

White paper

Food safety in developing countries: research gaps and opportunities

For further information, contact

Dr Delia Grace

International Livestock Research Institute
Box 30709-00100, Old Naivasha Road, Nairobi, Kenya
Tel: (254-20) 4223000, Fax: (254-20) 4223001
Via USA—Tel: 1-650-833-6660

Email: d.grace@cgiar.org

Contents

Acknowledgements	3
Acronyms and abbreviations	4
1. What makes food safety an important issue for development?	5
1.1. What are foodborne diseases?	5
1.2. Why does foodborne disease matter to developing countries?	5
1.3. Broader implications of food safety for development outcomes	8
2. Food safety challenges in developing countries	10
2.1. Health burden of foodborne disease	10
2.2. Main causes of foodborne disease	11
2.3. Major foods implicated	12
2.4. Problems along the value chain: inputs, production, processing, retail, household	13
2.5. Trends, regional patterns, hot spots	16
3. Managing food safety challenges in developing countries	17
3.1. Overview	17
3.2. Food safety initiatives	17
4. Feed the Future Innovation Labs feedback: Comments from a food safety perspective	21
References	25
Annex 1: Terms of Reference	30
Annex 2: Food safety myths, misperceptions and half-truths	31
Annex 3: Feedback from Innovation Lab directors	33

Tables

Table 1: Examples of recent hazard surveys of marketed food in developing countries	10
Table 2: Hazards encountered along the ‘farm to fork’ pathway	15
Table 3: Feed the Future Innovation Labs	24

Figures

Figure 1: Foodborne disease burden by cause and region.	11
Figure 2: Attribution of foodborne disease to different types of food.	12

Acknowledgements

This paper was funded through a consultancy with the United States Agency for International Development (USAID) Bureau for Food Security to support Feed the Future. Co-funding from the CGIAR Research Program on Agriculture for Nutrition and Health led by the International Food Policy Research Institute (IFPRI) is also acknowledged.

The author would like to thank Ahmed Kablan, John Bowman, John McDermott and Johanna Lindahl for their helpful reviews.

The information and insights from Innovation Labs are gratefully acknowledged.

Acronyms and abbreviations

ASF	Animal-source food
DALY	Disability Adjusted Life Year
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBD	Foodborne disease(s)
FSNAU	Food Security and Nutrition Analysis Unit
GAP	Good Agricultural Practice
GMP	Good Manufacturing Practice
HACCP	Hazard Analysis and Critical Control Points
HIC	High-income countries
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome
IFPRI	International Food Policy Research Institute
IHME	Institute for Health Metrics and Evaluation
IL	Innovation Lab
ILRI	International Livestock Research Institute
IOM	Institute of Medicine
IPM	Integrated Pest Management
IS	International standards
LMIC	Low- and middle-income countries
LSIL	Livestock Systems Innovation Lab
ppb	parts per billion
USAID	United States Agency for International Development
USD	United States dollars
WHO	World Health Organization

1. What makes food safety an important issue for development?

1.1. What are foodborne diseases?

Foodborne diseases (FBD) are illnesses caused by contaminated, or naturally harmful, food or beverages. A food safety hazard is anything in food that can harm consumers' health. There are three major types of hazards:

- Biological hazards are living organisms (including viruses, bacteria, protozoa, moulds and parasites), which have the ability to infect people or produce toxins injurious to health.
- Chemical hazards can be artificial chemicals produced by industry or natural chemicals (for example, those produced by heating food or toxic metals), which are injurious to health.
 - Mycotoxins (chemical compounds produced by moulds) and phycotoxins (chemical compounds produced by algae and accumulated in sea foods) are considered biological hazards by some and chemical hazards by others.
- Physical hazards include stones and fragments of metal or glass as well as sub-microscopic nanomaterials and radionuclides.

The health impacts of FBD can be measured in different ways, including annual cases of sickness and death. There is also a standard metric for measuring disease burden: the Disability Adjusted Life Year (DALY). One DALY is the equivalent of one lost year of healthy life. Measuring health impact in DALYs helps comparisons between dissimilar diseases and aids in prioritization.

1.2. Why does foodborne disease matter to developing countries?

Historically, FBD has not been considered a development priority. Assessing FBD in developing countries is not easy because many infectious diseases never receive a definitive diagnosis, that is, one which identifies the pathogen responsible. Even if a diagnosis is given, it may be difficult to know if the source was food, water, other people, animals or the environment. Moreover, there is a perception that FBD is a minor inconvenience and that it is largely unavoidable.

There is also a perception that FBD is a minor inconvenience and that it is largely unavoidable. However, research and practice shows that food safety exerts a considerable health burden, yet is amenable to solutions. Several developed countries have developed methods that allow assessment of the health burden FBD. These studies found that FBD was common (affecting around one in 3 to one in 6 people a year) and resulted in a high burden of disease (Gkogka et al., 2011; Kirk et al., 2014; Mangen et al., 2015; Scallan et al., 2011; Tam et al., 2014; Thomas et al., 2013). Moreover, the well-known gastrointestinal symptoms of FBD (vomiting and diarrhoea) were responsible for only about half the total health burden. An equally high, but less visible burden came from rare but serious effects such as septicemia, paralysis, stillbirth, and meningitis.

Moreover, FBD have other implications for development: direct effects include economic losses, trade impacts, market access and more complicated effects on nutrition and equity. The impacts are summarized in the next paragraphs.

Known health burden: Only recently has systematic and comprehensive evidence on the health burden of FBD in developing countries started to become available. The landmark first assessment of the global burden of FBD, conducted by the World Health Organization (WHO), considering 31 hazards for which there was enough information to allow global burden estimates, was published in 2015 (Havelaar et al. 2015). This shows that FBD has a health burden comparable to malaria,

HIV/AIDS or tuberculosis. Most (98%) falls on developing countries and 40% on children less than five years of age. The global burden of FBD caused by the 31 known hazards considered in 2010 was 33 million DALYs: children under five years bore 40% of this burden.

The WHO analysis was based on modelling and expert attribution of the role of food in disease. In developed countries there are also studies based more on clinical data, and these generally suggest higher levels than estimates in the WHO report. There have been few studies on foodborne diarrhoea in developing countries, with most coming from Southeast Asia and relying on the opinion of victims to determine if disease is foodborne: these also suggest higher levels of FBD (Bureau of Epidemiology 2004; Hoi et al. 2009).

Key research gaps:

- **Data on FBD at country level which would allow evidence-based prioritization of FBD.**
- **Diagnostic and reporting systems that would allow more accurate assessments of FBD, including FBD in the community.**
- **Ways to raise awareness of the importance of FBD through more effective risk communication.**

Unknown health burden: The WHO study reported global burden for only 31 hazards, which were relatively well characterized globally. Many hazards considered among the top causes of FBD (for example, *Staphylococcus aureus* and *Vibrio parahaemolyticus*) were not included. Moreover, there are several hazards for which there is much concern, and evidence suggestive of an associated health burden, but so far insufficient data to be certain of the health effects or their magnitude. For example, aflatoxins may contribute to stunting and certain pesticides may contribute to cancers in ways that are not fully understood.

Key research gaps:

- **Evidence on health burden caused by hazards known to be important but not included in the WHO study.**
- **Evidence on hazards of high concern whose effects are not fully known**
- **Methods to assess the costs and benefits of addressing or failing to address these 'known unknown' hazards in advance of definitive evidence about their impact**

Economic costs: These can be divided into: (a) the harm caused by the disease (e.g. lost productivity from illness); (b) the cost of response (treatment, food recalls) and (c) the cost of prevention (food safety governance; risk-reducing practices). Alternatively, costs may be allocated to different actors (consumers, healthcare, agro-food industry and government) (McLinden et al. 2014). Zoonotic diseases often exert additional burdens on the livestock sector. Economic studies use different methodologies, but the cost of FBD is high: for example, it is estimated to cost the United States of America from 15–80 billion United States dollars (USD) a year (Scharff 2012; Hoffmann et al. 2015). There are few studies from developing countries: one study from Nigeria estimated that costs were around USD 2 million a year (Grace 2011). In developing countries, high healthcare costs are often one of the most important reasons for households' descents into poverty (Krishna 2007).

Key research gaps:

- **Food safety works in developing countries often cite the lack of information on the cost of FBD a major reason for lack of engagement by national policymakers. Country-level data on the cost of FBD is important and should ideally be integrated with assessments of health burden.**
- **Standardized methods for assessing economic costs of FBD in developing countries would be helpful as use of different methods leads to wide variation in estimates.**

Market access and trade: International trade studies have found evidence that the fixed costs of

meeting international trade standards tend to favour established exporters and lead to a greater reduction in developing-country exports relative to those in developed countries (Unnevehr and Ronchi 2014). FBD can also lead to rejections and even lost markets; for example, in 2005, malachite green was found in Chinese eels, resulting in export losses of at least USD 860 million (Ellis and Turner 2008). There is also concern that poor producers and value chain actors will be displaced from rapidly growing export and domestic markets, because of inability to meet standards. This has already occurred in export markets where smaller farmers tend to drop out, as they lack the human and financial capital needed to participate in highly demanding markets. For example, in the 2000s both Kenya and Uganda saw major declines (60% and 40%, respectively) in small-scale farmers participating in export of fruit and vegetables to Europe under Global Good Agricultural Practices (GlobalGAP) (Graffham et al. 2007).

The implications of trade liberalization on food safety are both positive and negative. Increased food trade may introduce new safety hazards, revive previously controlled risks, and widely spread contaminated food (Hawkes et al., 2015). The increased complexity of the food supply makes the source of food safety risks more difficult to trace (Ercsey-Ravasz et al. 2012). Yet for low-income countries, most imported food can be reliably considered of higher sanitary quality than food in the domestic markets (Hawkes et al. 2015).

Key research gaps:

- ***Food safety and trade have been relatively well researched. More effort is needed on ways to maintain and improve developing countries' and small-scale farmers' access to opportunities offered by international trade and the livestock revolution.***
- ***Value chain development has been a major intervention but projects have often not integrated food safety.***

Shocks caused by food scares: FBD outbreaks often receive huge media attention and cause large declines in purchase of associated food (although this tends to return to pre-scare levels weeks or months later). For example, when pig diseases were initially reported by the media in Vietnam, the majority of consumers stopped eating pork, shifted to chicken, or went to outlets that were perceived to be safer (ILRI 2010). Food safety scares and the government responses to them (such as occurred during the avian influenza outbreak, the Rift Valley fever outbreak and melamine contamination incidents) have been shown to adversely affect the livelihoods of small farmers (2 billion in developing countries) and pastoralists (50–200 million) (ILRI 2007; Kavle et al. 2015).

