Food Safety

WORKING GROUP: TECHNICAL BRIEF

Food safety metrics relevant to low and middle income countries

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Innovative Methods and Metrics for Agriculture and Nutrition Actions

The Agriculture, Nutrition and Health (ANH) Academy is a global network for research into improving nutrition and health through agriculture and food systems, serving as a platform for learning and sharing. It is jointly founded by the Leverhulme Centre for Integrative Research on Agriculture and Health, the project on Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) and the CGIAR Research Program on Agriculture for Nutrition and Health.

Food Safety Technical Working Group

The ANH Academy constituted several working groups to advance knowledge among the global research community regarding methods and metrics relating to different aspects of nutrition and health. The working group on food safety was tasked to:

- review the metrics, tools, definitions and software platforms currently used in food safety research, with application to low and middle income countries;
- produce a summary of current gaps and challenges related to the use of these metrics;
- suggest additional metrics and refinements to existing methods that would help make research on food safety in low and middle income countries more robust and replicable; and
- identify needs and opportunities for extending research on food safety in low and middle income countries.

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UKaid from the British people

London School of Hygiene &Tropical Medicine

LCIRAH Leverhulme Centre for Integrative Research on Agriculture and Health

CGIAR Research Program on Agriculture for Nutrition and Health Led by IFPRI

RVC Royal Veterinary College University of London

Food and Agriculture Organization of the United Nations

Introduction

The term 'metric' originally referred to a scale or standard against which something was measured (for example, a ruler). This use has been extended to methods of measuring. 'Metric' is less commonly used to specifically refer to a derivative of two or more measures. In this brief, metrics will be used to refer to methods or ways for measuring, thus, food safety metrics broadly refers to methods used for measuring food safety.

The safety of food is a matter of growing concern, especially following the recent publication of the first ever global study on the burden of foodborne diseases. The study by the Foodborne Disease Burden Epidemiology Reference Group of the World Health Organization (WHO), nearly a decade in the making, estimated that the global burden of foodborne diseases was comparable to that of HIV/AIDS, malaria or tuberculosis; low- and middle-income countries (LMICs) bear 98% of this burden. The study covered 31 foodborne hazards, for which there was good-enough data available to develop global estimates. Together, these hazards caused an estimated 600 million foodborne illnesses and 420,000 deaths in 2010. Foodborne illness was most often caused by diarrhoeal disease agents (Havelaar et al. 2015). The combined burden of death and disability was estimated at 33 million Disability Adjusted Life Years (DALYs). One DALY can be thought of as one year of healthy life lost. Children under five years of age, who represent 9% of the global population, bore 40% of this burden. The greatest per capita burden fell on the sub-regions in Africa, followed by those in Asia and the eastern Mediterranean. The region with the highest total burden was Asia. The most frequent causes of foodborne illness were diarrhoeal disease agents, led by norovirus and *Campylobacter* spp.; however, the most important in terms of death were non-typhoidal *Salmonella enterica*, *S. typhi* and enteropathogenic *Escherichia coli*. Foodborne disease-specific estimates are conservative and the actual burden in LMICs is likely to be higher.

When discussing metrics and measures, it is important to distinguish between food safety and food quality. Food safety ensures that food is fit for human consumption and not injurious to human health and is most often under the competence of veterinary, health or agricultural inspectors while food quality is a market category which is usually the responsibility of food or market inspectors (World Bank 2014).

Recent reviews, specific to LMIC, found there is reasonable evidence for the following key facts related to food safety in LMICs (Grace 2015a; Grace 2015b; Havelaar et al. 2015; Hoffmann et al. 2017).

- Consumers and policy makers in LMICs are increasingly concerned about foodborne disease, but this is less the case for producers;
- Most of the (known) health burden of foodborne diseases comes from biological hazards: viruses, bacteria, protozoa and worms;
- The most risky foods are livestock products, followed by fish, then fresh vegetables, then fruit;
- Studies usually find high levels of hazards in food sold in both formal and informal markets;
- There is little information about the health risks associated with hazards measured in these studies;
- There are many promising approaches to managing food safety in LMICs, but few have demonstrated sustainable impact at scale.

