

EatSafe: Evidence and Action Towards Safe, Nutritious Food

Review of Measures and Indicators for Food Safety Performance

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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.

ALOP	Appropriate Level of Protection
CDC	Centers for Disease Control and Prevention (of the United States)
CIFOR	Council to Improve Foodborne Outbreak Response
Codex	Codex Alimentarius Commission
DALY	Disability-Adjusted Life Years
FAO	Food and Agriculture Organization (of the United Nations)
FERG	Foodborne diseases burden Epidemiology Reference Group
FSC	Food Safety Criterion
FSIS	Food Safety and Inspection Service (of the U.S. Department of Agriculture)
FSO	Food Safety Objective
GAIN	Global Alliance for Improved Nutrition
GAP	Good Agricultural Practice(s)
GFSI	Global Food Safety Initiative
GHP	Good Hygiene Practice(s)
GLP	Good Laboratory Practice(s)
GMP	Good Management Practice(s)
HAACP	Hazard Analysis and Critical Control Points
ICMSF	International Commission on Microbial Specifications for Foods
IFPRI	International Food Policy Research Institute
IHR	International Health Regulations
ILRI	International Livestock Research Institute
KAP	Knowledge, Attitudes, Practices
LMIC	Low- and Middle-income country
NFCS	National Food Control Systems
OIE	World Organization for Animal Health (Office International des Epizooties)
PC	Performance Criterion
PHC	Process Hygiene Criterion
PHEIC	Public Health Emergencies of International Concern
PO	Performance Objective
UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

EXECUTIVE SUMMARY

This review of food safety measures and indicators provides an overview of their 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 and indices linking food safety and nutrition.

The scope of this review covers indicators for public health (the burden of foodborne disease); the demand side (consumer and vendor knowledge, attitudes, practice indicators; civil society organizations); the supply side (food hazard standards and indicators; food industry performance indicators); and the enabling environment (core competencies of national food safety systems and indicators for performance; 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.

Some preliminary conclusions 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.

Identifying food safety indicators for use for EatSafe and other Feed the Future programs is an important aspect of EatSafe Phase 1. This summary review provides a broad overview of indicators and metrics used to assess different aspects of food safety systems and will foster the selection of priority indicators, including those linking food safety and nutrition.

GLOSSARY OF TERMS

For the purposes of this document, the following terms are defined as follows. Several definitions were adopted from established sources, as indicated below.

Activity: Actions taken, or work performed, through which inputs are mobilized to produce specific outputs.¹

Assessment: A process of determining the presence or absence of a certain condition or component, or the degree to which a condition is fulfilled.²

Control measure: action or activity that is essential to prevent a significant food safety hazard or reduce it to an acceptable level.³

Effectiveness: The extent to which National Food Control Systems (NFCS) objectives or related outcomes were achieved, or are expected to be achieved, considering their relative importance.⁴

Hazard: A biological, chemical, or physical agent in, or condition of, food with the potential to cause an adverse health effect.⁵

Indicator: Quantitative variable or qualitative factor that provides a simple and reliable means to measure achievement, to reflect the changes connected to activities, or to help assess the performance of a program or system.⁶

Inputs: The financial, human, technical and material resources used for activities.⁷

Instrument or tool: A testing device for measuring a phenomenon or collecting data (e.g. questionnaires, guidelines for observation, thermometers).⁸

Measures (Noun): The dimensions, capacity, or amount of something ascertained by measuring.⁹

Measures (Verb): The act of measuring something and determining its value (e.g. taking the temperature of meat, synonym of “measurement”) or the output data that result from measuring something (e.g. a thermometer reading).¹⁰

Metric: A method used for measuring something (e.g. patient admission sheets)¹¹, or the variable that is being measured (e.g. number of illness cases is a metric of disease burden).

¹ Codex 2017 (2), adapted from OECD. 2002. “Glossary of Key Terms in Evaluation and Results-Based Management.” Paris: OECD/DAC.

² Codex 2017 (2)

³ ISO 22000 (55)

⁴ Codex 2017 (2)

⁵ Codex 1997 (49)

⁶ Codex 2017 (2)

⁷ Codex 2017 (2)

⁸ Grace et al., 2018 (4)

⁹ Merriam Webster, 2020.

¹⁰ Grace et al., 2018 (4)

¹¹ Grace et al., 2018 (4)

Monitoring: determining the status of a system, a process, or an activity.¹²

Objective: A result to be achieved.¹³

Outcome: Intended effects or results that contribute to achieving the NFCS Objectives. Outcomes may be categorized at different levels, such as ultimate, high-level, intermediate, preliminary, or initial.¹⁴

Outputs: The products and services which result from activities; may also include changes resulting from activities which are relevant to the achievement of outcomes.¹⁵

Performance monitoring: A continuous or ongoing process of collecting and analyzing data to compare how well the stated objectives and outcomes of the NFCS are achieved.¹⁶

Risk: A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food.¹⁷

Risk analysis: A process consisting of three components: risk assessment, risk management and risk communication.¹⁸

Risk assessment: A scientifically based process consisting of the following steps: (i) hazard identification, (ii) hazard characterization, (iii) exposure assessment, and (iv) risk characterization.¹⁹

Standard: An agreed way of doing something. Standards provide rules, guidelines or characteristics for activities or their results and may apply to food products, test methods, codes of practice, or management systems.²⁰

Standard: Document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Note: Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits (1).

Target: The explicit statement of desired results for a specific indicator (e.g. 99% of milk sampled to comply with the pH standard).²¹

¹² ISO22000 (55)

¹³ ISO22000 (55)

¹⁴ Codex 2017 (2)

¹⁵ Codex 2017 (2)

¹⁶ Codex 2017 (2)

¹⁷ Codex 1997 (49)

¹⁸ Codex 1997 (49)

¹⁹ Codex 1997 (49)

²⁰ Grace et al., 2018 (4)

²¹ Grace et al., 2018 (4)

I. INTRODUCTION

Food safety is the outcome of the actions of many different participants within the food system, largely driven by private the private sector, starting with farmers and transporters, moving through food processors and retailers, to public consumers with oversight from governments. To ensure that food safety is managed effectively over time, all actors, from governments to local vendors, should consider the importance of performance monitoring.

This report consolidates knowledge and evidence of the food safety measures and indicators currently in use in different countries and those recommended for use by international agencies developing normative guidelines. It describes the types of measures and indicators currently in use to evaluate different outcomes of the food system, including public health outcomes, demand and supply side outcomes, and enabling environment outcomes, such as government and international drivers that shape the impacts of the larger food system on food safety.



Figure 1. Performance Monitoring Framework schematic, Codex (2017) (2).

Performance monitoring is a continuous or ongoing process of collecting and analyzing data to compare how well the stated objectives and outcomes contributing to safe food are achieved (2). The relationship between outcomes and indicators is illustrated below as a cycle of continuous feedback and improvement: defining outcomes to manage performance;

establishing indicators to monitor; using monitoring results to prioritize action; and informing the improvement of outcomes and indicators (**Fig.1**).

Food safety indicators 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, however, developing a framework that clearly defines the food safety objectives is an important step in developing effective indicators to measure performance along the supply chain.

The US government's Feed the Future initiative provides examples of national-level indicators to measure performance, as well as indicators assessed at implementing mechanism and Zone of Influence scales (62). While not specific to food safety, several indicators are relevant to food systems, nutrition, and related drivers. Some examples of national or zone of influence indicators include prevalence of wasting, stunting, underweight, or undernourishment in children and women, which are also relevant to food safety and to the United Nations Sustainable Development Goals (SDGs). Other indicators relevant to food safety include the percent of households with access to basic sanitation service, or households with soap and water at a handwashing station on premises.

Codex Alimentarius provides guidance on food safety principles, risk assessment and management approaches, and standards for specific foods. According to Codex Guidelines for Monitoring the Performance of National Food Control Systems (2), indicators should be designed:

- To be either quantitative or qualitative.
- To be unambiguous, easy to interpret, monitor and transparent.
- Closely linked to the outcome.
- Amenable to independent validation and verification.
- Within the limits of existing resources.

While food safety performance indicators can include practical protocols, e.g. completion of food business inspections or pre-operational sanitation, it is best to develop indicators clearly linked to the intended objectives or outcomes. Regardless of what form indicators take or the function they serve (e.g. measuring achievement, reflecting changes, assessing performance, or monitoring how specific activities contribute to specific outcomes), the usefulness of indicators is directly tied to the quality and representativeness of data associated with them, i.e. to the effectiveness of data collection and management systems. 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.

A report by the Lloyd's Register Foundation (3) conceptualizes different layers of food safety standard-setting systems used to manage food safety and shows how they build upon and

complement each other (**Fig. 2**). Those types of standards frequently contain the desired outcomes, which provide the drivers for indicators. The Lloyd’s Foundation work illustrates the linkages between sets of standards developed by different food system actors, including international organizations (e.g., Codex standards, WTO), national legislature and government agencies, third-party non-governmental organizations (ISO standards), and the private industry (GFSI, commodity boards, individual companies).

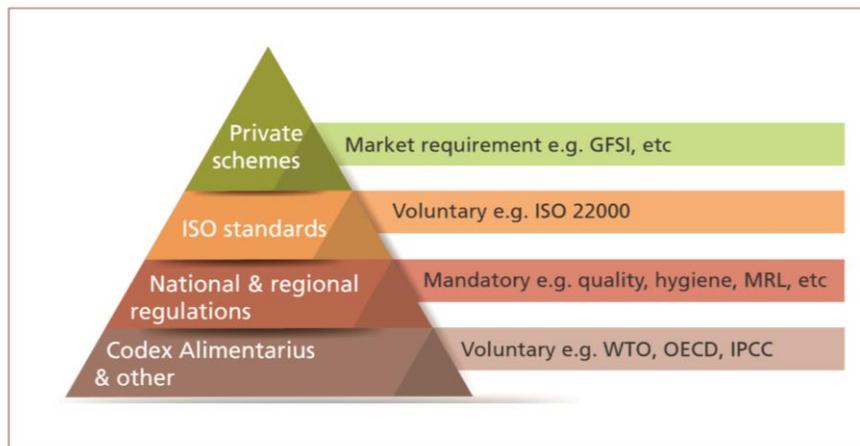


Figure 2. Pyramid of food safety schemes and standards (3).

Food safety standards can be mandatory or voluntary. While legal requirements illustrate mandatory standards, many retail food purchasers use voluntary buyer specifications, that also drive performance by the food industry. In the context of the informal food sector, where mandatory standards or their enforcement are often lacking, voluntary standards and the incentives for their adoption are of interest for EatSafe. A recent effort to synthesize metrics for food safety specific to LMICs, led by the Food Safety Working Group (4) also discusses the role of public vs. private standards, as well as export standards. Overall, this work groups metrics into three main categories: (1) Foodborne hazards and risks, (2) Food safety system performance, and (3) Foodborne disease outcomes (**Table 1**).

The measures and indicators described in this report (**Fig. 3**) were gathered using expert knowledge, together with targeted document searches specific to each category of indicators being described. For example, “consumer knowledge, attributes, and practices” were specifically searched to identify relevant studies, while information on Codex Alimentarius was provided through expert knowledge of the authors, one of whom represented both consumers and the U.S. government at Codex meetings where the guidelines described were developed. Similar approaches were used for each of the areas reviewed. Selected examples were illustrated in more details as representative of the “state of the art” in each category. While not exhaustive, this review provides a structured reference to discuss future efforts to develop harmonized indicators for food safety.