Key research gaps:

- ***Food scares are under-researched. Timely evidence is needed on the actual extent and impact of FBD outbreaks and research is needed into effective risk communication to mitigate adverse impacts of food scares.***

Amenability to solutions: Chapter 3 summarizes evidence on managing FBD in low- and middle-income countries (LMIC). While FBD remains a concern in high-income countries (HIC), and progress in tackling FBD appears to be less good compared to other infectious diseases (Grace 2015), there have been dramatic declines in FBD over the last two centuries (Cutler et al. 2006) and HIC are responsible for just 2% of the global burden of FBD (Havelaar et al. 2015). FBD is hence a solvable problem. Moreover, while some of the interventions that reduce FBD have high initial and recurrent costs (e.g. investment in infrastructure), other interventions are relatively low cost (e.g. treatment of water at point of use).

Key research gaps:

- ***There is little information on the costs and cost-effectiveness of different options for reducing FBD. This information, which has been developed for other diseases such as malaria, would be a useful guide for policymakers and investors.***
- ***There are few randomised controlled trials on food safety interventions, yet these***

provide the highest standard of evidence.

1.3. Broader implications of food safety for development outcomes

From the above summary, it can be seen that FBD has potentially important effects on poverty and equity; FBD also has implications for development issues, especially nutrition and gender.

FBD and nutrition: Stunting, or extreme shortness (very low height-for-age), is the result of a combination of long-term (chronic) poor dietary intake in terms of quality as well as quantity of food and repeated infectious disease episodes. Both wasting (extreme thinness, or low weight-for-age) and stunting are associated with increased mortality as well as poor health and longer-term development outcomes. FBD and hazards may contribute to both wasting and stunting through additional pathways, for example:

- Diarrhoea is associated with malnutrition but a causal link is hard to demonstrate; a 9-country study found that 25% of stunting could be attributed to experiencing more than four episodes of diarrhoea before the age of 24 months (Checkley et al. 2008). Studies find a strong peak in diarrhoea after the introduction of supplementary foods, and find that weaning foods often have high levels of microbial contamination and adulteration (Kumi et al. 2014).
- Aflatoxins may directly contribute to stunting, and there are demonstrated associations between higher toxin levels and poorer growth in several contexts, although a causal relation, while plausible, is as yet unproven (Leroy 2013).
- Ingestion of animal faecal material through food or from the environment may contribute to environmental enteric dysfunction¹ (George et al. 2015)

Box 1. Why nutritionists need to consider food safety: a thought experiment

Many nutritionists favour food-based approaches to improving nutrition. Animal-source food (ASF) and fresh produce are among the most highly nutritious foods. However, these foods are responsible for most FBD, so if their consumption increased (doubled or tripled) without accompanying action to improve safety then the burden of FBD would be likely to increase too.

Currently, FBD accounts for at least 33 million DALYs² and causes 420,000 deaths annually (Havelaar et al. 2015) while malnutrition accounts for 85 million DALYs and is the direct cause of 300,000 deaths (IHME 2012). Thus, promoting ASF and produce for nutrition reasons without addressing food safety would result in net worsening of health.

At the same time, there are potential trade-offs between food safety and availability. In most developing countries, informal traditional markets are the major source of the risky, fresh foods that are also among the most nutritious foods (e.g. eggs, green leafy vegetables and fish) (Grace 2015). Measures intended to improve the safety of food may have the unintended consequence of reducing its availability or the access of people to nutritious food. For example, in Kenya, pasteurized milk costs double the price of raw milk, putting it out of the reach of many poor families.

Key research gaps:

- ***There is a lack of understanding of which FBD agents are most important in terms of nutrition.***
- ***There is a lack of metrics for understanding trade-offs between food safety and nutrition.***
- ***More evidence is needed on contamination of supplementary foods, the nature***

¹ An incompletely defined syndrome of inflammation, reduced absorption and barrier function of the small intestine.

² Health burdens are often measured in Disability Adjusted Life Years (DALYs) to facilitate comparison and prioritisation (one DALY can be seen as one lost year of healthy life).

and origin of the pathogens involved and the fractional contribution to health outcomes arising from contamination outside and inside the household.

- ***Links between livestock keeping, gut microbiomes, diarrhoeal disease and health and nutrition outcomes are complex but poorly understood.***

FBD and gender: There has been little research on the intersection between gender and food safety, but FBD can have important implications for women's resilience and vulnerability.

- Firstly, food safety has direct implications for women's health. Pregnant and lactating women are especially vulnerable to FBD because of their modulated immune system. In addition, some FBD cause foetal abnormalities, abortion and stillbirths and some chemical hazards can be transmitted to the newborn through breast milk.
- Secondly, culture affects the relative consumption of risky foods by men and women. In Nigeria and Somalia, women consumed more low-value offal and men more high-value muscle meat (FSNAU 2010; Grace et al. 2012). Offal consumption has been found to be a risk factor for diarrhoea (Stafford et al. 2008; Grace et al. 2012). In Africa, men have more access to meat because they predominate in bars that serve meat and alcohol (Roesel and Grace 2014). Food eaten in these places has increased risk of FBD. A similar pattern is seen with fish-borne disease in China, Vietnam and Korea. Men have more frequent eating opportunities at restaurants than women and have a significantly higher rate of fish-borne fluke (Han et al. 2013).
- Thirdly, food safety has implications for women's livelihoods. Women have an important (even dominant) role in many traditional food value chains but as chains modernize, partly driven by food safety concerns, women may be excluded (Grace et al. 2015).
- Lastly, women are risk managers in the realms of food consumption, preparation, processing, selling and, to a lesser extent, production. However, they are often disadvantaged by less access to support and services such as education and extension. Because of these links, gender analysis is important in assessing and designing interventions to improve food environments by enhancing food safety.

Key research gap:

- ***Most research has focused on descriptive analyses of different roles of men and women. More research is needed into designing interventions that are gender-sensitive.***
- ***Leveraging women's higher concern over food safety, possibly better food handling behaviour as well as their role as primary risk managers in households and important risk managers along the value chain, and into opportunities for women.***

Other food issues may or may not have health implications.

- Food adulteration and food fraud is common in developing countries, especially for high-value foods. It may have health impacts if the adulterant is harmful (e.g. addition of melamine to milk) or if adulteration lowers the nutritional quality of food (e.g. addition of water to milk).
- Food spoilage is caused by microbes but these are mostly different from the microbes causing FBD. However, good hygienic practices can reduce both types of microbes.
- Antimicrobial residues very rarely cause adverse reactions in people consuming ASF. A more important human health impact is if the use of antimicrobials in agriculture leads or contributes to resistance in pathogens, which infect people.

2. Food safety challenges in developing countries

2.1. Health burden of foodborne disease

There is substantial information on the presence of hazards in foods in developing countries. In general, all studies that look for hazards find them, and often a large proportion or even majority of the marketed food is above safety standards (Table 1).

Table 1: Examples of recent hazard surveys of marketed food in developing countries

Country	Commodity	Hazard	Proportion of unsafe food	Reference
Ethiopia	Vegetables	Heavy metals	Average lead concentration > limits	Eliku and Leta (2016)
Ghana	Vegetables	Faecal bacteria	100% > limits	Abass et al. (2016)
Chile	Leafy vegetables	Pesticides	27% > limits	Elgueta et al. (2017)
Ethiopia	Milk	Aflatoxins	92% > EU standards	Gizachew et al. (2016)
Côte d'Ivoire	Milk	Specific microbes	30% > IS	Kouamé-Sina et al. (2012)
India	Milk	Coliforms	100% > India standards	
India	Pork	Enterobacteriaceae	89% > IS	Fahrion et al. (2014)
Nigeria	Beef	Total aerobic count	98% > IS	Grace et al. (2012)
Kenya	Maize	Aflatoxins	51% > Kenyan limit (20 ppb) in outbreak year; 16% in normal year	Daniel et al. (2011)
Ghana	Weaning food	Aflatoxins	83% > Ghana limit (20 ppb)	Kumi et al. (2014)

EU: European Union; IS: International standards; ppb: parts per billion

However, there is much less empirical information on the burden of FBD. There are five main sources of evidence for this:

1. **Official reports:** These tend to significantly under-estimate the burden of FBD; in many countries there is no requirement to report FBD. Even if there is a requirement, the reporting system may not be adequate, resulting in massive under-reporting. For example, in Gansu in China, there were an estimated 30 million cases of acute gastrointestinal disease but only 400 cases reported to the official system (Sang et al. 2014), and in Malaysia, estimates suggest less than 0.1% of cases are officially reported (Gurpreet et al. 2011).
2. **Community surveys of self-reported illness and cause:** Only a few surveys have been carried out in developing countries. The studies that exist find acute gastrointestinal disease is common (around one in two people a year or 50% of people report being affected, with much higher rates in some vulnerable populations) and around one-third of cases (12–55%) have been attributed to food (Bureau of Epidemiology 2004; Ho et al. 2010; Chen et al. 2013; Sang et al. 2014). However, self-reporting can be a reasonably good way to estimate occurrence of illness, but people are not good at attributing the source.
3. **Surveys of FBD using symptoms or diagnostic tests:** Some FBD can be diagnosed through characteristic symptoms in conjunction with diagnostic tests. These include many diseases caused by macro-parasites such as fish fluke or epilepsy caused by pig tapeworm. Reviews of hospital and community surveys often suggest relatively high levels of FBD (Torgerson et al. 2006; Bruno et al. 2013).
4. **Risk assessments:** This is a method for predicting the level of FBD based on the level of hazards in food consumed, the quantity consumed and the susceptibility of the population. There are a limited number of microbial and chemical risk assessments from developing countries and many are not quantitative but most indicate a high level of FBD, for example, around 13% of people suffer from pork-borne salmonellosis each year in Vietnam (Dang-Xuan et al. 2016) and around 1% of children are exposed to zoonotic *Cryptosporidium* in Nairobi (Grace et al. 2012).
5. **Health burden assessments:** Some FBD have been included in Global Burden of Disease

Assessments produced by WHO and the Institute for Health Metrics and Evaluation. These indicate high burdens for the included diseases. The recent WHO report on the global burden of FBD is the most definitive burden study. It found that 31 FBD agents (biological and chemical hazards) accounted for around 420,000 deaths in developing countries, imposing a burden of around 33 million DALYs each year. Moreover, this estimate is likely to be conservative.