In addition to the disease burden, foodborne disease in LMICs is also a concern because of a broad range of economic costs and its impacts on market access (Unnevehr and Ronchi 2014). Moreover, evidence is growing of complicated, bi-directional links between food safety, livelihoods, gender equity and nutrition disciplines, all of which have a broad variety of metrics. As food safety is positioned at the intersection of

agri-food systems and health, there are many ways of interpreting and approaching it and no discrete set of research tools for doing so.

This technical brief:

1) provides a synthesis of food safety metrics and measures currently used in or applicable to LMICs;

2) identifies the associated gaps and challenges; and

3) proposes how research can contribute towards improving these measures and metrics and optimizing their use.

METRICS AND MEASURES FOR FOOD SAFETY IN LMICS: GAPS AND CHALLENGES

This brief is based on the first technical report for food safety metrics in LMICs. However, the report has some gaps and challenges. Estimating the multiple burdens of foodborne disease is complex and expensive and many metrics exist[1]. However, there is a lack of standardisation of studies over time and space which makes generalisation difficult. In general, foodborne disease incidences are under-reported and official reports thus under-estimate the disease burden. While our review found an abundant literature on health indicators and their measurement, we did not find any reviews specific to food safety measures and metrics. Nor did we find any widely accepted consensus on which health metrics should be used for understanding food safety.

KEY DEFINITIONS RELATED TO FOOD SAFETY

Food safety: Reasonable certainty that no harm will result from intended uses under the anticipated conditions of consumption (OECD 1993).

Foodborne disease: A disease transmitted through ingested food and may be caused by microbial pathogens, parasites, chemical contaminants and biotoxins.

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

Risk: The likelihood of occurrence of harm resulting from a given exposure to a hazard.

Disability Adjusted Life Year: A summary measure of health equivalent to a lost year of healthy life.

Measure: The act of measuring something (e.g. taking the temperature of meat) or the data that result from measuring something (e.g. a thermometer reading).

Metric: A method of measuring something (e.g. patient admission sheets).

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

Indicator: A measure that demonstrates progress or change (e.g. low pH of milk is an indicator of spoilage).

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

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 ways of managing.

[1] 'Working Paper on Food Safety Metrics Relevant to Low and Middle Income Countries' - available at www.ANH-Academy.org

Conceptual framework

Figure 1. Food safety metrics conceptual framework.

In making suggestions and recommendations, we consider measures and metrics under three rubrics:

(a) measuring and evaluating the safety of food. For this we consider of hazards present and potential health risks entailed;

(b) measuring the food safety system performance which influences both the safety of food and the impacts of unsafe food;

(c) measuring the actual impacts of foodborne disease outcomes (health and economic burden as well as other considerations) (Figure 1).

Much of the information on use and abuse of metrics is drawn from high income countries, where understanding food safety has been a greater priority and is more advanced. Therefore, we discuss in light of its applicability to food safety research in LMICs as well as the implications for food safety research.

HOW TO MEASURE AND EVALUATE THE SAFETY OF FOOD

"Is my food safe?" is a fundamental question for consumers everywhere. Much of the historic efforts around food control have focused on determining what constitutes unsafe food and how to assess if a given food is safe or unsafe.

Hazard- and risk-based approaches

Public food safety standards are enacted to protect consumers' health by assuring safe food as well as to eliminate fraudulent practices. Historically, many food standards were hazard-based, specifying that a hazard should be absent according to a specified testing method or below a certain maximum permitted level. A variety of microbiological, chemical and physical methods are used to identify and quantify hazards in food, and the field is rapidly advancing due to research innovations. Table 1 gives examples of hazard-based standards along with the indicators and metrics. However, as analytical methods have become more sensitive, and as realization has grown that many hazards have a threshold level below which no effect was detectable (or even beneficial effects may result), it is increasingly realized that risk-based approaches are more useful for managing most hazards. As a result, food safety risk analysis has formalized and emerged as the best way to assess links between hazards in food and actual risks to human health. Risk analysis is a structured decision-making system composed of three highly interrelated components: risk management, risk assessment and risk communication. Traceability aids risk-based targeting of surveillance and improves understanding of the agri-food system.