Figure 3. Schematic of indicator categories included in this review.

2. PUBLIC HEALTH: INDICATORS OF FOODBORNE DISEASE BURDEN

Reducing the occurrence of foodborne disease (FBD) is the primary goal of food safety systems, and metrics are useful to measure the adverse health outcomes for consumers that are associated with foodborne hazards. These indicators, and the associated data, are mainly derived from disease surveillance programs at different geographical scales. FBD occurrence indicators are widely used in most countries and are aggregated at international level, e.g. by WHO. Basic units of measurement commonly used to assess FBD burden include 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 (4). Examples of indicators of or relevant to FBD burden, as included (explicitly or implicitly) in broader infectious disease and public health assessment frameworks, are shown in **Table 2**. Health surveillance data constitute the gold-standard metric to evaluate whether food safety programs have been effective and to track their impact over time and in different regions or populations.

Surveillance programs. Effective surveillance programs, and associated data management, analysis, and sharing, are key to ensure timely feedback on the performance of food safety systems, both regarding emergency response and preventive measures. Programs specific to

foodborne disease are particularly useful in tracking metrics relevant to food safety practices. In high-income countries, programs such as FoodNet (5) in the United States and TESSy (foodborne and waterborne) in the European Union (6) are examples of outbreak detection programs that track a set of indicators and interface with other actors to monitor, respond to, and prevent adverse food safety events, such as outbreaks or illnesses.

Surveillance programs can be passive, where cases or outbreaks are periodically reported to a national monitoring system by local or regional health departments, or active, where a public health authority initiates a dedicated data collection effort, e.g. tracking *Salmonella* case reports from laboratories. At the international level, the WHO coordinates efforts to detect and respond to public health emergencies through the Global Outbreak Alert and Response Network (GOARN), founded in 2000 and now a network of 250 international institutions (7). While focused on emergency response, data collected through this program contribute to health burden surveillance and associated indicators and to developing surveillance capacity. WHO also supports national-level surveillance capacity and infrastructure development.

Additional discussion on disease surveillance programs, in the context of government capabilities, can be found in **Section 5**. It is important to note that assessing progress over time requires the existence of reliable baseline data as well as the ability to carry out ongoing data collection, which highlights the importance of data management capabilities as well as the use of consistent indicators over time.

Foodborne disease attribution. Attributing foodborne disease incidence data to specific food categories or hazards is key to effectively control risk, first by removing the contaminated food from the market to stop the public health threat and second by providing food suppliers with the information they need to apply customized context-specific interventions at critical points in food production. Foodborne illness outbreaks generally trigger a public health response to identify the food source. Aggregating this outbreak data over time can provide the best data source to link common food and pathogen combinations. This knowledge is essential to inform the hazard analysis used to manage food safety risks under preventive control systems utilizing Hazard Analysis and Critical Control Points (HACCP) systems. Such data is not readily available in many countries (8).

These metrics are also estimated from disease surveillance data and other data sources, such as production and consumption data. Globally, the 2015 WHO FERG (Foodborne disease burden Epidemiology Reference Group) report (9,10) is the first comprehensive set of global estimates of foodborne health burden. FERG aggregated data over broad geographic regions to address gaps in data in many countries. Burden was also assessed by hazard group, outcome severity, and age of affected individuals. However, global data sources were not adequate to assess the burden by food or food category, which is essential to prioritize and design interventions tailored to the need of specific supply chains.

Attribution can be based directly on surveillance data, but other approaches exist. For example, to fully quantify the burden of disease sporadic cases need to be tracked or estimated, but efforts are generally targeted to priority hazards (e.g. only some pathogens are reportable, and foodborne pathogens are often not included). Hence, correct data-driven risk prioritization and timely feedback between risk prioritization and inclusion of a hazard in a surveillance system are also key to effective progress tracking. As an example of national initiatives, the U.S. Centers for Disease Control and Prevention (CDC) carries out regular attribution analyses following multiple approaches that can be applicable in other countries (11).

It is important to note that attribution is not necessarily limited to the point of food consumption. For instance, the FERG report highlights that, as a result of the complex network of pathways that lead to exposure, there are two main points of attribution: at exposure level (i.e. at the point of food consumption, for the foodborne pathway) and at reservoir level (i.e. where the hazard persists or circulates in non-human reservoirs such as food animals, pets, wildlife, and the environment—in other words, where the hazard is coming from when entering the food supply chain, for foodborne pathways) (9,10). While metrics and indicators are well established at exposure level, they are lacking at the reservoir level. FERG also states that for surveillance purposes, attribution at the point of human exposure is the most straightforward to implement and can be more directly linked to health burden. At the same time, for risk management purposes attribution at other points in the food system, such as primary production, processing, or preparation, can be crucial and should be considered.

Integrated surveillance systems for antimicrobial resistance arising through livestock production provide another model for data collection at three distinct points on the food supply chain: assessing microbial levels in the live animal, retail meats, and human clinical results (12,13). This shows the utility of evaluating data at different points to manage and prevent foodborne illness.

Outbreak and emergency response. Indicators are available that measure the ability and timeliness of outbreak response. While they are not an indicator of health burden *per se*, rapid investigation and response to outbreaks is directly linked to the ability to reduce the public health burden. Outbreak detection and its reporting to national authorities depends on the action of several actors, in particular consumers, healthcare providers, and state or local public health agencies (14). Outbreak investigations are often initiated by consumers, either by visiting a healthcare provider or by directly reporting a potential issue to the local health department (14) (see **Section 3** for a broader discussion of the role of consumers and civil society organizations in developing and using indicators). In food supply chains that span national and international distribution, detecting illness may become more difficult as cases are spread out and multiple national systems may need to coordinate detection and response efforts. Even for more geographically restricted supply chains where illness detection and reporting systems are not well connected, lapses occur.

To advance and harmonize outbreak response indicators, the Salzburg Global Seminar and Ending Pandemics working group defined a set of outbreak milestones that can be used to develop customized indexes of outbreak response performance, or outbreak timeliness metrics, in particular as it relates to timeliness of detection and response. The highlighted timeliness metrics include: (a) the time to outbreak detection, (b) time to outbreak verification, and (c) time to outbreak intervention (15). The concept can be extended to One Health systems and the detection of zoonotic disease outbreaks, including foodborne (16). These outbreak response metrics were included in the International Health Regulations, in addition to other metrics (descriptive “core capabilities”) needed to detect, assess, and report public health emergencies of international concern (PHEIC), including foodborne and zoonotic diseases.

The International Health Regulations (IHR), issued in 2005 (17), apply to 196 countries, including all WHO member countries, which can decide to adopt additional national regulations affording the same or a greater level of protection than IHR. IHR include recommendations for measures to adopt at ports, airports, and ground border crossings to avoid disease spread while avoiding disruptions to travel and trade. In addition, in 2019 the WHO released the Benchmarks for International Health Regulations 2005 to further define the capacities needed at subnational and national level to effectively implement IHR 2005 regulations (18). IHR 2005 also requires countries to develop several capacity areas, including: national legislation, policy and financing; coordination and national focal point communications; surveillance; response; preparedness; risk communication; human resources; and laboratory resources (17). The Benchmark tool is structured as 13 capacities related to the State Parties self-assessment, and 19 technical areas associated with the Joint External Evaluation (JEE) components of the IHR toolbox. To provide more guidance on how countries can achieve these requirements, WHO published a meta-analysis of lessons learned from past implementation of the IHR (19).

As an example of established performance indicators for surveillance and response systems at national level, the U.S. Council to Improve Foodborne Outbreak Response (CIFOR) (20,21) has also developed an extensive set of indicators relevant to outbreak response performance. This set of metrics, which encompasses the responsibilities of local and national government authorities, covers four central functionalities of food safety systems: “the surveillance system evaluated; follow up on complaints, cases and isolates; complaint/cluster investigations; and outbreak summaries and reporting to NORS (National Outbreak Reporting System)” (21). The CIFOR performance metrics include the indicator, the metric used to measure it, and an acceptable or target range (quantitative). Tables of these indicators can be found at <http://cifor.us/products/guidelines> (21).

Setting measurable health targets. Indicators are used to assess the performance of food safety and public health systems, not only in absolute term, but also against measurable objectives developed using the same metrics. For example, in the US Healthy People 2020,

now renewed as Healthy People 2030, specified quantitative objectives and tracked progress for approximately 1,300 objectives organized into 42 topic areas of public health, including food safety (22,23). Among foodborne disease burden control objectives, most are defined in terms of hazard (e.g. reducing incidence of nontyphoidal *Salmonella* infections) or in terms of hazard and food category (e.g. Shiga-toxin producing *E. coli* in beef). Health outcome indicators included are number of infections and number of outbreaks, as well as proportion of infections resistant to antimicrobials. Other Healthy People 2030 indicators include the extent of implementation of food safety practices (see **Section 4-1** and **Table 2**) (23). Food safety indicators are also included in international health targets, although not always explicitly. For example, WHO's Thirteenth Programme of Work (24) includes indicators of WASH, which is tightly linked with food safety, and mortality that includes FBD burden. However, food safety and FBD burden are not mentioned explicitly (**Box 1**). Consistency of indicator definition and use over time, as well as consistency in the methods used to collect indicator data, are key to reliable estimates of progress.

Box 1. Progress indicators in the WHO Thirteenth Program of Work.

In 2020, WHO released its Thirteenth Programme of Work (24) to address “the triple billions” health needs, including key indicators for monitoring progress. Key goals include universal health coverage, health emergency protection, and increased health, each most needed by one billion people. Outcome indicators comprise risk indicators as well as other associated with best practices, and include, although do not single out, outcomes associated with foodborne disease or food safety such as:

- Mortality rate from unintentional poisoning
- Mortality rate attributed to exposure to unsafe WASH services
- Proportion of population using safely managed drinking-water services
- Proportion of population using safely managed sanitation services
- Proportion of population using hand-washing facility with soap and water

Indicators also include developmental outcomes associated with nutrition and food safety, such as the proportion of children stunted, wasted, or obese.

Exposure indicators. In addition to measuring disease outcomes, measures exist to assess the degree of exposure to some hazards, such as chemical hazards. Such assessments usually need to be carried out at the individual level, then summarized at the population level. Exposure metrics, often called “markers” and usually based on measuring the marker’s concentration in a tissue or body fluid sample, may or may not be directly linked to the ultimate health outcome associated with the hazard. The marker can be the hazard itself, a by-product, or a physiological parameter whose link to exposure is well established. For example, long-term exposure to cadmium can be assessed by analyzing blood, urine, or hair samples via absorption spectrometry (25,26). Similarly, exposure to mercury can be assessed

by measuring the hazard's concentrations in tissues such as hair, urine, blood, nails, cord tissues or blood, and placenta (27). In those cases, only exposure is assessed, not its health outcomes. In the case of dioxins, established exposure biomarkers, such as serum levels of sex hormones, biomarkers of glucose homeostasis, or markers of semen quality, are physiological function metrics linked to an adverse effect (28). Exposure metrics exist for microbial pathogens, for instance detection of specific antibodies in blood. However, most foodborne pathogens do not confer long-term immunity, and hence exposure assessments at population level are both challenging and of limited usefulness.