Key research gap:

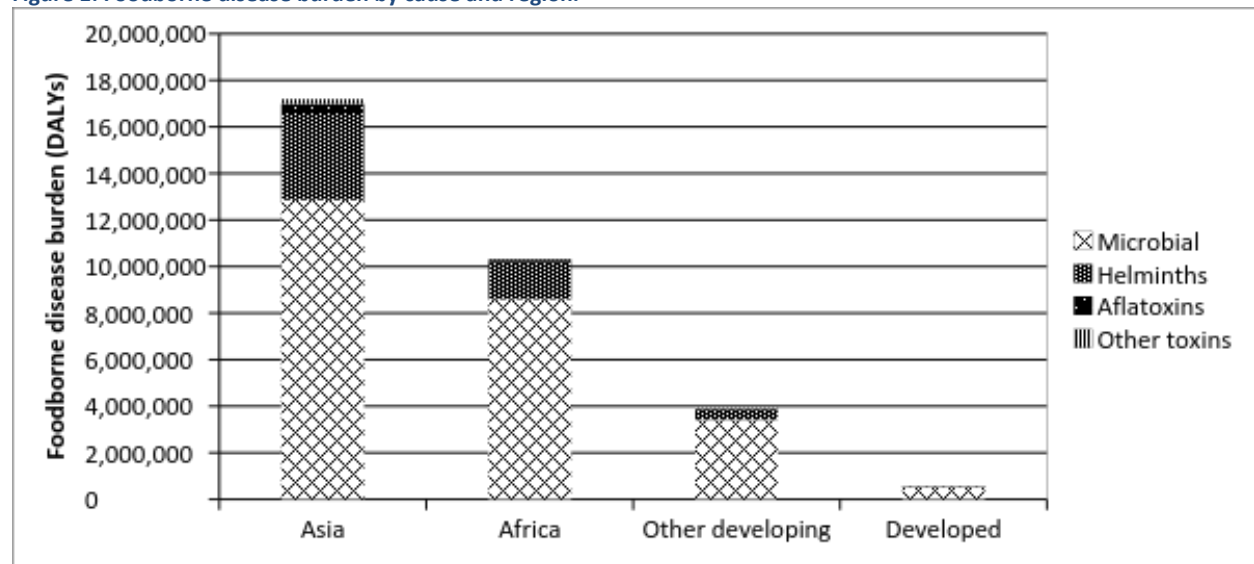
- **There is very little comprehensive, empirical evidence on FBD health burden in developing countries as most is derived from single studies or extrapolations; this country-specific information is needed to motivate engagement and investment by national stakeholders.**

2.2. Main causes of foodborne disease

The WHO report considered FBD caused by biological and chemical hazards (Havelaar et al. 2015). They found:

- **Microbial pathogens** are responsible for the great majority (79%) of the FBD burden (Figure 1). The most important pathogens are *Salmonella* spp., toxigenic *Escherichia coli*, Norovirus and *Campylobacter*, in that order.
- **Foodborne macro-parasites** are important causes of disease. The most important are the tapeworms responsible for cysticercosis, fish-associated fluke (common in Southeast Asia) and roundworms, which are sometimes foodborne and are widespread in poor countries.
- **Chemicals** are responsible for 3% of the overall assessed FBD burden. Aflatoxins, which are fungal toxins that contaminate mainly staple crops and dairy products in tropical and sub-tropical developing countries, are also associated with stunting in children, but the relation has not been established as causal (Leroy 2013). Other assessed chemicals were dioxins and cyanide in cassava.

Figure 1: Foodborne disease burden by cause and region.



Other known, but less important, causes of foodborne or food-associated disease are listed below:

- **Allergens** are proteins that can produce adverse immune responses in sensitive people; they can lead to acute, severe reactions or even symptoms similar to malnutrition and food allergies and underweight are associated (Boye 2012). They appear to be much less common developing countries than in rich countries (Boye 2012). Milk, eggs, aquatic products, groundnuts, and meat

are often a source for food allergens (Lee et al. 2013; Kung et al. 2014). Food allergies peak in the first two years of life, then diminish as tolerance develops (Grey and Levin 2014).

- **Food intolerances** are non-immunological adverse reactions to food as the result of pharmacological effects, non-coeliac gluten sensitivity or enzyme/transport defects. Lactose intolerance is common in developing countries, but rare before 4–5 years of age (Vandenplas 2015).
- **Anti-nutrients** (e.g. phytates and tannins) are naturally occurring substances that diminish or inhibit the utilization of nutrients. They are ubiquitous in plant-derived foods but may also be present in ASF (e.g. avidin in raw egg white).

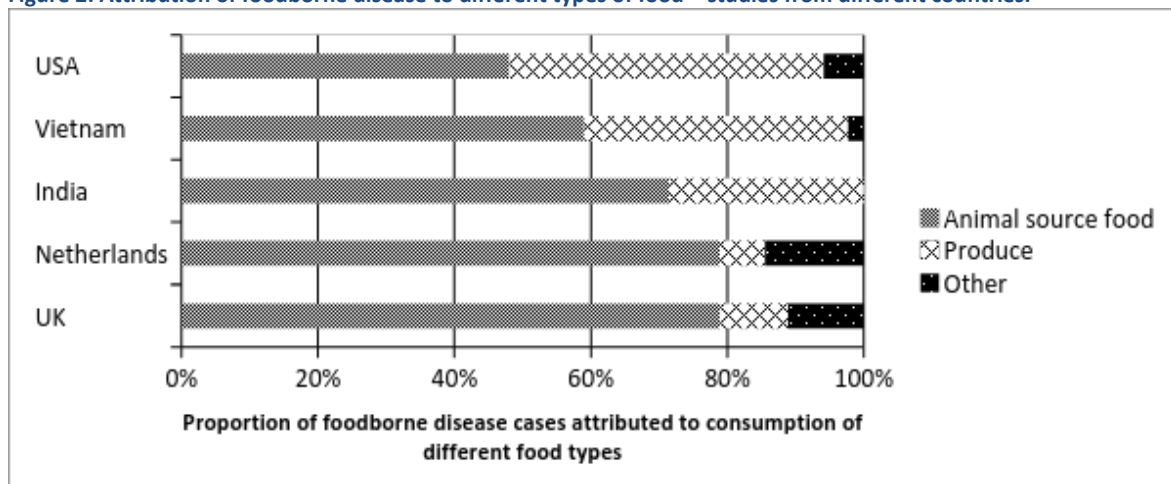
Key research gaps:

- **Although causes of FBD are relatively well understood for rich countries, this is not the case for developing countries. Identification of the main causes is needed for rational investment in mitigation.**
- **It is often more difficult to assess the health impacts of chemicals, which, combined with the high level of consumer and policymaker concern, warrants more research in this area.**
- **There is also a marked discrepancy between the causes of FBD which food safety experts think are most important and those which consumers and often policymakers think are most important. Research into risk communication is warranted.**
- **Food allergies are one of the most important food safety issues in rich countries. It is thought they are less common in poor countries but possibly increasing. More research is needed in this area, especially as consumption of ASF increases.**

2.3. Major foods implicated

There is very little information on the foods most responsible for FBD in developing countries. In developed countries, most FBD results from consuming ASF (i.e. livestock products and food derived from aquatic animals) and contaminated produce (i.e. fresh fruits and vegetables). In developing countries, less ASF and produce are consumed, but the fresh food consumed is often contaminated. The data on reported FBD by food source from developing countries show a similar pattern to developed countries (Figure 2). Meat consumption is a strong predictor of FBD mortality. In a cross-country study, for every additional metric ton of meat consumed per 100 people, FBD mortality increased by 6% (Hanson et al. 2012).

Figure 2: Attribution of foodborne disease to different types of food – studies from different countries.



Source: Grace (2015) adapted

Food consumption is determined by culture, religion, values and beliefs. These often affect consumption of the most risky foods which are often also the most nutritious and most societally valued. For example, in Ethiopia, raw meat is consumed; in Kampala, people were found to consume raw eggs in the belief it would cure illness; pastoralists in West Africa believed raw milk could not cause illness; and widespread consumption of raw, undercooked blood and raw fish in Southeast Asia leads to several zoonoses (Nasinyama et al. 2010; Carrique-Mas and Bryant 2013; Roesel and Grace 2014; Seleshe et al. 2014).

In HIC, the proportion of outbreaks attributed to fresh produce has been increasing in recent years (Lynch et al. 2009). Although there is less information from developing countries, similar trends are to be expected as drivers are similar, including: greater consumption of fresh produce; intensification increasing some risk factors; lengthening and increasing complexity of value chains; globalization; greater recognition of diseases linked to fresh produce; emergence of new diseases; increasing tendency to eat fresh produce without cooking; and the limited effect of washing in removing pathogens (Burnett and Beuchat 2001). Use of raw manure, sewage and contaminated water for irrigation and washing, and excessive use of pesticides are especially problematic in developing countries.

On the other hand, major chemical hazards which are well managed in HIC are still problematic in developing countries, making a direct extrapolation from HIC difficult. For example, most aflatoxin exposure results from consumption of maize, groundnuts and sorghum. In HIC, the burden from aflatoxins is negligible but in many developing countries it is a priority public health problem, and if the relation with stunting is proven, then the impact will be even higher. Similarly, in developing countries, there is no credible, comprehensive, quantified evidence on the impact of agricultural chemicals in food on human health (Käferstein 1997; Prüss-Ustün et al. 2011), but there is solid evidence that some health impacts occur, and suspicion that these could be substantial.

Research gap:

- ***Although causes of FBD are relatively well understood for rich countries, this is not the case for developing countries. There is also a marked discrepancy between the causes which food safety experts think are most important and the causes which consumers and often policymakers think are most important. Understanding the attribution of FBD is key to a rational approach to risk management.***

2.4. Problems along the value chain: inputs, production, processing, retail, household

It is essential that food safety be addressed from production to consumption. This comprehensive and integrated approach is known as ‘farm to fork’ or ‘stable to table’ or ‘boat to throat’; it implies the responsibility of providing safe food to the consumer is shared by all stakeholders along the chain. Ideally, the food is traceable, meaning that food items in the consumer kitchen can be traced all the way back to farm of origin.