To avoid the confusion caused by multiple different national standards, the Food and Agriculture Organization of the United Nations (FAO) and WHO established the Codex Alimentarius Commission (CAC) to address safety and nutritional quality of foods and develop international standards to promote trade among countries. The CAC establishes standards for maximum levels of food additives, maximum limits for contaminants and toxins, and maximum residue limits for pesticides and veterinary drugs. At national level, government food safety systems monitor compliance with official standards through food inspections.

Private standards are playing an increasingly important role in domestic formal markets and 'informal private standards', i.e. non-codified norms, are the de facto way that much

Table 1: Examples of hazard-based food safety standards, indicators and metrics

STANDARD	INDICATOR	METRIC	AUTHORITY
Coliforms (a type of bacteria) in milk	No more than 10 colony forming units in 100 ml	Microbiological culture	East African Community
Chloramphenicol (an antibiotic) residues	0.3 micrograms per kilogram	Enzyme-linked immunosorbent assay or gas chromatography	European Union

informal food is marketed (e.g. there is a societal expectation that milk vendors will not excessively adulterate products and that customers will continue to patronize sellers who provide good products). Historically, food safety assurance by private firms was mainly hazard- and process-based; Hazard Analysis and Critical Control Points is a keystone to these methods. Recent years have seen these essential measures and metrics complemented by development of a strong interface with risk-based approaches, aligning well with the international trade community.

Export standards under the World Trade Organization govern official international trade in food. Under this framework, the CAC has a major role in international standard formulation and standardization. Information from food importers and exporters is a good indicator of the safety of products traded and an indirect indication of the safety systems and performance in exporting countries. Examples of trade metrics include import rejections, records of administrative actions in importing countries (e.g. bans) and reports from exporting countries of problems related to food safety.

FOOD SAFETY SYSTEM PERFORMANCE

Our conceptual framework situates food safety system performance between the safety of food and the impacts of unsafe food. The food safety system is those activities whose primary purpose is to ensure food is safe to eat. As such, the food safety system includes actors whose main mandate is assuring food safety (e.g. food safety authorities) and actors who are concerned with food safety as one aspect of food (e.g. local government authorities, institutional providers of food, and workers at all stages of the 'farm to fork' food production-to-consumption pathway.

Performance metrics measure how well the food safety system delivers safe food. Performance indicators show progress against plans in the results chain, i.e. input, process, output, outcome and impact. Metrics for impact indicators (e.g. longevity or age at death) are closest to measuring the performance of the system but may be more difficult to collect and, as they are often the result of many factors, they may be difficult to interpret. Metrics for indicators at other levels (output or outcome) are easier to collect and interpret; they are more actionable but may be easier to manipulate.

Performance can be measured in different dimensions or aspects. The 3E framework asks whether the health system is **effective** (Does it produce desired outputs, outcomes or impact?), **efficient** (Are inputs wisely used to secure goals? Is there avoidable waste?) and **equitable** (Is it fair? Is it reaching certain beneficiaries or addressing specific health needs?). Other performance domains such as continuity, environmental sustainability or responsiveness are used in some health systems.

One comprehensive food safety system performance tool was developed and applied to OECD countries. This comprised a risk-based framework that assessed performance across three dimensions: risk assessment, risk management and risk communication. Recently this has been adapted for LMICS. Food safety system performance benchmarking can help decision-makers understand relative performance and motivate improvements. In addition, it can help in identifying capacity-building and investment needs, and in setting and monitoring targets.

FOODBORNE DISEASE OUTCOMES

The third part of our conceptual framework considers the impacts of foodborne disease.

