safety performance using different scales, from individual food samples to summary assessments at national level or on yearly time scales. They can assess the presence, levels, type, and features of microbial and chemical hazards, and those metrics are tightly connected to the protocols and assays used to carry out measurements.

At the international level, the Codex Alimentarius provides the most comprehensive set of international standards on food safety designed to be broadly applicable in LMICs (62). Some of these standards include acceptable or threshold level for specific hazards. While not intended as a substitute for national legislation, Codex guidelines provide a blueprint that can be voluntarily adopted by countries that have not yet developed their own food safety policy or legislation. The standards and guidelines are developed at Committee meetings that include national governments and observers.

Codex is comprised of General Standards Committees (e.g., Codex Committee on Food Additives; Codex Committee on Food Hygiene) and Commodity Committees (e.g., Codex Committee on Fresh Fruits and Vegetables; Codex Committee on Fats and Oils). These Committees develop standards of quality and safety for a broad range of food products (62). Codex standards are often adopted by countries, if domestic food safety regulations are not fully developed, as a starting point to build upon based on the specific national context (95–97).

Furthermore, Codex standards are divided into General Standards, which provide principles and guidance over broad topics, and Commodity Standards, which specify recommended microbiological or chemical standards to be met for specific commodities (62,98). Codex standards also serve as reference for international food trade. Individual commodity standards rely on Codex general standards for food safety and do not specify indicators or quantitative standards for the specific commodity (62).

Hazard metrics and indicators can refer not only to the finished product but also to the performance of different stages of the supply chain. Microbiological criteria are an example of key quantitative standards used to establish the acceptability of a food and its production process, in terms of microbial food safety variables such as presence or levels of a microbial hazard or toxins of microbial origin (99,100). An analogous concept can be applied to chemical hazards. The most common types of microbiological criteria used by regulatory agencies generally include (101):

- Food safety criteria (FSC): microbiological criteria that are applied to determine the safety of a food batch or lot, usually applied at the end of production and before retail.
- Process hygiene criteria (PHC): microbiological criteria applied to verify that hygiene measures or process controls are effective and working as intended. They are applied at a specified point in the manufacturing process.

At the international level, Codex and the ICMSF (International Commission on Microbial Specifications for Foods) have led the codification of principles and the development of microbiological criteria. Microbiological criteria are usually expressed as thresholds in a variable of interest, that triggers non-compliance if exceeded. This variable can be measured on a binary (presence/absence), semi-quantitative (e.g., below a specified level, or as discrete categories related to hazard level), or quantitative scale (e.g., concentration, number of cells in a specified amount of food). Exceeding a microbiological criterion may trigger corrective action to bring the system back into compliance. Frequency and severity of exceedances, summarized at national level or by industry segment, can also be used as indicator of sector performance.

4. Indicators of Food Industry Performance

The food industry, besides adhering to national or international standards, also uses voluntary performance indicators to track performance and internally evaluate their food safety systems, as well as to demonstrate compliance to standards established by their buyers. Individual companies or commodity organizations may adopt standards specific to their context. However, recently the availability of standardized certification and benchmarking programs has made it easier for businesses to adopt widely recognized standards, streamlining compliance processes and facilitating trade.

One of the largest industry-driven efforts, the Global Food Safety Initiative (GFSI) by the Consumer Goods Forum benchmarks private certification programs that assess and certify if food companies meet certain performance standards (102). Launched in 2000, the GFSI is a global initiative to improve food safety and foster business efficiency by harmonizing and standardizing food safety certification programs for food businesses, among other strategic objectives (102). GFSI has developed a set of benchmarking requirements specifying essential features of effective food safety programs. Certification programs that meet these requirements are officially recognized by GFSI.

Another major reference for food safety standards developed by non-governmental organizations is the ISO 22000 family of food safety management systems standards, developed by the International Standardization Organization (ISO) (103). The 22000 family of standards follows a quality management system approach (e.g., in alignment with ISO 9001) customized to food safety processes. ISO 22000 standards, whose second edition was released in 2018, are applicable to any organization in the food supply chain and are based on the following key principles: interactive communication; system management; prerequisite programs; HACCP principles. Other standards in the 22000 family apply to specific sectors or product categories.