Different hazards can be introduced at different points of the ‘farm to fork’ value chain and monitoring and control should take place at multiple points (Table 2). Some hazards can best or only be controlled at the pre-harvest stage, for example, antimicrobial residues in ASF. For other hazards, actions may be needed at multiple stages. In HIC, progress over the past decades in reducing the risk of FBD has largely resulted from improving post-slaughter or post-harvest practices (IOM 2012). However, in developing countries where there has been less success in improving food safety, it makes sense to tackle as many points as possible and rigorously evaluate where interventions are most effective.

Table 2: Hazards encountered along the ‘farm to fork’ pathway

Stage of pathway	Source of contamination	Hazards
Production	Soil	Sewage effluents; animal manure; soil-associated microbial pathogens (<i>Listeria</i> spp., <i>Clostridium</i> spp.); heavy metals; industrial chemicals
	Fresh water	Microbial contaminants; parasite eggs; heavy metals; industrial chemicals
	Salt water	Marine toxins Bacteria: <i>Vibrio</i> spp.
	Fertilizer and soil amendments	Pellet manure and fish emulsion can contain biological hazards; inorganic fertilizers may contain hazardous chemicals; biosolids may contain heavy metals
	Agricultural chemicals	Pesticides, fungicides, herbicides, rodenticides; antimicrobials; illegal growth promoters; disinfectants; fertilizers
	Fodder and roughage	Dioxins; mycotoxins; microbial pathogens (<i>Listeria</i> , <i>Neospora</i> , <i>Clostridium botulinum</i> , <i>Salmonella</i>)
	Animal feeds	Microbes; mycotoxins; metals; processing aids; anti-nutrients; veterinary drugs; persistent organic pollutants; plant toxicants (alkaloids)
	Agricultural workers	Faeces-associated pathogenic bacteria (<i>Salmonella</i> spp., <i>Shigella</i> spp., <i>E. coli</i> O157:H7 and others) Pathogenic parasites (<i>Cryptosporidium</i> , <i>Cyclospora</i>) Pathogenic viruses (hepatitis, enterovirus)
	Plant	Natural toxins: lectins; cyanogenic glycosides; oxalates; trypsin inhibitors
	Livestock	Microbes: <i>Salmonella</i> , <i>Campylobacter</i> , toxigenic <i>E. coli</i> and others Parasites: pork tapeworm; beef tapeworm; <i>Trichinella</i> Commensals Drugs: antimicrobials; hormones
	Aquatic animals	Pathogens: <i>Vibrio</i> spp. Commensals: <i>Clostridium</i> Parasites: trematodes, nematodes Contaminants: <i>Erysipelothrix</i> , <i>Listeria</i> Spoilage: histamine
Harvest	Plant harvesting	Physical hazards: stones, wood splinters Machine lubricants and cleaning materials
	Slaughter	Contamination of meat with gut contents is common; animal skin is another source of contamination; workers; water source; cleaning chemicals
	Aquatic capture	Infected workers
Processing	Infected food handler	Infected workers
	Adulteration with harmful substances	Unauthorized dyes; melamine; formaldehyde (as preservative)
	Processing conditions	Acrylamide
	Packaging	Packaging migrants; unfavourable conditions leading to microbial growth
	Peri-domestic pests	Flies, rodents, birds
Retail	Infected handlers	Infected workers
	Fomites	Equipment, surfaces, clothes
	Peri-domestic pests	Flies, rodents, birds
Home	Inappropriate storage	Temperature, non-food grade containers
	Cross-contamination	From fresh food, water, handlers, fomites
	Insufficient heating	

2.5. Trends, regional patterns, hot spots

There is no accurate reporting of FBD in developing countries and it is therefore difficult to monitor trends. However, in regions with good reporting such as North America and Europe, there has been no overall marked decline in FBD (although there have been successes in some places in control of specific pathogens) (Grace 2015). It is argued that the investments in food safety over the last 20 years have had limited impact, not because the strategies are ineffective, but because of other factors such as globalization, changes in eating habits and changes in farming practice increasing risk. Given the strong association between agricultural intensification and increase in FBD, it is likely that there will be sharp rises in FBD especially in those areas and countries where intensification is most rapid and least governed. The recent WHO study revealed that Africa has the highest burden of FBD per capita but Asia has the highest overall burden (Havelaar et al. 2015).

Key research gaps:

- ***The WHO study was a major advance in understanding the burden of FBD. Further research is needed to estimate the burden at country level and for specific food commodities.***
- ***The burden from chemicals needs further elucidation, as does the burden of probably important microbes not included in the WHO study.***

3. Managing food safety challenges in developing countries

3.1. Overview

The limited literature on domestic food safety regulation in developing countries shows that we do not yet have good models for standards and approaches that can work at scale to assure food safety where risks are pervasive, costs of compliance are high and enforcement capacity is weak (Grace and Unnevehr 2013). Given the very different farming systems and regulatory environments, the approaches used successfully in Europe cannot be directly applied to developing countries. A number of food safety interventions have been tried and evaluated with little evidence for benefit or sustainability. Nonetheless, other initiatives show promise, and a smaller number have been able to demonstrate sustained and scalable benefits.

There are four major lines of defence against FBD:

- Improving the safety of inputs;
- Improving the chemical and microbiological safety of raw foodstuffs;
- Using food processing technologies that mitigate risk (pasteurization and irradiation) and prevent contamination;
- Behaviour change aimed at food handlers, including home-based food handlers.

3.2. Food safety initiatives

In developing countries, there have been several attempts to improve food safety. In some cases, the primary goal is to improve food safety (e.g. upgrading abattoirs) while in others, food safety is one of many goals and sometimes not the most important (e.g. integrated pest management [IPM] or organic farming). Where food safety is one of many objectives, it is often assumed to result from other activities rather than actively planned and implemented, and as a result there is little evidence on food safety outcomes.

There is a consensus that food safety is best managed by a ‘farm to fork’ or ‘boat to throat’ approach that tackles food safety along the value chain. There should also be multiple barriers (or redundancy) in the system so that if one barrier to contamination fails there are other opportunities to block contamination or decontaminate.

Farm level

- *Producer organizations*: Organizing farmers in groups can improve bargaining power, reduce costs and make services, such as marketing, accessible; however, they have intrinsic challenges (including free-rider, horizon, portfolio, control and influence cost problems [Ortmann and King 2007]). Globally, about 10% of cooperatives are food related and 13% of Asians and 3% of Africans are reported to be members of cooperatives (Grace 2014). There is some evidence that cooperatives improve food safety practices (Kumar et al. 2013) and market access, but little evidence that food safety outcomes are improved. More flexible arrangements, such as self-help groups or dairy hubs, may also be effective and have potential for addressing food safety.
- *Farmer field schools*: Around 12 million farmers in over 90 countries across Asia, Africa and Latin America have been trained in Good Agricultural Practice (GAP) with an emphasis on IPM. A recent evaluation suggested that farmers in schemes benefited but there was little diffusion or sustainability beyond the project. While yields and profits appear to have increased, there is little evidence of health benefits, partly because these were often not monitored or evaluated

(Waddington and White 2014).

- ***Contract farming or outgrower schemes:*** These operate under an agreement for the farmer to produce a product in a given manner and the buyer to purchase it. Contract farming can facilitate access to inputs and innovation and reduce risk but often excludes the poorest farmers and there are concerns over power differentials leading to farmer exploitation (FAO 2006; Smalley 2013). Quality control is always part of the contract, but it may be more or less strict; several case studies show smallholders have achieved quality standards but there is little information on health outcomes (Minten et al. 2009).
- ***GAP:*** Smallholders can successfully meet export GAP standards if there are efforts made to include them (Unnevehr and Ronchi 2014). However, domestic GAP seems less successful both in terms of adoption and evidence of improved safety (Schreinemachers et al. 2012). Common challenges are that rules are complex and fees high and there is often little incentive for participation.
- ***Community-based certification:*** A range of quality assurance schemes have been developed, often involving a brand. These do not require government monitoring and are typically simpler and cheaper than GAP. There are local successes but insufficient evidence on scalability or effectiveness in improving food safety.

Along the value chain

- ***Technical innovations:*** A variety of innovations have been developed including simple cooling devices, food containers for storage and transport, and water disinfection. Some are locally successful, for example, transport of live fish in oxygenated tanks in Egypt and widespread use of trays for eggs (personal observation). However, many have not been widely adopted.
- ***Upgrading infrastructure:*** This has been a common approach with major objectives being upgraded slaughterhouses, chilling plants for milk and upgraded wet markets. There has been little evaluation of the long-term effects of this upgrading but the few studies done typically show poor success; this is attributed to the complexity of managing and the added expense and inconvenience, making them unpopular with users.
- ***Vertical integration:*** Large firms manage all stages in the value chain to enhance traceability and quality assurance. This model is increasingly popular especially in Southeast Asia. It is challenged by the increased cost and there is little compelling evidence that the products are safer.
- ***Traceability and certification:*** This is complicated by the large numbers of farmers, low trust of consumers, premiums associated with branded food and low availability. The case of Vietnam is typical: after more than 10 years of major efforts and investments by state authorities and market actors, the 'safe vegetable' production and distribution system has not yet been able to take a significant share of the vegetable market and gain widespread consumer trust (Nguyen-Viet et al. 2017). One survey found that around 10% of market vegetable retailers participate in the 'safe vegetable' scheme and that farmers of 'safe vegetable production cooperatives' in Hanoi market just 10% of their harvest through the safe vegetable channel (Hoi et al. 2009). Moreover, there is weak evidence that certified products are actually safer than traditionally produced and marketed vegetables.
- ***Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practice (GMP):*** Although most developing countries have adopted HACCP approaches to food safety, which are considered best practice, they have only been able to implement these for exported food and (to a limited extent) in some larger, formal sector agro-industries. This is not surprising given the failure of most small and medium companies in HIC such as the United Kingdom to implement these approaches (Taylor 2008).

Retail

- ***Export market:*** While smallholder farmers generally have challenges in participating in high-value export chains, and food safety standards are one of the barriers (Narro et al. 2009;

Unnevehr and Ronchi 2014), given intentional support, some smallholders have been able to successfully participate.