Public health outcomes

In high income countries, most public health systems have developed surveillance systems to detect and monitor health outcomes from foodborne disease. Information can be collected at different levels: health service institution, community or national population. Because these systems commonly rely on people seeking treatment in the health service, foodborne diseases are widely under-reported, a phenomenon that is much more of a problem in LMICs. Misdiagnosis is also a major problem and studies find evidence for both under- and over-diagnosis of foodborne diseases.

There are well-established epidemiological measures for health burden. These include incidence, prevalence and mortality. In the last decade, composite measures have been increasingly used that capture both the burden of morbidity and mortality. DALY has emerged as one of the most widely used measures. DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost due to premature mortality in the population and the Years Lost due to Disability for people living with the health condition or its consequences (CDC, 2006).

Economic outcomes

Economic outcomes can be divided into (a) the harm caused by the disease (e.g. lost productivity from illness), (b) the cost of response (e.g. treatment, food recalls) and (c) the cost of prevention (e.g. food safety governance, risk reducing practices. Alternatively, costs may be allocated to different actors (consumer, healthcare, agro-food industry, government).

There are well established ways of measuring the economic burden of foodborne diseases. Loss of life may account for the biggest share of health valuation estimates (Narain and Sall, 2016). Human capital approaches assess the value of lost years of health through the amount of money a person (or society) is willing to spend to avoid disease or the lost contribution to gross domestic product. The cost of illness (COI) approach seeks to account for the direct and indirect costs of death and illness. Direct financial costs include transport costs to get treatment, medical expenses paid by the patient, wages lost, and costs of public health provision. Indirect costs include productivity losses from missed business due to sick employees, the monetized value forgone household chores and others. Other metrics and measures assess losses from market rejects or from inability to capture or re-capture markets because of food safety problems.

Other considerations

Not all the outcomes and impacts of foodborne diseases can be easily captured by DALYs and dollars. Food safety has complex interactions with other societal concerns. For example, most of the risky foods in LMICs are sold in informal markets, which often have ambiguous legal standing, leaving the sellers insecure and vulnerable to harassment. As such, food safety has implications for the livelihoods. Likewise, foodborne diseases can have important implications for women's resilience and vulnerability: women predominate in traditional food processing and sales and are usually responsible for food preparation at home. They are also more biologically susceptible to some diseases.

Table 2. Frameworks for food safety measures and metrics in LMICs

Framework	Standards, measures and metrics	Aim	How it works	Challenges in LMICs	How research can contribute
Foodborne hazards and risks	Public standards	• Consumer protection • Elimination of fraudulent practices	• Hazard analysis • Risk analysis	• Adopting high-income country standards with little adaptation to local context. • Standards can act as a barrier to market participation. • Little capacity to enforce standards in informal markets. • Traceability is not a feature.	• Better adaptation of risk analysis metrics • Capacity building in risk analysis • Participatory risk analysis
	Private standards	Food safety assurance	• Hazard and process analysis • Risk analysis	• Fewer checks and balances as compared to high-income countries. • Little information on use of metrics outside of case studies and research projects. • Complex risk-based approaches and traceability not readily applicable.	Development of measures and metrics to systematically capture the negative externalities of the formal and informal food sectors.
	Export standards	• Consumer protection • Food safety assurance • Assurance of ethical food production	Trade-related metrics e.g. import rejections	• Costs of compliance and verification. • Complexity of international trade favours exporting high income countries. • Little information on the value of products rejected or their destination after rejection.	• Generation of data on health risks of global trade. • Research into trade flows, behaviour around food consumption, and barriers to participation in trade.
Food safety system performance	Performance indicators	Measurement of how well the food safety system delivers safe food	Benchmarking against defined indicators	Food safety systems suffer from consistent and systemic problems, including inadequate policy and legislation, inappropriate standards and failure to cover the informal sector.	• Optimizing the structure of food safety systems • Multi-disciplinary research to bridge the gap between policy/legislation and implementation.
	League tables	Measurement of food safety performance relative to other countries	Performance against risk indicators	Major deficits in data means that indirect indicators have to be used e.g. Transparency International's ranking as a proxy for risk communication	Develop more robust indicators and ways of capturing data from secondary sources
Foodborne disease outcomes	Health outcomes	• Surveillance • Detection of foodborne disease outbreaks	• Reporting by people seeking treatment • Calculation of DALYs	• Under-reporting of outbreaks. • Assessing the burden of foodborne disease due to manifestations other than gastrointestinal illness. • DALYs are not easily interpreted.	• Participatory epidemiology • Capacity building in use of DALYs • Country studies on foodborne disease health burden
	Economic outcomes	Provision of information for rational allocation of resources	• Calculation of DALYs • Cost of treatment • Cost of prevention	Lack of published information on economic costs, cost effectiveness and cost-benefit analysis of interventions to improve food safety in domestic markets.	• Simplified and comparable methods for assessing economic costs of foodborne diseases. • Generation of information on costs and cost effectiveness of different options for reducing foodborne disease.