Exposure metrics can be used by public health authorities to strengthen evidence linking a hazard to a health outcome, to evaluate whether a known hazard is being effectively controlled, or to anticipate potential risks based on exposure levels. While not commonly used as national-level health indicators, exposure indicators can complement disease surveillance programs. On their own, exposure measurements do not usually allow attribution to specific exposure pathways, such as food in general or a specific food. Hazard assessments (see **Section 4-1**) and associated data, which may include exposure markers, are needed to effectively characterize and manage foodborne risk.

Local and informal surveillance. While a national-level disease surveillance system provides a comprehensive data-driven resource that can be directly interfaced with policy and corrective action, several surveillance functions can also be carried out – to a certain extent – by actors other than government authorities. For example, civil society and advocacy organizations have conducted their own testing campaign to address specific consumer concerns and help keep government authorities accountable. Examples are discussed in **Section 3-2**. However, in the context of foodborne diseases the best consumer-focused indicators are testing for hazard in food before it is consumed, not clinical testing after.

Data collection, management, and access. The effectiveness of public health indicators and associated monitoring programs are tied to the ability to detect, collect, analyze, manage, and share data. Data collection programs can take the form of routine public health reporting, ad hoc surveys, or outbreak investigations. Data that require sampling, laboratory analysis, and data analysis and sharing, such as clinical, veterinary, and food hazard sampling-based assessments, face additional challenges due to the infrastructure, logistics, consumables (e.g. single-use vials, pipette tips, petri dishes, etc.), and skills required. A range of national and international initiatives aim to support countries in developing their analytical capacity in laboratories as well as at other stages of the data pipeline (29,30). New approaches are also being developed. For instance, the WHO is developing the Epidemic Intelligence from Open Sources, which is an event-based public health surveillance system able to receive data from a range of informal sources (31,32). While data and data-sharing standards for foodborne diseases and hazards are lacking, guidance developed as part of pathogen-specific

surveillance efforts such as the Pandemic Influenza Preparedness Framework (33) could provide useful templates.

3. THE DEMAND SIDE

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

Central to EatSafe’s work is understanding (and potentially shaping) the motivations, attitudes, beliefs, and practices of actors throughout the value chain. This is particularly important for those actors at the point of purchase—i.e., consumers and food vendors—as their actions can either exacerbate hazards that enter earlier in the supply chain or introduce new hazards. Choices made at the retail level and consumer demand more generally have been a major driver of safer food in middle- and high-income countries (34–36). While EatSafe will undertake novel primary research on consumer and vendor motivations and practices, it is essential to ensure that this work is informed by and builds on what has already been done—both in terms of methods used to select and measure consumer-level variables and results obtained. There are a variety of studies that focus on demand, and we have included both those that cover consumers and retail food service workers, where food handling behaviors are essential to food safety.

Studies of KAP (Knowledge, Attitudes, Practices) use both survey and observational techniques to document food safety perspectives within a given population. “Attitudes” can include the basic ideas and beliefs related to food safety (i.e., respondents ability to conceptualized “food safety” or hygiene); traditional cultural beliefs and traditions related to food safety and hygiene; and “willingness to pay” (37).

The impact of cultural differences in consumer knowledge, attitude, and practices in managing food safety can be profound, even within the boundaries of a single country. EatSafe will analyze the specific cultural context for each market that it studies. To understand the types of consumer practices that may serve as indicators, we reviewed a meta-analysis on “Consumer Food Safety Knowledge, Practices, and Demographic Differences: Findings from a Meta-Analysis” (38). This meta-analysis reviewed 20 studies to assess consumers’ knowledge and practices on a variety of food safety handling practice indicators related to:

- consumption of raw or undercooked beef, eggs, shellfish and raw milk;
- hygiene;
- cross-contamination;
- proper defrosting;
- safe food holding;

- proper cold storage;
- avoiding unsafe food sources; and
- proper cooking and heating.

While the practices studied are specific to conditions in North America, the variations in practices can help guide EatSafe in analyzing practices in other regions.

The consumer categories analyzed included gender, ethnicity, age, income, education, urbanization, and geographic region. The studies found a variety of differences based on those categories:

- Differences in gender were identified: women were less likely than men to consume raw or undercooked foods. Men were found to have less knowledge and reported use of good hygiene practices; practices to prevent cross-contamination; proper defrosting practices; and lower use of practices to identify safe food sources.
- Differences in ethnicity, age and education were observed. Some ethnic groups were less likely to consume raw or undercooked foods. Young adults were found to have the poorest food safety practices and the least knowledge on proper practices. Those with the least education reported consuming less raw and undercooked foods and reported higher rates of hygiene and proper cooking and heating practices.
- With respect to income, those in the higher income category reported more consumption of raw and undercooked foods and were least knowledgeable about good hygiene practices and preventing cross-contamination.
- Finally, consumption of raw and undercooked foods was reported more in urban areas and regional differences were observed: in the U.S. western region (Mountain), raw and undercooked beef and egg consumption was highest, while raw or undercooked shellfish was highest in the South Atlantic region, and raw milk consumption was highest in the West South Central, which was attributed in part to the consumption of raw milk cheeses by the Hispanic population in that area.

Shifting to an examination of studies from other regions to evaluate whether the indicators described for North America are relevant to consumers in other regions, several studies provide examples of measures and indicators on food safety knowledge, attitudes, and practices (KAPs) among consumers and food handlers in developing countries. While overall there is consistency in many of the indicators across the regions, additional analysis is needed to ensure cultural differences are understood. Measures in these studies are or are closely connected to basic metrics used in surveys and observation studies. Aggregated or large-scale indicators of consumer KAPs are less common. Also, metrics in such studies are not usually risk-based, so their relative and absolute impact on food safety and FDB needs further assessment.

One 2019 study compared countries in Asia and Africa (39). Using structured questionnaires, researchers surveyed 453 consumers comprising 265 from Africa and 188 from Asia. Practice indicators examined in the survey include:

- Consuming food kept for extended periods at room temperature.
- Tasting or dishing out food with unprotected hands while 48% of respondents sometimes do.
- Washing fruits or vegetables before eating.
- Reading the conditions of use and storage of packaged food.
- Defrosting food outside the refrigerator.
- Using an apron when cooking.
- Storing raw food separate from cooked food.
- Covering cuts with bandages and used gloves.
- Keeping food unrefrigerated for more than 2 hours.

Attitudes examined in the study include:

- Belief that food safety knowledge is important to them.
- Knowledge and attitude towards food safety affected respondents' practice of food safety procedures.

EatSafe conducted a literature review of consumer and food vendor perceptions related to food safety in Nigeria. The identified studies included many that evaluated critical food safety activities and knowledge, for example regarding handwashing, refrigeration temperatures, different types of foodborne pathogens, the use of protective clothing/equipment, and the importance of cleaning surfaces and/or utensils. For studies where vendor practice was observed, typical indicators included covering of food, wearing aprons and/or hairnets, having long nails, handling money or food with uncovered or unwashed hands, using dirty utensils and/or not washing utensils, and not working when ill. For observations of the environment surrounding vendors, typical indicators used included access to water/handwashing facilities, trash receptacles or presence of litter, presence of flies/rats, availability and type of toilet facilities, and cleanliness of the space (37). For consumers, surveys tended to cover similar questions to those used for vendors, but with a less technical focus. Main topics examined both knowledge and practice and included general awareness, types and causes of foodborne illness, hygiene practices, hand and utensil washing, food storage, clean water, and importance of proper cooking or refrigeration (37).

Another relevant study, published in 2016, examined food safety KAPs among food handlers in Ghana (40). The food handlers worked in institutional food service establishments that serve hospitals, boarding senior high schools and prisons in Accra, Ghana. A total of 278 food handlers (56.8% of hospital, 30.9% of schools and 12.3% of prison food service) participated in the cross-sectional study. Data was collected by face-to-face interviews, and responses

were scored to determine the level of food safety KAP. Respondents with $\geq 70\%$ of the maximum possible score were judged to have sufficient knowledge and practices and positive attitudes and results showed that respondents generally had insufficient food safety knowledge and practices. Practices of greatest concern identified by researchers were:

- 1) Lack of knowledge of sources of contamination/cross-contamination and appropriate holding temperatures for food.
- 2) Poor practices included multiple freeze-thaw cycles for frozen food and
- 3) Infrequent hand washing during food preparation after coughing or sneezing.

Researchers concluded insufficient food safety knowledge, attitudes and practices were observed for food handlers in institutional food service; significant gaps remain in safe food thawing and proper hand washing practices after coughing and sneezing; consistent and efficient training on food safety was needed to bridge gaps; and establishment of a food safety culture is necessary to enforce safe food practices. This study also provides an example for how to combine different metrics specific to e.g. survey questions into a summary indicator. In this step, the selection of meaningful basic metrics, as well the attribution of relative weight, are key for the development of a meaningful indicator.

Overall, while not established by standard-setting organizations, several measures and metrics to describe consumer knowledge, attitudes, and practices have been regularly used by researchers and practitioners working with consumers. These measures can form the basis for the development of indicators in this domain.

3.2 Indicators Used by Civil Society Organizations

Consumer organizations have developed methods to evaluate government food safety programs, work that is also relevant to identifying key food safety indicators. For example, one consumer organization developed a food attribution database, identifying food/pathogen combinations that help government and industry develop the hazard analysis used in their preventive control systems (8). Below are other examples of indicators developed and used by consumer organizations (14):

- Percent of solved outbreaks, those with both an identified food and identified pathogen
- Reported outbreaks per hundred thousand population (with the caveat that the more outbreaks reported likely indicate that the public health system is working)
- Size of reported outbreaks (smaller outbreak size indicates that the contaminated food was identified and removed from the market more quickly)
- Pathogens associated with foodborne illnesses and outbreaks
- Location of consumption of food implicated in outbreak
- Use of a standardized outbreak investigation protocol
- Consumer access to foodborne illness reporting systems

- Education and training of medical personnel in food hazards and outbreak reporting
- Use of up to date technology for outbreak detection
- Training of state or regional public health professionals in outbreak reporting
- Funding for public health departments

In a 2008 study by the Center for Science in the Public Interest (CSPI), CSPI surveyed 1200 consumers, identified areas of top consumer concern, and applied those in reviewing restaurant inspection reports (41):

- Employee cleanliness (in addition to handwashing)
- Rodents/insects
- Improper uses of wiping clothes
- Presence of ill restaurant workers
- Bare hand contact with raw food

Consumer innovations. In the internet age, information sharing platforms help consumers manage their food choices. These platforms can include metrics and rating scales (e.g. out of five stars) that allow consumers to provide a subjective evaluation as well as better interpret food safety data and guidelines. Systems like Yelp and TripAdvisor are used by consumers in many countries to rate restaurants and other food businesses. Yelp (www.yelp.com) is a crowd-sourced local business review and social networking platform and operates platforms in the U.S. and many European countries. In 2017, Yelp reported having 141 million unique monthly visitors and hosted 148 million reviews. The majority of Yelp searches are done on mobile devices. TripAdvisor (www.tripadvisor.com) reaches 463 million monthly visitors, and features 859 million reviews on its platform, covering 8.6 million establishments. These platforms give consumers the ability to report in real time on the quality of the food and any adverse experiences. While this types of platforms are a powerful tool that empowers consumers to share information and take charge of their purchasing experience, they are not immune from biases (e.g. reviews are virtually anonymous and could be manipulated to increase or decrease a score) and could be misleading.