- ***Modern retail:*** There is a trend for modern retail to increase and, especially in Southeast Asia, it has been favoured by governments as a way of improving food safety. Evaluations have been mixed: where there is demand, outlets have been successful but their share of the market remains low and there is limited evidence to suggest food is safer. They are challenged: by high costs; consumer preference for fresh, un-chilled food; and, resistance from retailers (Wertheim-Heck et al. 2015). In some contexts, products from formal retail are safer than those from the informal sector, but perhaps surprisingly, this is not always the case (Roesel and Grace 2014).
- ***High-end, niche sellers:*** Many developing countries have retailers which sell food at a premium with strong emphasis on safety; these may sell food as 'organic' and emphasize traceability. While these appear to be growing, they reach only a small segment of the better-off consumers. There is evidence that food safety practices are often better in these market segments but there is little evidence on food safety or health outcomes, although there is probably a tendency for more higher-end, more expensive products to be safer (Hoffmann and Moser 2017).
- ***Training informal sector retailers:*** There is evidence, mainly from the dairy sector and street vendors of ready- to-eat foods, that training informal sector retailers can improve food safety. It is important that there is an incentive to attend training and motivate behaviour change after the training and it has proven difficult to establish long-term monitoring. Short-term studies show food safety improves but there is limited evidence on longer-term effects.
- ***Training food handlers:*** The only meta-analysis of interventions to train food handlers found trained handlers had around 30% improvement in knowledge over controls (n = 9 studies) and 70% improvement in practices, but this was based on self-reported practices, which are prone to exaggeration; moreover, only three studies were from developing countries (Soon et al. 2012).

Consumer

- ***Education and information:*** There are few examples of evaluations of food safety interventions in developing countries. Experience in HIC suggests that while most home cooks know about safe home food handling procedures, compliance is generally low and has not been significantly improved by campaigns (Shapiro et al. 2011). Moreover, consumers expect food to be safe. In HIC, the most successful initiatives for food safety have been those which addressed FBD further upstream; however, in developing countries there are few examples of food safety control in value chains, so addressing food safety in consumer households should be investigated.
- ***Willingness to pay:*** Studies in developing countries found that consumers report they are willing to pay a premium for safer food (Jabbar et al. 2010). However, there are few studies on actual behaviour. Moreover, there are ethical issues in selling food as 'safe' including the risk of channelling least safe food to the poorest (Grace 2015).

Governance

- ***Enforcement of regulation versus co-regulation:*** An up-to-date and rational food safety system underpins delivery of food safety but regulatory enforcement must not be over-relied on. Developed countries have found that command-and-control approaches relying on inspection and punishment are less effective and affordable than empowering stakeholders to self-regulate, motivated by appropriate incentives (Garcia-Martinez et al. 2007). With this approach, emphasis moves from testing end-product safety to ensuring processes remain within safe limits. The concept of co-regulation emphasizes coordination between public and private agents in the regulatory process (Eijlander 2005).
- ***Risk analysis:*** There is international consensus that food safety risks are best managed through risk analysis. This is even more important in LMIC as risk assessment allows targeting of scarce resources to priority problems (Unnevehr and Hoffmann 2015). Unfortunately, capacity for risk assessment in LMIC is limited, but without effective, evidence-based risk assessment, policy may

be driven instead by consumer perceptions, special interests and political pressure.

- ***Single authority***: A single unified structure or an integrated system is likely to be more effective, but is not sufficient to improve food safety. When restructuring is not possible because of historical or political reasons, a national food control strategy can identify roles of the different government divisions involved in food safety (FAO/WHO 2003).

Research gap: We do not yet have good models for standards and approaches that can work at scale to assure food safety. However, there have been many initiatives to improve food safety and much could be learned by a systematic assessment of these. Some of the more promising areas for research may be:

- ***Appropriate, cheap, robust technologies***
- ***Kiosk side diagnostics suitable for consumers and market actors***
- ***Research on incentives for behaviour change***
- ***Better addressing food safety in popular and/or growing agricultural development mechanisms such as contract farming and innovation platforms***
- ***Investigating the policy/regulation implementation gap***
- ***Developing approaches to risk analysis suitable for developing countries***
- ***Appropriate governance for developing countries***

4. Feed the Future Innovation Labs feedback: Comments from a food safety perspective

Helpful feedback was received from 12 out of 24 Innovation Labs (ILs) and three out of the six ILs for which we considered food safety was likely most important. The information is set out in Annex 3. In general, ILs perceived food safety to be essential or very important. However, only for a minority of ILs did food safety appear to be a major research thrust. Key insights from ILs included:

Important food safety questions to be addressed:

- Are small and medium enterprises a danger for food safety?
- How to adapt good practices to small-scale actors?
- How best to adapt food safety policy and regulation to developing countries?
- How is the food supply system shifting in response to food safety?
- How can consumer demand influence food supply and food safety?
- How to ensure safe consumer drinking water in irrigated areas?
- What is the role and means of improving food safety at household level?
- How to improve use of veterinary drugs and management of animal waste?
- Need for less expensive, more reliable laboratory testing.

Significant work being carried out by ILs:

- Food safety and penetration of processed food
- Consumer demand for food safety
- Post-harvest storage technologies
- Identification and development of IPM for high-value fruit and vegetable crops
- Cohort and cross-sectional studies on aflatoxin and nutritional outcomes
- Food safety in abattoirs, pastoralist communities and smallholder milk, and feed safety
- Phased risk communications plan tailored for different mycotoxin stakeholder groups

Comparing the current concerns and activities, some recommendations for the ILs can be made.

- **Prioritization:** When considering the known burden of FBD, problems caused by microbes and parasites are orders of magnitude greater than those caused by chemicals or pesticides, yet most of the ILs do not show a systematic or comprehensive approach to prioritization. It is true that it is harder to estimate the disease burden of chemicals and toxins and the unknown or potential burden could be high. This would justify a precautionary approach to reducing chemical and toxin burdens. At the same time, the most rational response is to invest in tackling known burdens and finding more out about unknown burdens, and using this information to inform appropriate investments, while also investing in reducing potential risks in advance of conclusive evidence if concern is sufficiently high.
 - **Suggestion: It may be helpful for ILs to better understand FBD burden and prioritization.**
- **Managing multiple objectives:** Food safety is often one of many considerations. This is seen in areas such as food processing, integrated pest management, food security policy and production of high-risk commodities such as produce and ASF. However, literature and experience suggests that when food safety is one of many issues, it is often managed poorly and not measured (e.g. experience of Farmer Field Schools). There is sometimes an assumption that if practices are improved then food would automatically be safer, but research by the International Livestock Research Institute (ILRI) and others has shown the relation is weak: practices can be better yet food less safe. If ILs consider food safety to be

important, they must clearly set out food safety outputs and outcomes, invest to achieve them and measure success in terms of reduced risk of disease or reduced exposure.

- **Suggestion: Where food safety is considered important it should be tracked as a distinct output/outcome.**
- **The best is the enemy of the good:** Many food safety initiatives seek to apply ‘best’ rather than ‘good enough’ practices. In developing (or low-income) countries, for example, HACCP is a gold standard for managing food safety in food businesses. However, even in Europe, while HACCP is widespread in large food operations, its use is limited within small companies (Taylor 2008). In developing countries, uptake is lower still. Under these circumstances, modified HACCP such as the Salford model (Taylor 2008) may be more appropriate for LMIC. Likewise, while a gradual shift to larger scale formal retail is underway, there is considerable evidence that ‘premature industrialization’ or efforts to move developing country agriculture to ‘modern systems’ can result in paradoxical worsening of food safety as well as hampering other objectives such as increasing the accessibility of highly nutritious food. The same may be the case when a country adopts very strict regulations for hazards, which would be very good if they were enforced, but the high prevalence may cause the regulators to avoid enforcements, since the consequences would be too high.
 - **Suggestion: Caution is needed in assuming that traditional agriculture and supply chains are a food safety problem and that modernization is the only way to solve it. More success may be attained by working with the traditional sector to gradually improve.**

Under-researched areas

- Most known burden is due to microbial pathogens in fresh foods sold in wet markets yet this is a minor part of IL research.
- Food safety is a whole diet problem; considering only aflatoxins ingested from peanuts is less informative than considering all dietary sources (maize, sorghum, milk), and considering multiple mycotoxins may be more useful than just measuring aflatoxins. Only the nutrition IL takes a dietary approach to food safety hazards.
- Most work is hazard-based rather than risk-based; hazard studies look at the presence of harmful substances in foods but risk takes this forward to understand the impact on human health. Hazards may be low but risks high and vice versa. The more important consideration from the perspective of public health is risk not hazard, so focusing on risks will lead to greater health impacts than focusing on hazard. However, the presence of hazards may be a major issue from the perspective of consumer acceptance and market access.
- Gender is an important issue in food safety because of different biological vulnerabilities, highly gendered roles in agri-food chains and women’s key roles as food retailers, processors and their predominant role in preparing food in households. This aspect was not mentioned.
- Food safety is an emerging issue in agricultural research and it is important to improve our basic understanding of prevalence and impacts. At the same time, food safety is an evolved science in HIC and there should be many opportunities to research into food safety solutions. The current portfolio is biased towards food safety assessment and understanding rather than food safety management.

Table 3: Feed the Future Innovation Labs

Led by universities in the United States of America, Feed the Future Innovation Labs are central to advancing novel solutions that support our goals to reduce global hunger, poverty and undernutrition.