Standardization and certification are by definition lacking in the informal sector. While several food safety best practices are applicable to small and micro-sized enterprises, the complex infrastructure, data collection, and system management required by industry standards schemes hinder their application to resource-poor contexts. Some Codex standards provide guidance specifically to informal sector businesses, for example the regional guidelines for street-vended food (104,105) (CAC/GL22R-1997), which include the design, maintenance, and sanitation of establishments; street food centers (e.g., design, waste management, consumer facilities); control of operation (e.g., ingredients, cooking and handling, serving, storage, transportation, water, management and supervision); personal health; and training (105). The GFSI has also launched the “Global Markets” program to provide small businesses with a step-by-step program to start or improve food safety system (106).

5. Indicators of Core Competencies of National Food Safety Systems

Evaluating core competencies in national food safety control system is an important step forward to assist LMIC to develop an improvement plan for food safety. According to a 2005 report by the Safe Food International, a FAO/WHO working group with consumer organizations (107), there are eight essential components of an effective food safety regulatory system, each with a set of indicators to evaluate performance:

- Food laws and regulations
- Food control management
- Inspection services
- Recall and tracking systems
- Food monitoring laboratories
- Foodborne disease surveillance and investigation systems
- Information, education, communication and training
- Funding

Codex has advised governments on the design, operation, and performance monitoring of their food safety systems, and these documents define objectives and desired outcomes for the development of indicators. For instance, the Codex *Principles and Guidelines for National Food Control Systems* (CAC 82-2013) (108) states that the central objective of a national food control system is to protect the health of consumers and ensure fair practices in the trade of food products. Essential principles include:

- Protection of consumers
- The whole food chain approach from primary production to consumption
- Prevention, intervention, and response
- Self-assessment and review procedures
- Resources dedicated to national food safety programs.

As outlined in the 2017 *Codex Principles and Guidelines for Monitoring the Performance of National Food Control Systems*, monitoring the performance of national food safety systems is a continuous development process of collecting and analyzing data to compare how well the stated objectives and outcomes contributing to safe food are achieved (109). The relationship between outcomes and indicators can be thought of as a cycle that includes: defining outcomes to manage performance; establishing indicators to monitor; using monitoring results to prioritize action; and informing the improvement of outcomes and indicators (109). Codex provides further guidance on each of these steps, which should take into account available data and resources (financial, human, technical, and material), as well as plans to develop lacking resources. A key tenet of these guidelines is that while food safety performance indicators can include the completion of specific activities, e.g., completion of food business inspections or pre-operational sanitation, it is best to develop indicators clearly and logically linked to the intended objectives or outcomes, in a tiered fashion, e.g., through quantitative or qualitative theory of change or logic model approaches.

The most comprehensive review of food safety indicators so far, including and beyond indicators of national food safety core competencies, was compiled by the 2017 *FAO Regional consultation on food safety indicators for Asia and the Pacific* (110). The FAO expert workgroup identified five categories of indicators relevant to national food safety systems: (A) System-level indicators; (B) Capacity-level indicators; (C) Sector-specific indicators; (D) Specific food safety topic indicators; and (E) Indicators on surrounding factors. Within those categories, they placed 139 indicators found through a literature review. Examples of capacity-level indicators identified include:

- Percentage of food safety incidents in which the origin of the problem was identified.
- Number of guidelines drafted on HACCP, GMP, and GLP (Good Laboratory Practices).
- Number of food inspectors trained and on official food control.
- Number of established and equipped laboratories.
- Number of consumers reached by information activities.
- Number of workshops held number of participants and follow-up trainings.
- Number of food producers and traders working according to HACCP.
- Rejections of food exports by importing country.

For low- and middle-income countries (LMICs), food safety indicators should also consider the underlying infrastructure (and associated indicators), such as: core infrastructure such as clean water, electricity, transport, and sanitation; safe food storage; cold chain; sanitary food handling facilities; effective processing equipment; laboratory capacity; and food service facilities (111).