A platform popular in Europe, called Open Food Facts, gathers nutritional and other labelling data for over a million products (3). It has 50,000 contributors from Europe and provides the information free of charge. Over 100 applications communicate the information, which is used by millions of consumers daily. In the U.S., the USDA Food Safety and Inspection Service—the government agency in charge of meat and poultry inspection – developed FoodKeeper, a phone or computer app for consumers. Through the app, consumers can look up or receive information on current outbreaks and recalls, as well as information on proper food handling and preparation at home (42). While currently unidirectional, this type of dedicated information channel can increase consumers’ awareness and knowledge, in turn increasing consumer demand for safer foods and their ability to maintain food safety at home.

In addition, consumer organizations play a potentially significant role in fostering discussion and influencing legislators and government agencies to improve national food safety systems, including by developing or supporting indicators. For instance, the Safe Food International project, started in 2003 by CSPI with support from the WHO and FAO, consulted a range of consumers organizations worldwide to gather input on approaches and features of effective national food safety control systems. The resulting “Guidelines for Consumer Organizations to Promote National Food Safety Systems” (43), covering eight key elements of effective national food safety programs, are shown in **Table 3**. While descriptive in nature, each recommendation can also be associated with indicators (or an indicator in itself) to track the implementation of the guidelines.

4. THE SUPPLY SIDE

4.1 Food Hazard Standards and Indicators

Knowing the common food/hazard combinations, where hazards are introduced or exacerbated in the production or supply chain, and whether their level is acceptable to protect public health is key to manage foodborne risk. 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 at 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 metrics are tightly connected to the protocols and assays used to carry out measurements (**Box 2**).

Box 2. Examples of basic metrics of hazard occurrence.

- Presence/absence (detection), in an individual or composite sample
- Prevalence: proportion of detected samples in a set (e.g. 22% positives)
- Concentration: amount of a hazard in a defined volume or weight (e.g. number of virus particles in 100 ml, or metrics representative of concentrations e.g. genomic copies, genome sequencing reads)
- Hazard subtyping (microbial): fingerprint of a microbial sub-type, e.g. to identify common source (e.g. outbreak investigation)
- Genomics characterization (microbial): genetic fingerprint of an isolate, or relatedness to other isolates, used to characterize isolate traits or identify a common source
- Harmful trait detection: presence of a harmful characteristic in a microbial isolate, identified via phenotypic or genetic approaches (e.g. virulence, antimicrobial resistance)
- Harmful trait level: degree of expression (or potential expression) of a harmful trait in an isolate (e.g. minimum inhibitory concentration to quantify level of antimicrobial resistance)

Codex Alimentarius standards. Codex provides the most comprehensive set of international standards on food safety designed to be broadly applicable in LMICs (44). 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 uses a consensus building process, which frequently takes several years to complete. 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 (44) (see **Table 4**). 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 (45,46,47). All Codex texts (standards, guidelines, and codes of practice) are voluntary, and must be included into national legislation to be enforceable. In addition to reference standards and scientific advice, the Codex Commission also provides capacity building to allow LMIC to participate in standard setting activities and training.

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 (44,48). Codex standards also serve as reference for international food trade. Individual commodity standards rely on Codex

Box 3. Example of Codex standards language

From “STANDARD FOR TOMATOES (CODEX STAN 293-2008)” (44):

7. CONTAMINANTS

7.1. The produce covered by this Standard shall comply with the maximum levels of the **Codex General Standard for Contaminants and Toxins in Food and Feed** (CODEX STAN 193-1995).

7.2. The produce covered by this Standard shall comply with the **maximum residue limits** for pesticides established by the Codex Alimentarius Commission.

8. HYGIENE

8.1. It is recommended that the produce covered by the provisions of this Standard be prepared and handled in accordance with the appropriate sections of the Recommended International **Code of Practice -General Principles of Food Hygiene** (CAC/RCP 1-1969), **Code of Hygienic Practice for Fresh Fruits and Vegetables** (CAC/RCP 53-2003), and other relevant Codex texts such as Codes of Hygienic Practice and Codes of Practice.

8.2. The produce should comply with any microbiological criteria established in accordance with the **Principles for the Establishment and Application of Microbiological Criteria for Foods** (CAC/GL 21-1997).

general standards for food safety and do not specify indicators or quantitative standards for the commodity (see **Box 3**). General Standards provide principles and guidance for countries to develop their own quantitative standards, while establishing a common framework for harmonized assessments across countries. Codex standards are periodically reviewed and updated, which should be considered when selecting indicators consistent with Codex.

Hazard indicators in the supply chain. From the technical point of view, hazard metrics and indicators can encompass a range of scales and refer not only to the finished product but also to the performance of different stages of the supply chain. Codex has defined key types of indicators that can be used for hazard monitoring in food supply chains. Food safety objectives (FSO) and performance objectives (PO), as well as performance criteria (PC) are key categories of hazard indicators that are used to manage risks from microbial hazards in food (49,50). According to Codex, they can be defined as:

- Food Safety Objective (FSO): the maximum frequency and/or concentration of a [microbiological] hazard in a food at the time of consumption that provides or contributes to the appropriate level of protection (ALOP)
- Performance Objective (PO): the maximum frequency and/or concentration of a hazard in a food at a specified step in the food chain before the time of consumption that provides or contributes to an FSO or ALOP, as applicable
- Performance Criterion (PC): the effect in frequency and/or concentration of a hazard in a food that must be achieved by the application of one or more control measures to provide or contribute to a PO or an FSO.

These concepts are key to the development of risk-based indicators that tie operational performance to food safety (e.g., hazard levels) and health risk outcomes (e.g., morbidity or mortality).

Microbiological criteria. Microbiological criteria are 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 (50). According to Codex, “a microbiological criterion is a risk management metric which indicates the acceptability of a food, or the performance of either a process or a food safety control system following the outcome of sampling and testing for microorganisms, their toxins/metabolites or markers associated with pathogenicity or other traits at a specified point of the food chain” (49). An analogous concept can be applied to chemical hazards. The most common types of microbiological criteria used by regulatory agencies generally include (51):

- 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.

The food industry also often sets their own internal standards and objectives in terms of hazard occurrence, or other metrics known to correlate to hazards (such as refrigerator temperature necessary to control bacterial growth, or concentration of chlorine in wash water). Industry standards are discussed in **Section 4-2**.

4.2 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.

GFSI certification benchmarking. One of the largest industry-driven efforts, the Global Food Safety Initiative (GFSI) by the Consumer Goods Forum, benchmarks different private certification programs that assess and certify if food companies meet certain performance standards (52). Launched in 2000, the GFSI is an industry-driven 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 (52). GFSI has developed a set of benchmarking requirements specifying essential features of effective food safety programs. After being reviewed, programs that meet these requirements are officially recognized by GFSI.

With its “Once certified, recognized everywhere” approach, GFSI claims to foster equivalence and convergence among food safety management systems, improve their efficiency, and

avoid the redundancy of multiple certifications. GFSI benchmarking requirements include management and auditing criteria (“Hazard and risk management systems requirement” and “Food safety management systems requirements”) together with review of the content of food safety management systems (Good Industry Practices, Good Manufacturing Practices, Good Agricultural Practices) (53). Example of content requirement categories include: location, design, and layout; product development; product labelling and product information; prevention of cross contamination; water quality, waste management; personnel health and hygiene; housekeeping, cleaning and disinfection; personnel training; site inspection/checks; input (e.g. ingredients); transport; storage; equipment (54). The Version 2020 of the Benchmarking Requirements introduced new focus areas on hygienic design and food safety culture and brought the requirements in greater alignment with Codex Alimentarius guidelines and ISO 22000 standards. In general, GFSI standards include many principles and best practice guidelines found in Codex standards.

ISO 22000 requirements. 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) (55). The 22000 family of standards (**Box 4**) 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.

Box 4. Standard and/or project under the direct responsibility of ISO/TC 34/SC 17 Secretariat.

ISO 22000:2018. Food safety management systems — Requirements for any organization in the food chain

ISO/TS 22002-1:2009. Prerequisite programs on food safety — Part 1: Food manufacturing

ISO/TS 22002-2:2013. Prerequisite programs on food safety — Part 2: Catering

ISO/TS 22002-3:2011. Prerequisite programs on food safety — Part 3: Farming

ISO/TS 22002-4:2013. Prerequisite programs on food safety — Part 4: Food packaging manufacturing

ISO/TS 22002-5:2019. Prerequisite programmes on food safety — Part 5: Transport and storage

ISO/TS 22002-6:2016. Prerequisite programmes on food safety — Part 6: Feed and animal food production

ISO/TS 22003:2013. Food safety management systems — Requirements for bodies providing audit and certification of food safety management systems

ISO 22005:2007. Traceability in the feed and food chain — General principles and basic requirements for system design and implementation

Other standards in the 22000 family apply to specific sectors or product categories. Specification for auditing organizations are included (ISO TS 22003). Overall, these standards integrate the HACCP (Hazard Analysis and Critical Control Points) risk management approach and key principles and guidelines developed by Codex. ISO 22000 standards also form the basis for the Food Safety Certification Scheme FSCC 22000 for food safety management systems, which has also been approved by GFSI. Technical Standards include industry-specific prerequisite programs that food companies should establish. This is where detailed standards associated with food safety practices are specified. Prerequisite programs include categories of standards common to all types of food businesses, as well as industry-specific ones. Prerequisite categories for farming, as example of industry-specific requirements, are listed in **Box 5** (56). Prerequisites for food stores are included in the “catering” prerequisites (57).

Box 5. Prerequisite categories in the ISO/TS 22002-3:2011 Prerequisite programs on food safety — Part 3: Farming (56).

5. Common Prerequisite Programs

- 5.1 General
- 5.2 Location
- 5.3 Construction and layout of premises
- 5.4 Equipment suitability and maintenance
- 5.5 Personnel hygiene
- 5.6 Working animals
- 5.7 Purchasing management
- 5.8 On-farm storage and transport
- 5.9 Cleaning
- 5.10 Waste management
- 5.11 Pest control on farm premises
- 5.12 Management of products suspected to be unsafe
- 5.13 Outsourced activities

6. Prerequisite programs specific to crop production

- 6.1 General
- 6.2 Irrigation
- 6.3 Fertilization
- 6.4 Plant protection products
- 6.5 Harvest and post-harvest activities

7. Prerequisite programs specific to animal production

- 7.1 General
- 7.2 Feed and water for animals
- 7.3 Health management
- 7.4 Milking
- 7.5 Shell egg collection
- 7.6 Preparation for slaughter
- 7.7 Growing, harvesting, and handling of aquatic animals

Industry standards in the informal sector. The standards and certification programs discussed above have been successful in large companies and are increasingly adopted by medium-size food businesses. However, 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 (58,59) (CAC/GL22R-1997). Categories covered in CAC/GL22R-1997 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 (59). While not all informal sector activities are covered by Codex guidelines (for example, marketplaces are currently not), existing standards provide a set of relevant indicator categories that may be adapted to other informal sector businesses. Extensive data collection would be required to go from descriptive guidelines to measurable indicators used to assess progress. However, guidelines often articulate desired practices and outcomes, which can form the basis for measures and associated targets. Hence, they represent a key and often necessary step in the indicator development process. To offset some of these challenges, the GFSI has launched the “Global Markets” program, which provides small businesses a step-by-step program to start or improve their food safety system (60). The program involves three pre-certification steps (self-assessment, basic, and intermediate) and covers primary production and food manufacturing. After the intermediate step is completed, the business may apply for certification through a GFSI-approved scheme. While the availability of simplified stepwise programs (and associated metrics) that progressively build capacity within a continuous improvement approach are very helpful, they still cater for the formal sector, and their applicability to informal contexts is in question.