Innovation Lab	Lead	Food safety*	Issues	
Aquaculture and fisheries	OSU	High	Parasites; bacteria; antimicrobials; chemicals	Hilla
Assets and market access	UCD	High	Food safety an important barrier for access	Mich
Horticulture	UCD	High	Pesticides, bacteria, parasites	Eliza
Food processing and post-harvest	Purdue	High	Biological and chemical hazards	Bett
Livestock systems	UF	High	Bacteria; parasites; antimicrobials; chemicals; aflatoxins	Gbol
Peanut production and mycotoxin control	UG	High	Mycotoxins	Dave
Climate-resilient millet	UCD	Moderate	Aflatoxins	Edua
Climate-resilient sorghum	UG	Moderate	Aflatoxins	Andr
Food security policy	MSU	Moderate	Food security requires food safety	Myw
Grain legumes	MSU	Moderate	Nutrition objective; aflatoxins	Irv
Integrated Pest Management	VT	Moderate	Pesticides, chemicals	Mun
Nutrition	Tufts	Moderate	Multiple relations food safety and nutrition	Patri
Reduction of post-harvest loss	KSU	Moderate	Spoilage related to contamination	Jagg
Rift Valley fever control in agriculture	UT	Moderate	Rift Valley fever transmitted by butchering	Geor
Small-scale irrigation	TAMU	Moderate	Grey water issues	Nevi
Sorghum and millet	KSU	Moderate	Mycotoxins	Tim
Sustainable intensification	KSU	Low	Health externalities from intensification	Vara
Climate-resilient beans	PSU	Low	Favism, chemicals	John
Climate-resilient chickpea	UCD	Low	Chemicals	Doug
Climate-resilient cowpea	UCR	Low	Chemicals	Tim
Genomics to improve poultry	UCD	Low	Disease resistance	Huai
Soybean value chain research	UI	Low	Health concerns	Pete
Applied wheat genomics	KSU	Low		Jesse
Climate-resilient wheat	WSU	Low		Kulvi

OSU: Oregon State University; UCD: University of California, Davis; UF: University of Florida; UG: University of Georgia; MSU: Michigan State University; VT: Virginia Tech; KSU: Kansas State University; UT: University of Texas at El Paso; TAMU: Texas A&M University; PSU: Penn State University; UCR: University of California, Riverside; UI: University of Illinois; WSU: Washington State University

* Based on literature, the report author categorized the likely importance of food safety to this area

Red means a response was received

References

- Abass, K., Ganle, J.K. and Adaborna, E.J. 2016. Coliform contamination of peri-urban grown vegetables and potential public health risks: Evidence from Kumasi, Ghana. *Community Health* 41: 392. doi:10.1007/s10900-015-0109-y
- Boye, J.I. 2012. Food allergies in developing and emerging economies: Need for comprehensive data on prevalence rates. *Clinical and Translational Allergy* 2: 25. doi: 10.1186/2045-7022-2-25
- Bruno, E., Bartoloni, A., Zammarchi, L., Strohmeyer, M., Bartalesi, F., Bustos, J.A., Santivañez, S., García, H.H., Nicoletti, A. and the COHEMI Project Study Group. 2013. Epilepsy and neurocysticercosis in Latin America: A systematic review and meta-analysis. *PLoS Neglected Tropical Diseases* 7(10): e2480. doi:10.1371/journal.pntd.0002480
- Bureau of Epidemiology. 2004. Situation of diarrheal diseases. Bangkok, Thailand.
- Burnett, S.L. and Beuchat, L.R. 2001. Human pathogens associated with raw produce and unpasteurized juices, and difficulties in decontamination. *Journal of Industrial Microbiology and Biotechnology* 27(2): 104–110.
- Carrique-Mas, J.J. and Bryant, J.E. 2013. A review of foodborne bacterial and parasitic zoonoses in Vietnam. *Ecohealth* 10(4): 465–489. doi:10.1007/s10393-013-0884-9
- Checkley, W., Buckley, G., Gilman, R.H., Assis A.M.O., Guerrant, R.L., Morris, S.S., Mølbak, K., Valentiner-Branth, P., Lanata, C.F., Black, R.E. and the Childhood Malnutrition and Infection Network. 2008. Multi-country analysis of the effects of diarrhoea on childhood stunting. *International Journal of Epidemiology* 37(4): 816–830. doi:10.1093/ije/dyn099
- Chen, Y., Yan, W.-X., Zhou, Y.-J., Zhen, S.-Q., Zhang, R.-H., Chen, J., Liu, Z.-H., Cheng, H.-Y., Liu, H., Duan, S.-G., Lan, Z., Sun, J.-C., You, X.-Y., Li, J.-G. and Wu, Y.-N. 2013. Burden of self-reported acute gastrointestinal illness in China: A population-based survey. *BMC Public Health* 13: 456. doi:10.1186/1471-2458-13-456
- Cutler, D., Deaton, A. and Lleras-Muney, A. 2006. The determinants of mortality. *Journal of Economic Perspectives* 20(3): 97–120.
- Dang-Xuan, S., Nguyen-Viet, H., Unger, F., Pham-Duc, P., Grace, D., Tran-Thi, N., Barot, M., Pham-Thi, N. and Makita, K. 2016. Quantitative risk assessment of human salmonellosis in the smallholder pig value chains in urban of Vietnam. *International Journal of Public Health* doi:10.1007/s00038-016-0921-x
- Daniel, J.H., Lewis, L.W., Redwood, Y.A., Kieszak, S., Breiman, R.F., Flanders, W.D., Bell, C., Mwihi, J., Ogana, G, Likimani, S., Straetemans, M. and McGeehin, M.A. 2011. Comprehensive assessment of maize aflatoxin levels in eastern Kenya, 2005–2007. *Environmental Health Perspectives* 119: 1794–1799.
- Eijlander, P. 2005. Possibilities and constraints in the use of self-regulation and co-regulation in legislative policy: Experience in the Netherlands – Lessons to be learned for the EU? *Electronic Journal of Comparative Law* 9(1).
- Elgueta, S., Moyano, S., Sepúlveda, P., Quiroz, C. and Correa, A. 2017. Pesticide residues in leafy vegetables and human health risk assessment in North Central agricultural areas of Chile. *Food Additives & Contaminants: Part B*. doi:10.1080/19393210.2017.1280540
- Eliku, T. and Leta S. 2016. Assessment of heavy metal contamination in vegetables grown using paper mill wastewater in Wonji Gefersa, Ethiopia. *Bulletin of Environmental Contamination and Toxicology* 97(5): 714–720. doi:10.1007/s00128-016-1915-3
- Ellis, L.J. and Turner, J.L. 2008. *Sowing the seeds: Opportunities for U.S.—China cooperation on food safety*. Woodrow Wilson International Center for Scholars, China Environment Forum. Washington, DC: USA.
- Ercsey-Ravasz, M., Toroczkai, Z., Lakner, Z. and Baranyi, J. 2012. Complexity of the international agro-food trade network and its impact on food safety. *PLoS ONE* 7(5): e37810.

- Fahrion, A.S., Jamir, L., Richa, K., Begum, S., Rutsa, V., Ao, S., Padmakumar, V.P., Deka, R.P. and Grace, D. 2014. Food-safety hazards in the pork chain in Nagaland, North East India: Implications for human health. *International Journal of Environmental Research and Public Health* 11(1): 403–417.
- FAO (Food and Agriculture Organization of the United Nations). 2006. *The state of food and agriculture in Asia and the Pacific*. Bangkok, Thailand: FAO.
- FAO/WHO (Food and Agriculture Organization of the United Nations/World Health Organization). 2003. *Assuring food safety and quality: Guidelines for strengthening national food control systems*. Rome, Italy: FAO and Geneva, Switzerland: WHO.
- FSNAU (Food Security and Nutrition Analysis Unit). 2010. *Offal consumption among the Somali population in Boroma, Burao and Bossaso towns*. Somalia: FSNAU.
- Garcia-Martinez, M., Fearne, A., Caswell, J. and Henson, S. 2007. Co-regulation as a possible model for food safety governance: Opportunities for public–private partnerships. *Food Policy* 32(3): 299–314.
- George, C.M., Oldja, L., Biswas, S.K., Perin, J., Lee, G.O., Ahmed, S., Haque, R., Sack, R.B., Parvin, T., Azmi, I.J., Bhuyian, S.I., Talukder, K.A. and Faruque, A.G. 2015. Fecal markers of environmental enteropathy are associated with animal exposure and caregiver hygiene in Bangladesh. *American Journal of Tropical Medicine and Hygiene* 93(2): 269–275. doi:10.4269/ajtmh.14-0694
- Gizachew, D., Szonyi, B., Tegegne, A., Hanson, J. and Grace, D. 2016. Aflatoxin contamination of milk and dairy feeds in the Greater Addis Ababa milk shed, Ethiopia. *Food Control* 59: 773–779.
- Gkogka, E., Reij, M.W., Havelaar, A.H., Zwietering, M.H. and Gorris, L.G.M. 2011. Risk-based estimate of effect of foodborne diseases on public health, Greece. *Emerging Infectious Diseases* 17(9). doi:10.3201/eid1709.101766
- Grace, D. 2011. *Assessment of risks to human health associated with meat from different value chains in Nigeria: Using the example of the beef value chain*. Nigeria Integrated Animal and Human Health Management Project Draft Report. Nairobi, Kenya: ILRI.
- Grace, D. 2014. *Measuring the size and scope of the cooperative economy*. New York: UN DESA.
- Grace, D. 2015. Food safety in low and middle income countries. *International Journal of Environmental Research and Public Health* 12(9): 10490–10507.
- Grace, D., Olowoye, J., Dipeolu, M., Odebode, S. and Randolph T.F. 2012. The influence of gender and group membership on food safety: The case of meat sellers in Bodija market, Ibadan, Nigeria. *Tropical Animal Health and Production* 44 (Suppl 1): S53–S59.
- Grace, D., Unnevehr, L. 2013. The role of risk assessment in guiding aflatoxin policy. In: Laurian Unnevehr and Delia Grace (Ed.), *2020 Focus “Aflatoxins: finding solutions for improved food safety”* (Focus 20, Brief 19). Washington, DC: International Food Policy Research Institute
- Grace, D., Roesel, K., Kang'ethe, E., Bonfoh, B. and Theis, S. 2015. Gender roles and food safety in 20 informal livestock and fish value chains. IFPRI Discussion Paper 1489. Washington, DC: IFPRI (International Food Policy Research Institute).
- Graffham, A., MacGregor, J. and Karehu, E. 2007. *Impact of EurepGAP on small-scale vegetable growers in Kenya*. London, UK: International Institute for Environment and Development.
- Grey, C.L. and Levin, M.E. 2014. Epidemiology of food allergy. *Current Allergy and Clinical Immunology* 27(3): 270–276.
- Gurpreet, K., Tee, G.H., Amal, N.M., Paramesarvathy, R. and Karuthan, C. 2011. Incidence and determinants of acute diarrhoea in Malaysia: A population-based study. *Journal of Health, Population and Nutrition* 29(2): 103–112.
- Han, S., Zhang, X., Chen, R., Wen, J., Li, Y., Shu, J., Ling, H. and Zhang, F. 2013. Trends in prevalence of clonorchiasis among patients in Heilongjiang Province, Northeast China (2009–2012): Implications for monitoring and control. *PLoS ONE* 8(11): e80173. doi:10.1371/journal.pone.0080173
- Hanson, L.A., Zahn, E.A., Wild, S.R., Döpfer, D., Scott, J. and Stein, C. 2012. Estimating global