Best principles for developing measures and metrics

It is a truism that 'what cannot be measured cannot be managed' but it is also commonly noted that 'you get what you measure' and that 'meeting the target can lead to missing the point'. Appropriate metrics can support rational resource allocation, enhance accountability, facilitate comparison, help in monitoring progress and exert pressure to improve performance. At the same time, they can be prone to manipulation and their implementation may entail more costs than benefits.

While metrics are considered key to monitoring and improving performance, they can also have unintended consequences, including focusing efforts on the thing to be measured rather than the ultimate goal of improving the thing being measured; stifling innovation through standardization; costs that increase in disproportion to benefits attained; incentivizing perverse behaviour to game metrics and decreased attention to things that are not measured (Bardach and Cabana 2009).

Some principles relevant to appropriate design of food safety measures and metrics include:

- A strategic plan must precede the development of measures with clear and realizable goals and practical steps for implementation, including metrics. It is important to align the measure with the desired goal and communicate the goal not just the measure.
- When a measure becomes a target, it ceases to be a good measure. Targets should therefore be designed with the possibility of gaming in mind and avoid using metrics as performance targets.
- Food safety is complex and single measures can be misleading. Therefore, multiple indicators are needed to obtain a comprehensive measure that describes food safety.
- Measures should assess outcomes and impact as well as processes.
- Measures should be designed in a way that they encourage actions to improve outcomes. A poorly designed measure will encourage actions to achieve high scores.
- The context of measures should be considered; if significant changes outside the control of the agency are occurring (e.g. migration or climate change) then metrics should be interpreted in light of this.
- Measures should be easily understood and accepted by a range of stakeholders and the underlying data should be widely available.
- Measurements have costs and the benefits should be demonstrated to outweigh the costs.

What matters for food safety in LMICs?

A major challenge in LMICs is that only a small unknowable fraction of foodborne diseases is reported. Many victims go untreated or get unspecific treatments from unqualified people. Even if treated at a health facility, there is often no biolgical sample collection for laboratory examination. When laboratory tests are performed, they may not cover all potential causes and, if a pathogen is identified, this is not followed by investigation of the source. Another challenge is assessing the burden of foodborne disease with symptoms other than gastrointestinal illness (especially chronic manifestations, e.g. acquired epilepsy, ocular syndromes etc.). Therefore, there is little information or ability to collect evidence on this. On the other hand, although good data exist on import rejections, there is less information on the value of products rejected or their destination after rejection. There is concern that foods rejected from more fastidious countries may end up in other markets, and there is some evidence this happens; for example, milk powder contaminated with melamine in China appears to have reached other markets.

Risk analysis has been officially adopted by most LMICs but their ability to implement it is very limited. Conventional risk analysis is often expensive, time consuming and requires considerable amounts of data and quantitative analysis. In most LMICs, risk analysis is not used in setting standards or regulations for food sold in domestic markets, and government and private sector efforts to build capacity have focused on the export sector or formal private sector. Multi-national companies operating in LMICs and (to a lesser extent) the domestic formal sector apply similar private standards to those prevailing in HICs. However, there are typically fewer checks and balances that help assure the relatively high safety standards of food sold in HICs. At the same time, the challenges of attaining food safety presented by poor infrastructure and production practices are more acute. Therefore, food sold by the formal sector is not always or necessarily safe. Moreover, most food continues to be sold in informal, traditional or wet markets.