5. CORE COMPETENCIES OF NATIONAL FOOD SAFETY SYSTEMS AND INDICATORS FOR PERFORMANCE

Identifying the key competencies necessary for an effective food safety system is a prerequisite to articulating the indicators for national systems. Countries have used many variations when designing their systems. In some countries, a single agency manages food safety while in others, responsibilities are spread across several agencies. Some countries rely on regional or local authorities to manage functions like food business inspections. Others have a national inspection force. Some countries are dependent on food imports for a larger percentage of their national diet, so the national system is focused on imported foods and its safety is determined and certified outside national borders. Other countries have developed very modern systems for the regulation of exported products, but exercise more limited control for foods intended for domestic consumption

Codex has advised governments on the design, operation and performance monitoring of their food safety systems, and these documents define important objectives and desired outcomes for the development of indicators. The Codex *Principles and Guidelines for National Food Control Systems* (CAC 82-2013) (61) defines 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. It describes the following essential principles, among others:

- 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.

See **Appendix 1** for Codex standards for designing effective national food control systems.

Codex also offers guidance for national governments in the development of their own indicators for food safety, in the *“Principles and guidelines for monitoring the performance of national food control systems”* (CAC/GL 91-2017) (2). It recommends governments establish food safety indicators for each desired outcome for the effective national food control system. Codex advised that indicators should be: 1) unambiguous, 2) easy to interpret and monitor, 3) transparent, 4) closely linked to the outcomes, 5) meaningful from an organizational perspective, 6) amenable to independent validation and/or verification, and 7) obtainable given the available resources.

National food safety indicators rely on the collection of datasets to conduct the necessary measurements. According to an expert panel on food safety indicators at a 2017 FAO regional meeting, “If no data collection is done in a country when one important indicator requires such data, having this particular indicator is already a significant help in identifying minimum priorities to set up relevant data collection mechanisms. Data collection mechanisms do not have to be highly sophisticated, and often simple data collection methods will suffice. However, it should be noted that some forms of datasets exist in almost all countries, including developing countries. What is really missing are the systematic data compilation and sharing mechanisms within a country. In order to use national food safety indicators to obtain their maximum potential, data compilation and sharing among partner agencies are key components.” (FAO *Regional consultation on food safety indicators for Asia and the Pacific*, 6–8 December 2017, Singapore) (63).

While it may be best for the national competent authority to develop its own indicators in order to capture country-specific capacities and situations, many countries have identified hurdles, e.g. various technical and capacity challenges they face in developing useful national food safety indicators.

Experts participating on the FAO panel also opined that national food safety indicators could be used in four different ways: 1) as a measuring tool to review the current status of food safety in the country; 2) to identify the successful areas and areas needing intervention and/or improvement; 3) to allocate resources so that actions can be taken to improve areas that have been identified as requiring an intervention; and 4) to evaluate the impact of such interventions.

Indicators of food safety regulatory activities. The most comprehensive source for food safety indicators was contained in the 2017 FAO regional report, cited above (63). 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 they had found through a literature review (**Table 5**). Examples of capacity-level indicators identified by FAO 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 must first consider the underlying infrastructure. According to a report from the Global Food Safety Partnership (64), the physical infrastructure needs are extensive:

- Clean water/electricity/transport/sanitation (core infrastructure)
- Safe food storage
- Cold chain
- Sanitary food handling facilities
- Effective processing equipment
- Laboratory capacity
- Food service facilities

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. The OIE has a model tool, called the PVS Toolkit (65). It contains the key components for a national control system for animal health, with a ladder of development for the competencies. A similar tool would be extremely valuable for food safety competencies.

According to a 2005 report by the Safe Food International, a FAO/WHO working group with consumer organizations (43), there are eight essential elements for an effective food safety regulatory system (see **Table 3**):

- 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

In the Safe Food International *Guidelines for Consumer Organizations to Promote National Food Safety Systems* (43), indicators were identified to evaluate each of those areas. Of note, the aspect of self-assessment and review procedures was not covered in that document.

Ref.	Type of indicator	Weighting factor
FSI1:	Mandatory notification with regard to food safety	1,16
FSI2:	Self-checking systems in the supply sector for primary production	0,9
FSI3:	Self-checking systems in the primary sector	0,71
FSI4:	Self-checking systems in the transformation sector	1,16
FSI5:	Self-checking systems in the community kitchen sector	0,79
FSI6:	Monitoring of self-checking throughout the food chain	2,06
FSI7:	Inspections of infrastructure, installations and hygiene in the sectors of distribution, hotels & restaurants and community kitchens	1,88
FSI8:	Inspections regarding traceability within the food chain	1,65
FSI9:	Residues from pesticides/herbicides in fruit and vegetables of Belgian origin	0,98
FSI10:	Acrylamide	0,41
FSI11:	Lead and cadmium in fruit and vegetables	0,75
FSI12:	Aflatoxin and deoxynivalenol	0,9
FSI13:	Substances with an anabolic action, unauthorized substances and veterinary drugs for cattle and pigs	1,5
FSI14:	Sulfite in minced meat	0,38
FSI15:	Dioxins and dioxin-like PCBs in dairy products and in eggs	0,98
FSI16:	Mercury in molluscs, crustaceans and fish	0,53
FSI17:	Residues from pesticides/herbicides in fruit and vegetables originating from other EU countries and third countries	1,39
FSI18:	Forbidden colorants	0,53
FSI19:	Chemical and microbiological hazards in imported animal products intended for human consumption	1,73
FSI20:	Dioxins and dioxin-like PCBs in feed	0,94
FSI21:	Contact materials	0,64
FSI22:	<i>Salmonella</i> sp. in meat pigs	0,49
FSI23:	<i>Salmonella</i> sp. in layer hens	0,49
FSI24:	<i>Salmonella</i> sp. in poultry and pigs	0,98
FSI25:	<i>E. coli</i> in carcasses and cut meat	0,68
FSI26:	<i>E. coli</i> in foodstuffs	0,71
FSI27:	<i>Listeria monocytogenes</i> in foodstuffs	0,9
FSI28:	Foodborne outbreaks	1,46
FSI29:	Salmonellosis in humans	1,28
FSI30:	Listeriosis in humans	1,09

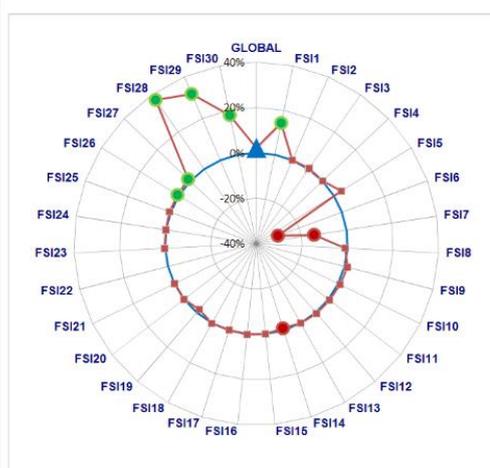


Figure 4. Priority food safety indicators included in the Belgian AFSCA Barometer (66).

Example of national and regional food safety indicators. An interesting example of government-developed indicators focused on food safety is the FASFC Barometer developed by the Belgian government (**Fig. 4**) (66). This set of 30 key indicators were chosen not to be

comprehensive, but to track priority food safety issues that matter most at national level. Individual indicators are also assigned a weight based on their importance and aggregated into a single “Barometer” indicator that provides an overall assessment of national progress.

The African Union, through the Comprehensive Africa Agriculture Development Programme (CAADP), has developed a set of indicators (Fig. 5) 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) (67,68):

- **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 violation on trade, within the goal of tripling food commodity trade by 2025.

These indexes are included in a country scorecard, updated every two years.

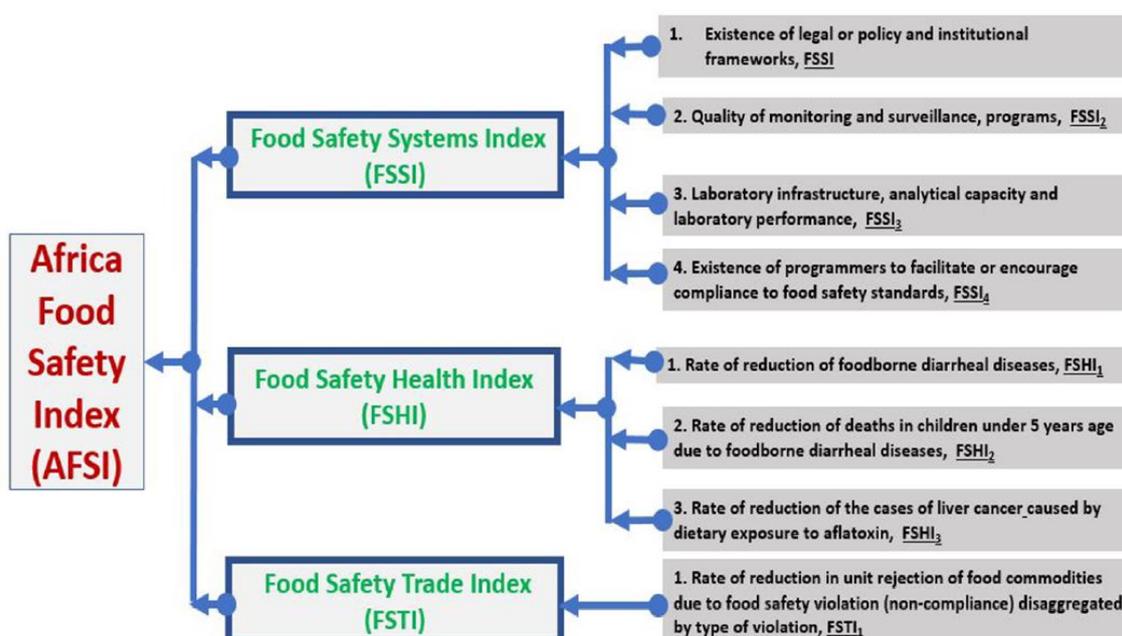


Figure 5. Main indicators included in the African Food Safety Index (67,69).

In conclusion, there are a broad variety of indicators available to evaluate government-managed food control systems. Ideally, broad indicators can be designed around clear categories, with the objective to give governments a development ladder to track and improve their food safety programs, similar to the PVS Toolkit (65).

6. OTHER 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).

In general, enabling environment factors should have:

- a significant impact on the desired outcomes,
- the ability to have a positive impact (including via removal of barriers) and
- the ability to foster improvements in multiple connected systems, including via feedback loops.

Enabling environments can take different forms depending on the scale, e.g. from local informal food markets to regional food production to international import/export. Of importance, a key system component can -and often is- part of the enabling environment of another sector; for example, food safety standards can be seen as part of the enabling environment for food business development (potentially as a positive influence, or as a barrier).