- mortality from potentially foodborne diseases: An analysis using vital registration data. *Population Health Metrics* 10: 5. doi:10.1186/1478-7954-10-5
- Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T., Lake, R.J., Praet, N., Bellinger, D.C., Silva, N.R. de, Gargouri, N., Speybroeck, N., Cawthorne, A., Mathers, C., Stein, C., Angulo, F.J. and Devleesschauwer, B. on behalf of World Health Organization Foodborne Disease Burden Epidemiology Reference Group. 2015. World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Medicine* 12(12): e1001923.
- Hawkes, C., Grace, D. and Thow, A.M. 2015. Trade liberalization, food, nutrition and health. In: Smith, R., Blouin, C., Mirza, Z., Beyer, P. and Drager, N. (eds), *Trade and health: Towards building a national strategy*. Geneva, Switzerland: World Health Organization. pp. 92–116.
- Ho, S.C., Chau, P.H., Fung, P.K., Sham, A., Nelson, E.A., and Sung, J. 2010. Acute gastroenteritis in Hong Kong: A population-based telephone survey. *Epidemiology & Infection* 138(7): 982–991. doi:10.1017/S0950268809991087
- Hoffmann, S., Maculloch, B. and Batz, M. 2015. *Economic burden of major foodborne illnesses acquired in the United States*. Economic Information Bulletin No. 140. Washington, DC: U.S. Department of Agriculture, Economic Research Service.
- Hoffmann, V. and Moser, C. 2017. You get what you pay for: The link between price and food safety in Kenya. *Agricultural Economics*. doi:10.1111/agec.12346
- Hoi, P.V., Mol, A.P.J. and Oosterveer, P.J.M. 2009. Market governance for safe food in developing countries: The case of low-pesticide vegetables in Vietnam. *Journal of Environmental Management* 91(2): 380–388.
- IHME (Institute for Health Metrics and Evaluation). 2012. *The global burden of disease: Generating evidence, guiding policy*. Washington, DC: IHME.
- ILRI (International Livestock Research Institute). 2007. Learning the lessons of Rift Valley fever: Improved detection and mitigation of outbreaks. Participatory assessment of Rift Valley fever surveillance and rapid response activities. Nairobi, Kenya: ILRI. (Available at <https://cgspace.cgiar.org/handle/10568/32816>)
- ILRI (International Livestock Research Institute). 2010. *Demand for pork by Vietnamese consumers: Implications for pro-poor livestock policy and development agenda in Vietnam*. Project brief 1. Nairobi, Kenya: ILRI. (Available at <http://hdl.handle.net/10568/2465>)
- IOM (Institute of Medicine). 2012. *Improving food safety through a One Health approach: Workshop summary*. Washington, DC: National Academies Press. (Available at <https://www.ncbi.nlm.nih.gov/books/NBK114508>)
- Jabbar, M.A., Baker, D. and Fadiga, M.L. (eds). (2010). *Demand for livestock products in developing countries with a focus on quality and safety attributes: Evidence from Asia and Africa*. ILRI Research Report 24. Nairobi, Kenya: ILRI.
- Käferstein, F.K. 1997. Food safety: A commonly underestimated public health issue. (Available at <http://apps.who.int/iris/handle/10665/54778>)
- Kavle, J.A., El-Zanaty, F., Landry, M. and Galloway, R. 2015. The rise in stunting in relation to avian influenza and food consumption patterns in Lower Egypt in comparison to Upper Egypt: Results from 2005 and 2008 Demographic and Health Surveys. *BMC Public Health* 15: 285.
- Kirk, M., Ford, L., Glass, K. and Hall, G. Foodborne illness, Australia, circa 2000 and circa 2010. 2014. *Emerging Infectious Diseases* 20(11): 1857–1864.
- Kouamé-Sina, S.M., Bassa, A., Makita, K., Costard, S., Grace, D. and Bonfoh, B. 2012. Hazard identification and exposure assessment for bacterial risk assessment of informally-marketed milk in Abidjan, Côte d'Ivoire. *Food and Nutrition Bulletin* 33(4): 223–234.
- Krishna, A. 2007. For reducing poverty faster: Target reasons before people. *World Development* 35(11): 1947–1960.
- Kumar, A. and Parappurathu, S. and Jee, S. 2013. Do dairy co-operatives enhance milk production, productivity and quality? Evidences from the Indo-Gangetic Plain of India. *Indian Journal of*

- Agricultural Economics* 68(3): 457–468.
- Kumi, J., Mitchell, N.J., Asare, G.A., Dotse, E., Kwaa, F., Phillips, T.D. and Ankrah, N.-A. 2014. Aflatoxins and fumonisins contamination of home-made food (Weanimix) from cereal-legume blends for children. *Ghana Medical Journal* 48(3): 121–126.
- Kung, S.-J., Steenhoff, A.P. and Gray, C. 2014. Food allergy in Africa: Myth or reality? *Clinical Reviews in Allergy & Immunology* 46(3): 241–249. doi:10.1007/s12016-012-8341-z
- Lee, A.J., Thalayasingam, M. and Lee, B.W. 2013. Food allergy in Asia: How does it compare? *Asia Pacific Allergy* 3(1): 3–14. doi:10.5415/apallergy.2013.3.1.3
- Leroy, J.L. 2013. Child stunting and aflatoxins. In: Unnevehr, L. and Grace, D. (eds), *Aflatoxins: Finding solutions for improved food safety*. 2020 Vision Focus 20(4). Washington, DC: International Food Policy Research Institute (IFPRI).
- Lynch, M.F., Tauxe, R.V. and Hedberg, C.W. 2009. The growing burden of foodborne outbreaks due to contaminated fresh produce: risks and opportunities. *Epidemiology & Infection* 137(3): 307–315. doi:10.1017/S0950268808001969.
- Mangen, M.-J.J., Bouwknegt, M., Friesema, I.H.M., Haagsma, J.A., Kortbeek, L.M., Tariq, L., Wilson, M., Pelt, W. van and Havelaar, A. H. 2014. Cost-of-illness and disease burden of food-related pathogens in the Netherlands, 2011. *International Journal of Food Microbiology* 196: 84–93.
- McLinden, T., Sargeant, J.M., Thomas, M.K., Papadopoulos, A. and Fazil, A. 2014. Component costs of foodborne illness: A scoping review. *BMC Public Health* 14: 509 doi: 10.1186/1471-2458-14-509
- Minten, B., Randrianarison, L. and Swinnen, J.F.M. 2009. Global retail chains and poor farmers: Evidence from Madagascar. *World Development* 37(11): 1728–1741.
- Narrood, C., Roy, D., Okello, J., Avendano, B., Rich, K. and Thorat, A. 2009. Public- private partnerships and collective action in high value fruit and vegetable supply chains. *Food Policy* 34(1): 8–15.
- Nasinyama, G.W., Cole, D.C. and Lee-Smith, D. 2010. Health impact assessment of urban agriculture in Kampala. In: Prain, G., Karanja, N. and Lee-Smith, D. (eds), *African urban harvest: Agriculture in the cities of Cameroon, Kenya and Uganda*. New York, USA: Springer, IDRC, CIP. pp. 167–190.
- Nguyen-Viet, H., Tuyet-Hanh, T.T., Unger, F., Dang-Xuan S. and Grace, D. 2017. Food safety in Vietnam: where we are at and what we can learn from international experiences. *Infectious Diseases of Poverty* 6: 39.
- Ortmann, G.F. and King, R.P. 2007. Agricultural cooperatives I: History, theory and problems. *Agrekon* 46(1): 40–68.
- Prüss-Ustün, A., Vickers, C., Haefliger, P. and Bertollini, R. 2011. Knowns and unknowns on burden of disease due to chemicals: A systematic review. *Environmental Health* 10: 9. doi:10.1186/1476-069X-10-9
- Roesel, K. and Grace, D. 2014. *Food safety and informal markets: Animal products in sub-Saharan Africa*. London, UK: Routledge.
- Sang, X.-L., Liang, X.-C., Chen, Y., Li, J.-D., Li, J.-G., Bai, L. and Sun, J.-Y. 2014. Estimating the burden of acute gastrointestinal illness in the community in Gansu Province, northwest China, 2012–2013. *BMC Public Health* 14: 787. doi:10.1186/1471-2458-14-787
- Scallan, E., Hoekstra, R.M., Angulo, F.J., Tauxe, R.V., Widdowson, M.-A., Roy, S.L., Jones, J.L. and Griffin, P.M. 2011. Foodborne illness acquired in the United States—Major pathogens. *Emerging Infectious Diseases* 17(1): 7–15.
- Scharff, R.L. 2012. Economic burden from health losses due to foodborne illness in the United States. *Journal of Food Protection* 75(1): 123–131. doi:10.4315/0362-028X.JFP-11-058
- Schreinemachers, P., Schad, I., Tipraqsa, P., Williams, P.M., Neef, A., Riwthong, S., Sangchan, W. and Grovermann, C. 2012. Can public GAP standards reduce agricultural pesticide use? The case of fruit and vegetable farming in northern Thailand. *Agriculture and Human Values* 29(4): 519–529.
- Seleshe, S., Jo, C. and Lee, M. 2014. Meat consumption culture in Ethiopia. *Korean Journal for Food*