Even in HICs, small and medium firms find it difficult to comply with complex and technocratic rules, measures and metrics that are characteristic of best practice food safety management systems and risk-based approaches: these methods are hardly applicable in LMICs. The same applies for traceability, which appears only attainable in niche, high-value markets in LMICs. Initiatives to adapt food safety processes for small firms in HICs might be more useful approaches in LMICs. And given that national official standards are often not aligned to the reality of LMICs, it has been suggested that LMICs should create more adapted domestic and regional standards, or rather a range of options, which would provide an upgrading pathway for food producers and handlers.

Risk communication has been under-researched in LMICs. The public, and even decision-makers, generally do not distinguish well between risk and hazard, and their perception of risk is prone to many biases, making it difficult to convey objective, science-based evidence, and address misperceptions.

Based on a series of food safety stakeholder workshops and situational analyses conducted in countries in Africa and Asia, we suggest three aspects of food safety which should be of most interest to food safety decision-makers in LMICs, especially government policymakers, development planners, researchers and donors.

1. **Impact:** Is foodborne disease a problem? If so, how big a problem and what are its impacts? What are the trends? Where is this a problem? Who is affected by it? What foods are responsible for the problem?

2. **Concern:** Who is concerned about this problem? How will their concern affect their behaviour? How can their concerns be managed? How can their concerns lead to behaviour or system change? Do concerns align with evidence and risk? How can concerns be better aligned to reality?

3. **Management:** How does current food safety management work? What can best be done to improve food safety management? Are the people creating the food safety problem sufficiently involved in management? What specific processes and stakeholders are involved? Which aspects need to be managed first? What are the options for management? How effective are they? What are their costs and benefits? Where do these costs and benefits fall? What behaviour change is needed for better management and what are the incentives for this?

Key gaps in food safety measures and metrics

This study allowed us to identify some key gaps in food safety measures and metrics which future research or development initiatives may address:

- While the first global assessment of the burden of foodborne disease represented a great leap forward, information at national level is needed to inform planning and investment. Metrics and measures should be available at country level.
- An important question is whether foodborne disease is in decline, like other infectious diseases, or is it trending upwards, like other food associated diseases. Metrics should be sufficiently robust to detect temporal change.
- Food safety initiatives in developing countries often cite the lack of information on the cost of foodborne disease as a major reason for lack of engagement by national policymakers. Country-level data on the cost of foodborne disease are important and should ideally be integrated with assessments of health burden. Standardized methods for assessing economic costs of foodborne disease in developing countries would be helpful as use of different methods leads to wide variation in estimates.
- While metrics and measures for foodborne disease burden assessment are relatively well advanced, there is much less consensus on metrics and measures for foodborne disease management and communication.
- There is a lack of metrics for understanding trade-offs between food safety and other development issues such as nutrition, equity, or environmental sustainability.

Conclusion

Foodborne disease has not been considered a development priority in many LMICs. However, perceptions are changing and concern over food safety in these countries is on the increase, a trend that is likely to continue in the long term as consumers become more urbanized and conscious of the quality of food they eat.

Currently, food safety research does not have a consensus toolkit of metrics. However, interest in foodborne disease is increasing and there are likely to be increasing research and development initiatives in the coming years.

As food safety occurs at the intersection of health and agriculture, a multi-disciplinary approach and greater collaboration among food, water, health and nutrition sectors would improve the design and use of food safety metrics in LMICs.

This Technical Brief provides a summary of the more extensive review conducted by the ANH Academy Food Safety Working Group. The '*Working Paper on Food Safety Metrics Relevant to Low and Middle Income Countries*' is available at www.ANH-Academy.org.

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