While the objective of the food safety system to provide universal access to safe nutritious food is clear, there are no consistent and vetted set of indicators for food safety enabling environments. Many indicators already discussed in this review, such as the establishment of a dedicated food safety agency, the adequacy of laboratory capacity, or the adoption of food safety legislation, are directly connected to and impacted by enabling environment. Main components of enabling environments for food safety include but are not limited to:

- **Geographical, climatic, and natural resources** (e.g. per capita availability of water, risk of flooding, water quality, extent of droughts, seasonal factors) that impact multiple aspects of food production and processing
- **Biodiversity** and other biotic/ecologic factors (e.g. proximity between food animals and wildlife, ecosystem services, ecosystem health) which can affect and help control foodborne hazard occurrence and transmission in the food supply chain

- **Socio-economic status**, which impact access to a range of services including education, financial, and health care (indicators include average income, percentage in poverty, percentage in formal-sector employment, etc.)
- **Population health**, e.g. the occurrence of other diseases that can impact food safety or spill over into food supply chains (e.g. HIV incidence may render part of the population more vulnerable to foodborne diseases; malaria incidence may affect ability to prepare meals or maintain home hygiene)
- **Healthcare system**, which impacts how well foodborne disease can be identified and treated (indicators include health worker density, distance to health center, outpatient services utilization, immunization coverage, International Health Regulations capacity index, etc.) (70)
- **Education and human capital**, which impact job skills and ability to make evidence-based choices both for food safety professionals and citizens (indicators include average education level, education by gender, % literacy, etc.)
- **Cultural context** impacting food and health choices (e.g. popularity of raw meat dishes, % consuming raw vegetables, preference for processed food, brand preference, risk awareness or avoidance, food safety culture in restaurants, retail, and other food businesses, religious beliefs, gender roles, etc.)
- **Water, sanitation, and hygiene (WASH)** systems and infrastructure, which directly impact food and environmental contamination (indicators include % access to improved water facilities, % access to improved sanitation, distance/time taken to get water, availability of clean drinking water, behaviors such as % washing hands) (71)
- **Infrastructure** (in addition to water and sanitation) such as roads, transportation (e.g., rail, ports, airports), internet access, satellites, mobile phone services and ownership by gender, access to electricity, marketplace structures, etc. that affect the food business operations through the supply chain as well as consumer food safety
- **Democracy and government** stability (e.g. indicators of corruption, press freedom, market regulations, justice system, democratic elections, etc.) that affect the functioning of all civil society actors and organizations
- **Regulatory environment and institutions** such as the presence of a clear policy and legal framework for food safety, and its implementation and enforcement, extent of public-private dialogue
- **Business, trade, and entrepreneurship** environments at international, national, and local scales, which impact the ability to start new businesses, and run and grow existing businesses (indicators may include presence and quality of trade regulations, taxes, market stability, stable currency, anti-trust, presence of business development networks, labor market, insurance or other safety nets, amount of investments).

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 (71). 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 (72). In addition to discussing the hierarchy of enabling

environment factors (73), the framework points to sets of established indicators such as the World Bank Group's Ease of Doing Business Index (www.doingbusiness.org), the Growth Competitiveness Index, or the Current Competitiveness Index and the Business Competitiveness Index by the World Economic Forum (74), as well as the toolkit developed by the USAID Agriculture-Commercial Legal and Institutional Reform (AgCLIR) to assess business environments (75,76). While not currently linked to food safety system performance or public health outcomes, tailoring existing indicators to encompass food safety outcomes could assist in identifying key enabling environment factors.

Discussions around enabling environments for food security and nutrition can be particularly useful as they consider factors affecting the functioning of food production and supply systems, as well as consumers. In the context of the USAID Feed the Future initiative, the "Enabling environments for food security" project (77) 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 (78) has defined the key categories of enabling environment factors, divided by supply chain segment, including:

- 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).

The guidance document includes indicators for each of those broad categories, developed within the context of the project (i.e. animal source food markets in low- and middle-income countries targeted by Feed the Future) (78).

Finally, individual food safety projects have included factors from enabling environments. For example, the International Livestock Research Institute (ILRI) has included enabling environments for food safety in several projects, for example when investigating the role of capacity strengthening to enable food safety in informal markets (79). 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.

7. CONCLUSION AND IMPLICATIONS FOR EATSAFE PROGRAM DESIGN

This review highlights key categories of measures and indicators relevant to food safety and provides examples of national and international sets of indicators and associated standards that have been developed in the last decades. This body of work, while not comprehensive, provides a reference to discuss future development of harmonized indicators for food safety, and to adopt indicators that account for impact pathways between nutrition and food safety, in the context of food systems.

Preliminary conclusions can be drawn from this review, including:

- **Food safety indicators** serve multiple goals. They support developing measurable food safety objectives; tracking progress in a range of system functions; benchmarking; identifying needs and prioritizing interventions; and communicating using a common vocabulary.
- **Indicators of foodborne disease** burden are generally well developed and clearly defined; however, the surveillance and data management systems needed to effectively deploy these indicators to manage risk are often lacking, and vary considerably from country to country;
- **Indicators of hazard of occurrence** are also well developed, with an extensive set of General Standards and commodity-specific standards being provided by the Codex Alimentarius Commission.
- **Codex guidelines and standards** provide a common food safety vocabulary based on current knowledge, serving as a reference to exchange information across countries to better manage food safety, protect consumer health, and facilitate food trade. Countries can utilize Codex to establish their own standards.
- **Indicators of national government performance** have been established, both internationally and regionally, based on key operations usually carried out by governmental organizations. However, large variations exist across countries.
- **Indicators of consumers' ability to effectively act** as positive agents in food safety systems are not well developed. While there are established metrics of knowledge, attitudes, and practices that have been used in research and monitoring contexts, these metrics have generally not been adopted as official indicators.
- **Consumer and civil society organizations** have also developed food safety indicators, sometimes independently from and complementing indicators developed by governments. Such indicators have fostered multi-sector discussion and encouraged governments to increase, refocus and refine their efforts.
- **Indicators and standards have been developed and applied by the food industry**, which sit outside the government-sanctioned standards, where available. Industry-driven indicators have been developed for low- and middle-income countries by international organizations; such indicators are widespread in large or multinational companies, but less so in small companies and informal supply chains

- **Enabling environments** comprise a complex network of resources and drivers that impact the effectiveness of food safety systems. Indicators on enabling environments exist in different sectors and disciplines, although **in general they are not yet included in food safety frameworks**.
- **Data collection, management, and sharing systems** are key to the effectiveness of indicators across all categories, and hence are themselves key functionalities to monitor.
- **Indicators relevant to the informal sector are lacking**. While several metrics are shared with the formal sector, adaptations to the needs and capabilities of informal supply chains is needed.
- **Gender-relevant factors** are only occasionally included in indicators (e.g. indicators of health burden disaggregated by gender, metrics of consumer KAPs, enabling environments); further discussion of gender-related factors in indicator design and selection is warranted.
- **Risk-based indicators** are often limited to health burdens and hazards, and to formal supply chains under government oversight; more effort is needed to better link other indicators to ultimate health goals in an evidence-based manner;
- **Food safety and healthy nutrition** are interdependent; future work should include the interactions and impact pathways between the two domains and work towards synergistic and integrated indicators.

Preliminary consideration for indicator selection and application to EatSafe and other food safety programs are summarized in **Box 6**.

Box 6. Recommendations for Intervention Design and Future Studies under EatSafe

This summary review provides a broad overview of indicators and metrics used to assess key aspects of food safety systems.

In addition to the indicators highlighted above, EatSafe should consider measurements that have yet to be incorporated as part of food safety performance including:

- **Metrics of consumer and vendor** knowledge, attitudes, and practices are available but have not been broadly included in food safety indicators;
- The impact of **indicators developed by consumer organizations**, e.g. food/pathogen attribution data, provide evidence and templates for how the civil society can drive food safety improvements by demanding data transparency and relevance, and by interfacing with both governments and market actors.
- **Risk-based indicators** should be preferred to ensure we are monitoring and incentivizing effective practices; risk ranking approaches can help customize indicators to the most important risk factors;
- Effort is needed to develop or **customize indicators that are relevant to informal supply chains and marketplaces**, e.g. accounting for low infrastructure, and relying more on consumer-driven than government-driven indicators;
- **Indicators relevant to enabling environments** for food systems exist but may need to be adapted to food safety objectives and better integrated into food systems;
- A common vocabulary based on indicators may also foster the harmonization of data and practices across formal and informal food supply chains.
- Gender factors and impacts need to be better included in the selection and application of food safety indicators
- **Indicators used in a country should be customized** to the level of development of the national food safety system, as well as cultural and enabling environment factors such as literacy, societal values, religion, and access to information;
- **Industry-developed standards**, where applicable to small and medium-size businesses, may be adapted to support monitoring food safety improvement in informal markets;
- **Consumer-driven rating schemes** have been successful, in high-income settings, to incentivize businesses to improve service quality and to share information among consumers.
- **Where mandatory food safety indicators are lacking**, EatSafe may consider the utility of voluntary standards and incentives for their adoption.

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TABLES

Table 1. Food safety indicators from Food Safety Working Group “Food safety metrics relevant to LMICs” (Grace et al., 2018) (4).

Indicator	Description	Notes
General	<p>Strategic plan must precede the development of measures with clear and realizable goals and practical implementation steps (including metrics).</p> <ul style="list-style-type: none"> - Alignment of the measure with the desired goal; goals rather than measures should be communicated. - Metrics should not be used as performance targets. - Measures should assess outcomes, impact, and processes. They should be easily understandable by diverse stakeholders. - Data should be widely available. - Single measures can be misleading → multiple indicators required for comprehensive measure. - Metrics should be robust to detect temporal change, benefits of measurements should be demonstrated to outweigh costs. 	<p>Metrics can have unintended consequences, e.g. focusing efforts on measuring something rather than the ultimate goal of improving what is being measured; stifling innovation through standardization; costs that increase in disproportion to benefits attained; incentivizing decreased attention to things that are not being measured.</p> <ul style="list-style-type: none"> - Data on import rejections exist, but no information with regards to what happens to foods post-rejection and whether foods end up in other markets. - Conventional risk analysis: often expensive, time consuming, requires many data. - Lack of understanding between trade-offs of food safety and other development issues such as nutrition, equity, or environmental sustainability.
Hazard- and risk-based approaches	<p>Hazard Analysis and Critical Control Points are particularly important in informal settings.</p>	<p>Examples of trade metrics: import rejections, records of administrative actions in importing countries (e.g. bans) and reports from exporting countries of problems related to food safety.</p>
	<ul style="list-style-type: none"> - Public standards: consumer protection by assuring safe food and to eliminate fraudulent practices, historically hazard-based; many hazards have a threshold level below which no effect is detectable → risk-based approaches more useful. 	<ul style="list-style-type: none"> - Standards can act as barrier to market participation - Little capacity for enforcement in informal markets - Missing traceability
	<ul style="list-style-type: none"> - Private standards: important in domestic formal markets and “informal private standards”. 	<ul style="list-style-type: none"> - Fewer checks/balances compared to high-income countries. - Traceability may be an issue.
	<ul style="list-style-type: none"> - Export standards: Codex Alimentarius Commission has major role in international standard formulation/standardization. 	<ul style="list-style-type: none"> - Compliance/verification costs. - Complexity of international trade favors exporting high-income countries.

	Information from food im-/exporters: good indicator of the safety of traded products and indirectly of the safety systems and performance in exporting countries.	
Food Safety System Performance	<p>Performance indicators: show progress against plans in the results chain.</p> <ul style="list-style-type: none"> - <i>Performance metrics:</i> measure how well the food safety system delivers safe food. - <i>Metrics for impact indicators</i> (e.g. longevity or age at death): closest to measuring the performance of the system, may be more difficult to collect and interpret. <p>Metrics for indicators at other levels (output or outcome): easier to collect and interpret; more actionable but may be easier to manipulate.</p>	Consistent and systematic problems.
	<p>League tables: measurement of food safety performance relative to other countries.</p>	Major data deficits require use of indirect indicators.
Foodborne Disease Outcomes	<p>Public health outcomes: surveillance systems to detect/monitor health outcomes. Collected at different levels, e.g. health service institution, community, national population.</p> <ul style="list-style-type: none"> - <i>Epidemiological measures</i> for health burden: incidence, prevalence, mortality. - <i>Composite measures:</i> capture burden of morbidity and mortality, e.g. Disability adjusted life years (DALY): sum of Years of Life Lost due to premature mortality in the population and Years Lost due to Disability for people living with the health condition or its consequences. 	<ul style="list-style-type: none"> - In LMIC often no treatment is sought and/or no biological samples are collected and/or no source identification occurs. - Burden assessment is difficult for many adverse outcomes, particularly chronic outcomes. - DALY is not easily interpreted.