The African Union, though the Comprehensive Africa Agriculture Development Programme (CAADP), has developed a set of indicators relevant to agricultural development and food security, as part of the broader effort towards the development goals of the 2014 Malabo Commitments. These indicators include three food safety indexes, within the "End hunger by 2025" goal, that can be further combined into an African Food Safety Index (AFSI) (112,113):

- **Food safety systems index (FSSI)**: tracks progress in government capabilities including policy and regulatory development, monitoring and surveillance programs, and laboratory infrastructure, with a goal of developing food safety inspection systems by 2025.
- **Food safety health index (FSHI)**: assesses the reduction in foodborne health burden, with the specific goal of reducing FBD burden by >50% by 2025 (based on FERG 2015 burden estimates).
- **Food safety trade index (FSTI)**: assesses the impact of food safety violations on trade, with the goal of tripling food commodity trade by 2025.

In conclusion, there is a broad variety of indicators available to evaluate government-managed food control systems. Ideally, large-scale indicators can be designed around clear categories, with the objective to give governments a development ladder to track and improve their food safety programs, similarly to the PVS Toolkit for animal health (114). It is important to note that national food safety indicators, as any other indicators, rely on the collection of accurate and representative data. Indicators should be established based on available data sources, considering both established standards of data quality as well as available capabilities for data collection, analysis, and communication. While data collection programs exist in most countries, systematical data compilation and sharing among relevant agencies is often lacking, thus hindering coordinated action (110).

6. Indicators of enabling environments for food safety

Enabling environments can be defined as a set of conditions, rules, or forces outside the direct boundaries of the systems under consideration that can significantly influence it and enable its success. In general, what is part of an enabling environment varies with the system under consideration, its goals, and the perspective adopted (e.g., consumers vs. food producers).

Main components of enabling environments for food safety include but are not limited to:

- Geographical, climatic, and natural resources
- Biodiversity
- Socio-economic status
- Population health
- Healthcare system
- Education and human capital
- Cultural context
- Water, sanitation, and hygiene

- Infrastructure
- Democracy and government
- Regulatory environment and institutions
- Business, trade, and entrepreneurship

For many components of enabling environments listed above, indicators and metrics have been established. For example, WASH indicators have been developed and used by many organizations in the last decades, including quantitative indicators by WHO and UNICEF (115). Another example is the FAO's conceptual framework for enabling business environments, which focuses on factors impacting agribusiness success including policies, institutions, and business support services (116).

In the context of the USAID Feed the Future initiative, the "Enabling environments for food security" project (117) tackles factors that are also relevant to food safety, in particular the legal, institutional, and regulatory factors that impact food markets and trade, and hence food security. The "Enabling environments for animal source food market system success" component of this project (118) has defined the key categories of enabling environment factors, divided by supply chain segment:

- Supply-side factors that affect livestock production (e.g., factors affecting access to animal feed, animal genetics, animal health products and services, labor, land, and water).
- Marketing factors that affect markets and access to markets for animal source foods (e.g., infrastructure, price transmission, sanitary and phytosanitary standards, trade agreements).
- Financial services factors that affect business operations by mitigating risks or facilitate the adoption of new technologies and practices (e.g., availability and access to credit and insurance).

While no consistent and vetted set of indicators has been developed for food safety enabling environments in low- and middle-income countries, individual projects are building a body of evidence on key factors. For example, the International Livestock Research Institute (ILRI) has included enabling environments for food safety in several projects, e.g., when investigating the role of capacity strengthening to enable food safety in informal markets (119).

7. Conclusions

Some preliminary conclusions from the review include:

- Food safety indicators are useful for all actors in the supply chain and serve many goals.
- While public health measures and indicators are well developed, the systems to monitor and manage them are often lacking and vary considerably from country to country.
- On the demand side, indicators of consumers' ability to effectively act as positive agents in food safety systems are lacking, though in some regions (primarily in developed countries) consumer-driven food safety indicators and ratings have been developed by civil society organizations.
- On the supply side, indicators and standards have been developed and applied by the food industry, including for low- and middle-income countries, though their use is less common or applicable in small companies and informal supply chains.
- Indicators of national government performance are well developed, although large variations in national programs exist across countries. Codex standards and guidelines provide a range of food safety standards used by many countries to manage food safety.
- Adaptation of indicators to the needs and capabilities of LMICs and informal supply chains (i.e., that government programs or industry standards may not reach) is needed.

- Some indicators are lacking, especially on enabling environments and gender factors.

This summary review provides a broad overview of indicators and metrics used to assess different aspects of food safety systems and can support the selection of priority indicators for food safety efforts in LMICs, including those linking food safety and nutrition.