	<p>Economic Outcomes: include harm caused by the disease (e.g. lost productivity from illness), cost of response, cost of prevention (e.g. food safety governance, risk reducing practices)</p> <ul style="list-style-type: none"> - <i>Loss of life:</i> biggest share of health valuation estimates. - <i>Human capital approaches:</i> assess value of lost years of health through the amount of money a person/society is willing to spend to avoid disease or the lost contribution to gross domestic product. - <i>Cost of illness approaches:</i> aim to account for direct (e.g. transportation costs to get treatment, medical expenses, lost wages) and indirect costs (e.g. productivity losses from missed business due to sick employees) of death and illness. 	<p>Lack of published information on economic costs, cost effectiveness and cost-benefit analysis of interventions to improve food safety in domestic markets.</p>
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Table 2. Healthy People 2030 Food Safety Workgroup Objectives (23).

Reduce infections caused by Campylobacter — FS-01
Reduce infections caused by Shiga toxin-producing E. coli — FS-02
Reduce infections caused by Listeria — FS-03
Reduce infections caused by Salmonella — FS-04
Prevent an increase in the proportion of nontyphoidal Salmonella infections that are resistant to multiple drug classes — FS-05
Prevent an increase in the proportion of macrolide antibiotic-resistant Campylobacter infections — FS-06
Increase the proportion of people who wash their hands and surfaces often when preparing food — FS-07
Increase the proportion of people who use separate cutting boards when preparing food — FS-08
Increase the proportion of people who cook food to a safe temperature — FS-09
Increase the proportion of people who refrigerate food within 2 hours after cooking — FS-10
Reduce outbreaks of Shiga toxin-producing E. coli, Campylobacter, Listeria, and Salmonella infections linked to beef — FS-D01
Reduce outbreaks of Shiga toxin-producing E. coli, Campylobacter, Listeria, and Salmonella infections linked to dairy — FS-D02
Reduce outbreaks of Shiga toxin-producing E. coli, Campylobacter, Listeria, and Salmonella infections linked to fruit and nuts — FS-D03
Reduce outbreaks of Shiga toxin-producing E. coli, Campylobacter, Listeria, and Salmonella infections linked to leafy greens — FS-D04
Reduce outbreaks of Shiga toxin-producing E. coli, Campylobacter, Listeria, and Salmonella infections linked to poultry — FS-D05
Reduce the number of norovirus outbreaks — FS-D06
Reduce the number of food allergy reactions requiring emergency treatment — FS-D07
Increase the proportion of delis where employees wash their hands properly — FS-D08
Increase the proportion of delis where surfaces that touch food are properly cleaned and sanitized — FS-D09
Increase the proportion of delis where foods are refrigerated at a safe temperature — FS-D10
Increase the proportion of delis where hot foods are kept at a safe temperature — FS-D11

Table 3. Food safety indicators from the Safe Food International “Guidelines for Consumer Organizations to Promote National Food Safety Systems” (43).

Food safety system element	Guideline/Indicator	Guiding questions
Food Safety Legislation	<ul style="list-style-type: none"> - Should be developed with all stakeholders. - Should be based on high quality, transparent, independent scientific advice that is in line with standards, guidelines, other recommendations of the Codex Alimentarius, contain clear definitions and articulate high level of health protection. - Should ensure that the food authority and producers/processors provide consumers accurate information about food products. - Should include traceback/recall mechanisms for contaminated foods. - Put primary responsibility on food producers/processors - Regular monitoring/evaluation. - Should apply to food aid. <p>Legislation should also establish requirements for labelling relevant aspects pertaining to food safety and risk management, e.g. ingredients, allergen presence; and should ensure safety of feed for food-producing animals.</p>	<p>Have food laws been updated/modernized in the last 10 years?</p> <p>Are food laws responsive to current food safety problems and flexible enough to address new technologies/food products?</p>
Surveillance and Investigation Systems	<ul style="list-style-type: none"> - Should include data on symptoms/effects of chronic exposure to foodborne contamination. - National food control system: links between symptomatic foodborne-illness and the food-monitoring system. - Early warning systems. 	<p>Is there a reporting mechanism for doctors/health workers for (unusual) cases of illness?</p>

	<ul style="list-style-type: none"> - Identification of diseases in animals. 	<p>Are doctors/health-care providers given training materials on how to identify classic foodborne illnesses?</p> <p>Does the surveillance system cover rural areas and those with limited/no healthcare access?</p> <p>Is surveillance coordinated between different country-regions?</p> <p>Is information disseminated quickly to consumers?</p> <p>How sensitive is the alert system – is it active or passive?</p>
<p>Food Control Management</p>	<ul style="list-style-type: none"> - Integrated national food control authority addressing the entire food chain from farm-to-table with the mandate to move resources to high-priority areas. - Development/implementation of integrated national food-control strategy. - Setting standards/regulations; approving ingredients/technologies; participation in international food-control activities. - Development of emergency response activities. - Risk analysis: assessment (hazard identification/characterization, exposure assessment), management (legal, regulatory, educational, voluntary actions). - Monitoring enforcement activities/performance; implementing mechanisms for stakeholder involvement at different stages. - Development of food safety training curricula/programs. 	<p>Requires sufficient resources.</p> <p>Risk assessment: should be carried out by independent scientific committees.</p>

<p>Inspection Services</p>	<p>Should extend from farm to restaurants to ensure that all foods are produced, handled, processed, packed, stored, distributed in compliance with legislation and regulations. Traditional functions include responding to non-compliance with food laws, handling consumer complaints, advising the food sector.</p> <p>Inspections should be based on the risks posed by different foods and the history of problems in a particular sector of the food supply.</p> <p>Information on food inspection results (e.g. hygiene scores) should be made available to the public through different communication channels.</p> <p>Modern food safety inspection functions additionally include:</p> <ul style="list-style-type: none"> - Inspecting premises/processes; - Evaluating HACCP plans and recommending formal action where food safety lapses could endanger public health; - Food sampling during harvest, processing, storage, transport, sale and recognizing spoiled/hazardous food or food that is otherwise unsafe for human consumption or deceptively sold to consumer; - Inspection, sampling, certification of food for im-/export; recognizing, collecting, transmitting evidence; - Encouraging the use of voluntary quality assurance systems; - Conducting risk-based audits of food establishments with HACCP or other safety assurance programs. 	<p>Are inspectors government employees or paid by the food industry?</p> <p>Are there high-risk food facilities that are not inspected?</p> <p>How often are plants inspected and how many samples are analyzed?</p> <p>How are inspectors trained?</p> <p>How are consumer complaints reviewed/handled?</p>
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Recall and Tracking Systems	<p>Food that does not comply with national standards that inadvertently reaches any part of the supply chain.</p> <p>Recalling of contaminated foods can be triggered by different entities; tracking systems are used to trace the route of contaminated foods.</p>	<p>Does the national program require companies to label processed food products and recall unsafe food products?</p> <p>Are processed foods required to be packed in a manner that would make tampering evident?</p>
Food Monitoring Laboratories	<p>Allow examination of food for chemical and microbiological hazards.</p> <p>Can be critical to:</p> <ul style="list-style-type: none"> - Identifying contaminated foods or sources of foodborne disease outbreaks; - Allowing regulators to enforce action against adulterated/unsafe foods; - Confirming the safety of domestic food products, imports/exports; - Allowing for dietary exposure assessments as well as monitoring and analysis of food quality at the user end; - Assisting in regulatory decision-making process and evaluating the effectiveness of risk management interventions. 	<p>How many food safety labs are funded by the government and how often does government audit private laboratories?</p> <p>Do laboratories have adequate analytical ability – what tests are lacking?</p> <p>What types of food are tested, how often, and by whom (private vs official labs)?</p> <p>Does government have an emergency plan in case a large number of laboratory tests are needed in a short time?</p> <p>How often do laboratories have to meet accreditation or certification requirements?</p>
Information, Education, Communication, Training	<p>Risk should be communicated in the context of the overall diet.</p> <p>Communication: with public and industry in emergency situations (e.g. outbreaks, recalls), should be 2-way process.</p>	<p>How often does government communicate with public on food safety matters and what mechanisms are used?</p> <p>Is the government trusted when it issues food safety information?</p>

	<p>Information: Informing the public and food industry about trends in food and foodborne diseases via alert systems.</p> <p>Education: Providing advice on how to avoid foodborne illness, also targeting high-risk groups (e.g. children, pregnant women)</p> <p>Ongoing trainings: for diverse stakeholders.</p>	
<p>Funding and Affordability</p>	<p>Sufficient and transparent funding is required to ensure regular inspections, testing, setting of standards, and risk analysis.</p> <p>Building capacity for food safety systems in poorest economies should be a focus of bi-/multilateral assistance.</p> <p>Food safety programs must be structured to protect/promote public health and be affordable/accessible to small farmers and producers.</p>	<p>Nature of the funding must not compromise their integrity and independence.</p> <p>What is the annual budget?</p>

Table 4. List of active Codex Alimentarius Committees that provide guidelines and standards (80).

General Subject Committees	
CCCF	Codex Committee on Contaminants in Foods
CCFA	Codex Committee on Food Additives
CCFH	Codex Committee on Food Hygiene
CCFICS	Codex Committee on Food Import and Export Inspection and Certification Systems
CCFL	Codex Committee on Food Labelling
CCGP	Codex Committee on General Principles
CCMAS	Codex Committee on Methods of Analysis and Sampling
CCNFSDU	Codex Committee on Nutrition and Foods for Special Dietary Uses
CCPR	Codex Committee on Pesticide Residues
CCRVDF	Codex Committee on Residues of Veterinary Drugs in Foods
CCCPL	Codex Committee on Cereals, Pulses and Legumes
CCFFV	Codex Committee on Fresh Fruits and Vegetables
CCFO	Codex Committee on Fats and Oils
CCPFV	Codex Committee on Processed Fruits and Vegetables
CCSCH	Codex Committee on Spices and Culinary Herbs
TFAMR	Ad hoc Codex Intergovernmental Task Force on Antimicrobial Resistance

Table 5. FAO 2017. Example of food safety indicators relevant to national governments, from “Regional consultation on food safety indicators for Asia and the Pacific” (FAO, 2017) (63).

Indicator	Description	Notes
General	<p>National food safety competent authorities need useful tools/performance indicators to</p> <ol style="list-style-type: none"> 1) Help identify any needs for capacity development; 2) Systematically detect food safety problems; and 3) Assess the effectiveness of new policies/measures to allocate resources to priority areas for the enhancement of food control systems. 	<p>If the number of outbreaks is difficult to measure for a country, it might be worthwhile to consider measures to be implemented to avoid outbreaks as alternative indicator(s). The number of food business operators having standard operating procedures in place to ensure good hygiene practices could be a more realistic and measurable indicator.</p>
System level indicators	<ul style="list-style-type: none"> - Clear government commitment to protect consumers' health and interests and ensure fair practices in food trade. - Enabling policy (legal/regulatory framework) for food safety; functioning food inspection and certification systems; capable diagnostic/analytical laboratories; working mechanisms for information, education and communication with stakeholders. - Presence of an agency to ensure the safety and health of food; Organizations with clearly defined roles/responsibilities for food control management, communication, coordination. - Existence of an institute (governmental or commercial) that collects data on food safety and quality issues, a Codex committee (with staff and budget), a well-functioning body providing advice to government on food safety and quality issues, government representatives, inspection agencies, and relevant international and national NGOs. - Goals, objectives, activities are clearly described for all governmental bodies operating in the field of food safety and quality. 	

	<ul style="list-style-type: none"> - Roles and responsibilities for food safety are appropriately assigned and harmonized across different agencies, clearly defined and implemented in a consistent and coordinated way. - An integrated food chain approach, transparency and the participation of all concerned stakeholders from farm to plate. - Leaders set clear objectives concerning hygiene and food safety and strive for a continuous improvement of hygiene and food safety. - Monitoring of self-checking throughout the food chain. - Conformity with relevant policy and legal frameworks, use of standard operating procedures for food inspection and diagnostic analysis - Mandatory notification. - Presence of relevant certificates. 	
Capacity-level indicators	<ul style="list-style-type: none"> - Food policy research capacity indicators. - Risk-based inspection and audits; risk analysis to inform/support decision-making and establish food safety control measures. - Ability to meet/demonstrate compliance with international food safety/quality requirements and obligations. - Inspections regarding traceability within the food chain. - Sufficient staff, necessary infrastructure and financial resources are available to work in a hygienic/food safe environment. - Number of Codex documents received, made available for access, and disseminated to stakeholders. - Frequency with which government representatives attend international working groups on Codex issues. - Frequency of interaction between national food safety advisory body and regulatory authority. - Frequency with which data are collected on different steps of the food supply chain and reported back to the Food Safety. - Guidelines exist on emergency preparedness and response, stating responsibilities, parties and necessary actions - Percentage of food safety incidences in which the origin of the problem was traced down. - Number of guidelines drafted on HACCP, GMP, and GLP. 	<p>Additional considerations:</p> <ul style="list-style-type: none"> - National food safety emergency response capacity. - Consistency in food recalls and food traceability. - Leaders are clear about expectations concerning hygiene and food safety towards employees and address issues in a constructive and respectful manner. - Operators can communicate about hygiene/food safety with leaders. - Employees get sufficient time to work in a hygienic/food safe way, can discuss problems concerning hygiene/food safety with colleagues, and are actively involved by leaders in hygiene/food safety related matters. - Sufficient education and training related to hygiene/food safety is given and good procedures are in place.

	<ul style="list-style-type: none"> - 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. - Percentage of inspection reports and letters in which a clear distinction is made between legal requirements and recommendations. <p>Food safety culture:</p> <ul style="list-style-type: none"> - Hygiene/food safety risks are known and are under control. - Colleagues are alert and attentive to potential problems/risks related to hygiene/food safety and leaders/operators have a realistic picture. - Leaders are able to motivate their employees to work in a hygienic/food safe way and listen to employees, if they have remarks/comments concerning hygiene/food safety - Leaders clearly consider hygiene/food safety to be of great importance and communicate regularly and clearly with operators about hygiene/food safety - Leaders set a good example concerning hygiene/food safety and act quickly to correct problems/issues that affect hygiene/food safety. 	<ul style="list-style-type: none"> - Provision of an appropriate level of protection against food safety risks for domestic consumers. - Provisions on a rapid alert system are made in food legislation. - Confidence to explain the importance of food safety, the concept of risk analysis, different aspects of a food law, the concept of “farm-to-plate” approach and to disseminate acquired knowledge and skills. - European Rapid Alert System for Food and Feed (RASFF) Notification (Measures) - Extra-European Union (EU) Food Imports (Vulnerability)
Sector-specific indicators	<ul style="list-style-type: none"> - Percentage of the population with access to potable water. - Percentage of food business operators who have systems and procedures in place which allows them to identify any person from whom they have been supplied with a food, a feed, a food- producing animal, or any-substance intended to be, or expected to be, incorporated into a food or feed. - Percentage of producers that have implemented a traceability system and of those that are implementing HACCP/ have certification. - Percentage of producers that have implemented GHP/GAP/GMP have certification - Percentage of producers that are complying to (other) project specific regulations (e.g. not using certain pesticides or specific quality schemes) - Outbreaks of food borne illness (Outcome). - Certifications of good practice (Measures). 	<ul style="list-style-type: none"> - Presence of a formal grocery sector - Self-checking systems in the supply sector for primary production, in the primary sector, in the transformation sector, in the community kitchen sector. - Inspections of infrastructure, installations and hygiene in the sectors of distribution, hotels and restaurants and community kitchens. - Importance of hygiene and food safety is permanently present by means of, for example, posters, signs and/or icons related to hygiene and food safety.

<p>Specific food safety topic-based indicators</p>	<ul style="list-style-type: none"> - Chemical risk in production (e.g. pesticide use) and consumption. - Microbial risk: incidence of reported illness by foodborne pathogen and relevance to national food consumption or dietary intake reporting. - Radionuclide standards. - Allergenic risks (labelling food and indicating allergens). - Residues from pesticides and/or herbicides in fruit; acrylamide; lead and cadmium in fruit/vegetables; aflatoxin and deoxynivalenol. - Substances with anabolic action, unauthorized substances and veterinary drugs for cattle/pigs. - Sulfite in minced meat; dioxins and dioxin-like PCBs in dairy products and in eggs; mercury in molluscs, crustaceans, fish. - Forbidden colorants. - Chemical and microbiological hazards in imported animal products intended for human consumption. - Dioxins and dioxin-like PCBs in feed. - Contact materials. - Salmonella spp. in meat pigs, layer hens, poultry. - <i>E. coli</i> in carcasses, cut meat, foodstuffs. - <i>Listeria monocytogenes</i> in foodstuffs. - Foodborne outbreaks: Salmonellosis, listeriosis in humans; overuse of food additives; microbial contamination; poor food quality indicators; pesticide residues; contamination of metal elements; detection of non-food substances; mycotoxin contamination. 	
<p>Indicators on surrounding factors</p>	<ul style="list-style-type: none"> - Change in public trust in food safety over a five-year period. - Agricultural science and technology indicators (ASTI). - Statistics of public expenditure for economic development (SPEED). - Global hunger index (GHI). - Agricultural total factor productivity (TFP). - International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). 	

APPENDIX

I. Codex Standards for Designing Effective National Food Control Systems

To help guide governments in designing effective national food safety systems, in 2013, Codex Alimentarius adopted the *Principles and Guidelines for National Food Control Systems* (CAC 82-2013) (61) to assist governments in the development, operation, evaluation and improvement of their national food control systems. According to Codex, 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. The following were identified as essential principles, among others:

- 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

These Guidelines state that the design and implementation of a national food safety system should include the “consistent application of a systematic framework for the identification, evaluation and control of food safety risks associated with existing and emerging hazards.”. Accordingly, Codex recommends and provides support for the development of essential components, or functionalities, of national food safety systems, which can be associated with indicators of performance.

Framework for the development of a national food control system

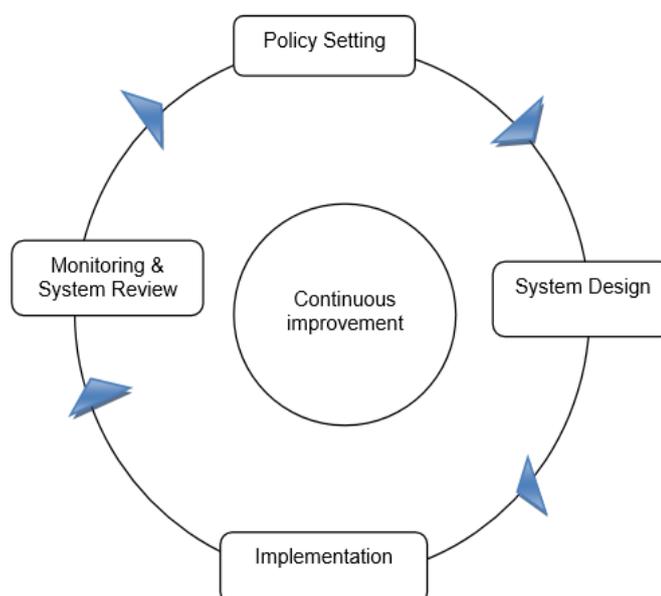


Figure A1. Schematic outlining key phases of the development of national food safety policy, in the context of continuous improvement (59).

Codex also advised national governments to adopt three “characteristics:”

- Situational awareness means a system uses accurate and current information on the entire food chain.
- Pro-activity means it can identify existing and emerging hazards before they become risks in the food production and processing chains, without relying on end product analysis. Early warning and rapid alert systems, traceability and contingency planning are inherent to pro-activity.
- Continuous improvement means the system uses a process of review and reform to evaluate the ability of the food safety system to meet its objectives.

Key guidance from Codex includes sections regarding food businesses, government agencies, legislation, public health activities, and communication.

Food business operators (see **Section 4-2**) are assigned the primary responsibility for managing the safety of their products. Control programs should be targeted at the point in the production or supply chains where hazards can be best controlled, given available resources. Utilizing preventive control programs that are implemented by the industry is recommended, including Good Agricultural Practices (GAP); Good Manufacturing Practices (GMP); Good Hygiene Practices (GHP) and Hazard Analysis and Critical Control Point programs (HACCP), and governments are advised to take them into account. Each of these programs include a set of prescriptive measures, which are or can be linked to indicators.

Governments are advised to utilize scientific information, evidence and risk analysis principles in designing and managing their control systems. The key components of the regulatory control program includes inspection, verification and audits based on on-site visits; market surveillance; sampling and analysis; examination of written and other records; documentation of observations and findings; and examination of the results of any verification systems (“self-check”) operated by the establishment. Compliance and enforcement programs should ensure the government agency can take timely corrective actions to protect consumers, where food business operators are not meeting food safety requirements or where product is not in compliance. Resources needed for those activities should be provided and managed appropriately.

Each country should adopt **legislation** identifying the principle agency or agencies within the government to manage food safety. The legislation should authorize a range of powers and mechanisms to manage and operate the national food control system. Legislation should establish that it is the obligation of food business operators to manage and control food safety hazards so that they provide only safe food products. Governments should establish national standards to control food hazards and monitor and enforce those standards. Standards should also be set to ensure the safe use of chemical inputs into the food supply, e.g. pesticides, food additives and veterinary drugs. Other authorities should mandate enforcement and compliance actions by regulatory authorities.

Public health activities are also central to an effective national food safety system. Surveillance of foodborne illnesses, together with effective investigation of adverse events, are essential to ensure regulatory agencies can manage timely responses. Emergency response activities can include removal and recall of unsafe products from the market, which depend heavily on the ability to identify and trace products.

Governments are advised to be transparent with all stakeholders as this is seen as vital to promoting consumer confidence. **Communication** between the relevant government agencies, consumers, civil society organizations and food business operators is emphasized. Programs to promote food safety educations for stakeholders at all levels is encouraged. Training programs are advised for all officials engaged in food safety regulation and appropriately designed and targeted materials for stakeholders.