- Science of Animal Resources* 34(1):7–13. doi:10.5851/kosfa.2014.34.1.7
- Shapiro, M.A., Porticella, N., Jiang, L.C. and Gravani, R.B. 2011. Predicting intentions to adopt safe home food handling practices. Applying the theory of planned behavior. *Appetite* 56(1): 96–103. doi:10.1016/j.appet.2010.11.148
- Smalley, R. 2013. *Plantations, contract farming and commercial farming areas in Africa: A comparative review*. Land and Agricultural Commercialisation in Africa (LACA) Working Paper 055. Brighton, UK: Future Agricultures Consortium.
- Soon, J.M., Baines, R. and Seaman, P. 2012. Meta-analysis of food safety training on hand hygiene knowledge and attitudes among food handlers. *Journal of Food Protection* 75(4): 793–804.
- Stafford, R.J., Schluter, P.J., Wilson, A.J., Kirk, M.D., Hall, G., Unicomb, L. and the OzFoodNet Working Group. 2008. Population-attributable risk estimates for risk factors associated with *Campylobacter* infection, Australia. *Emerging Infectious Diseases* 14(6): 895–901.
- Tam, C.C., Larose, T. and O'Brien, S.J. 2014. *Costed extension to the Second study of infectious intestinal disease in the community: Identifying the proportion of foodborne disease in the UK and attributing foodborne disease by food commodity*. (Available at: https://www.food.gov.uk/sites/default/files/IID2%20extension%20report%20-%20FINAL%2025%20March%202014_0.pdf)
- Taylor, E. 2001. HACCP in small companies: Benefit or burden? *Food Control* 12(4): 217–222.
- Taylor, E. 2008. HACCP for the hospitality industry: History in the making. *International Journal of Contemporary Hospitality Management* 20(5): 480–493. doi: 10.1108/09596110810881427
- Thomas, M.K., Murray, R., Flockhart, L., Pintar, K., Pollari, F., Fazil, A., Nesbitt, A. and Marshall, B. 2013. Estimates of the burden of foodborne illness in Canada for 30 specified pathogens and unspecified agents, circa 2006. *Foodborne Pathogens and Disease* 10(7): 639–648.
- Torgerson, P.R., Oguljahan, B., Muminov, A.E., Karaeva, R.R., Kuttubaev, O.T., Aminjanov, M. and Shaikenov, B. 2006. Present situation of cystic echinococcosis in Central Asia. *Parasitology International* 55(Supplement): S207–S212.
- Unnevehr, L. and Hoffmann, V. 2015. Food safety management and regulation: International experiences and lessons for China. *Journal of Integrative Agriculture* 14(11): 2218–2230. doi:10.1016/S2095-3119(15)61112-1
- Unnevehr, L. and Ronchi, L. 2014. *Food safety and developing markets: Research findings and research gaps*. IFPRI Discussion Paper 1376. Washington, DC: International Food Policy Research Institute (IFPRI).
- Vandenplas, Y. 2015. Lactose intolerance. *Asia Pacific Journal of Clinical Nutrition* 24(Suppl 1): S9–S13.
- Waddington, H. and White, H. 2014. *Farmer field schools: From agricultural extension to adult education*. 3ie Systematic Review Summary 1. London, UK: International Initiative for Impact Evaluation (3ie).
- Wertheim-Heck, S.C.O., Vellema, S. and Spaargaren G. 2015. Food safety and urban food markets in Vietnam: The need for flexible and customized retail modernization policies. *Food Policy* 54: 95–106.

Annex 1: Terms of Reference

Write a white paper (approximately five to eight pages in length plus references) that presents current food safety challenges in developing countries, the state of research to address these, followed by key research gaps that need to be addressed. Take a broad look at the Feed the Future Innovation Labs' research and consider the missing links in the Feed the Future research division portfolio that are not addressed under the current research programs.

Discuss the global research questions/evidence gaps on agricultural production (e.g. aflatoxins, pesticides, pathogens), post-harvest handling and processing of foods (e.g. meat, milk, fresh fruits and vegetables), opportunities and risks associated with value addition (e.g. processing, storage) and reaching target consumers in specific crops and countries.

The white paper should review the existing evidence and provide details on the major researchable questions/evidence gaps based on the best knowledge available and not currently a research theme by any of the Feed the Future Innovation Labs.

Outline

What makes a food safety challenge important? (2 pages)

1. Impact on human health: cases, deaths, disease burden. Gaps, opportunities
 - a. Known burden
 - b. Unknown but potentially high burden
2. Economic and trade impacts
3. Public concern and spillover to other sectors (especially nutrition, gender and economic considerations)

Food safety challenges in developing countries (3 pages)

1. Health burden of FBD
2. Main causes of FBD
3. Major foods implicated
4. Problems along the value chain: inputs, production, processing, retail, household
5. Regional patterns, trends, hot spots

Managing food safety challenges in developing countries (2 pages)

1. Approaches based on improving food safety
 - a. Safety certification
2. Approaches with food safety as one of several goals
 - a. Farmer Field Schools, GAP, value chain linkages, collective action
3. What are Feed the Future Innovation Labs doing in this area?
4. Research gaps

Feed the Future Innovation Labs and food safety challenges (1 page)

1. Which Innovation Labs are most likely to face food safety challenges and what?
2. What are Innovation Labs currently doing?
3. What is the potential for action?

Annex: Questions for an e-consultation

- This paper will be used as basis for an e-consultation as you know and we want to have

provocative and engaging questions to drive wide audience base and participation.

Annex 2: Food safety myths, misperceptions and half-truths

Questions for e-consultation

Do you know how big is the foodborne disease burden in the country/region you work in? What other disease might this be comparable to? (Indicate one: diphtheria, tuberculosis, iodine deficiency).

Answer: Tuberculosis

Foodborne disease has been estimated to cost the United States of America up to USD 80 billion a year. What might be some of the economic effects of foodborne disease in poor countries?

Answer: Cost of illness, cost of healthcare, loss of markets, fall into poverty trap

A USAID-funded survey in Vietnam asked people what were their top concerns in life; what do you think the top two were? (Rank: climate change, educational opportunity, corruption, employment, food safety).

Answer: Employment, then food safety

Where can food safety best be managed? On the farm, during processing or retail, or in the household?

Answer: It is agreed that food safety should be managed along the farm-to-fork pathway, but experience shows management is often most effective further down the chain, e.g. nearer production.

Most infectious diseases are declining, as non-communicable diseases become more important. Is foodborne disease getting worse or getting better?

Answer: Although the evidence is limited, it appears that foodborne disease is an exception and is getting worse because of the rapid growth in demand for the most risky products (ASF and fresh produce) and the rapid, un-organized development of the value chains that supply them.

How important are informal markets in supplying fresh foods in Asia and Africa and who mainly supplies these?

Answer: Fresh markets typically supply over 80% of food consumed and most comes from smallholders.

Who cares most about food safety, men or women?

Answer: Surveys in many countries have found that women care more about food safety; this is not surprising as in most cultures, women manage the food consumed by the family.

Where does most of the burden of foodborne disease fall?

Answer: According to a 2015 WHO report, 98% of the burden falls on developing countries and children are disproportionately affected. Children under five years of age represent 9% of the world's population but bear 40% of the foodborne disease burden.

Many development workers would agree to some or all of the below statements. The e-consultation and evidence document will show how much and how little evidence there is for these!

Food safety is a kitchen problem not an agricultural problem. It should be tackled in the household and not in the value chain.

Diarrhoeal diseases are mostly the result of inadequate water supplies and lack of latrines.

Foodborne diseases are not serious; many people have diarrhoea and get on with their daily work without problems. We should tackle more serious health problems first.

The most serious food safety problems are those due to chemicals, toxins and genetically modified organisms. Natural, unprocessed food is largely safe.

Modern agri-food systems are by nature safer than traditional systems. We should encourage modernization of agriculture to make food safer.

We should work with the big domestic and international firms because it is much easier for them to adopt food safety technologies and they are easier to regulate.

Most food sold in markets in developing countries is unsafe. That means we need much stronger legislation and more inspection and enforcement to punish those who are selling unsafe food.

Safe food is a human right. There are no circumstances under which we should tolerate unsafe food.

Food safety isn't a researchable issue; we know how to make food safe – GAP, GMP and HACCP.

I see from the official statistics that foodborne disease is not a problem in my country.

Annex 3: Feedback from Innovation Lab directors

Issue	Food safety	Important issues	Current research	Planned re
Fish	Essential	<p>Cold chain development and security: woefully lacking in many countries.</p> <p>Infrastructure and market support: needed to get fresh product to urban conurbations.</p> <p>Preparation, cooking, drying and value-added products (fish paste, fish sausage, algae 'syrup' etc.) reliable information: for general knowhow in the household, shops, restaurants etc.</p> <p>HACCP training: for export market. Other quality assurance–quality control technologies for export market also could be useful but not necessarily for small-scale fish farms; depends largely on cooperatives and market structure.</p>	<p>None at present. Some current socio-economics work wraps around concepts of food safety and nutrition. Older research available from our website: AquaFish.oregonstate.edu</p>	<p>No, we are on overall. If an association were to be available, we entertain this area</p>
Rift Valley fever	Important	<p>Rift Valley fever can be transmitted via butchering</p> <p>Lack of effective surveillance</p> <p>Loss of food supply</p>	<p>Developing a vaccine</p>	<p>No</p>
Food safety policy	Very Important	<p>Are food processing small and medium enterprises – compared to large local companies and imported food – a danger for food safety? Many think they are but we don't have data. If they are, this creates a problem from many perspectives: much processed food currently comes from such firms, and they have higher labour-to-output ratios than do large firms, meaning that if they were to be regulated out of the market, employment would suffer.</p> <p>What are consumers willing to pay for food safety?</p> <p>What, if any, changes are chain supermarkets making in their procurement systems in response to perceived demand for food safety?</p> <p>Understanding consumer demand for food quality as it pertains to various food safety certifications and quality attributes.</p>	<p>Food safety is one aspect of research we are starting on the penetration of processed foods into rural areas and smaller towns of Tanzania.</p> <p>Evaluating consumer demand for food safety and food quality</p> <p>http://www.sciencedirect.com/science/article/pii/S0306919210001442</p> <p>https://academic.oup.com/ajae/article/94/2/489/57117/Chinese-Consumers-Demand-for-Food-Safety</p>	<p>See previous</p>
Post-harvest	Essential	<p>Mycotoxins, especially aflatoxin</p> <p>Hazards in food processing</p> <p>Specific safety protocols dependent on the process and the final product</p>	<p>Food safety through drying technologies: (1) development and testing of two types of grain drying technologies (solar and drying stove) designed for smallholder farmers, (2) development of low-cost moisture determination technologies and methods.</p> <p>Food safety in storage: Research will be conducted to develop innovations for mycotoxin control in hermetic storage. This involves determination of optimum conditions under which grain can be safely stored in hermetic conditions in the humid tropics, and to identify optimum grain moisture content for storing grains without</p>	<p>We have many breakthrough areas listed in terms of technology and methods are in the process of testing the</p>

			<p>compromising quality.</p> <p>Food safety is an integral part of delivering processed foods to consumers and includes putting in place GMP and HACCP. Sometimes goes further in the value chain to GAP.</p>	
Grey water	Somewhat important	Water safety	n/a	n/a
Poultry genomics	Very important	Pathogens on poultry could contaminate poultry meat and eggs and/or infect humans	Understand molecular and cellular mechanisms of host response to <i>Salmonella</i> , <i>Campylobacter</i> and avian influenza infection in poultry and elucidate the interaction among host gut-associated immune system, poultry gut microbiome and pathogens and develop better strategy to enhance colonization resistance to pathogen infection in poultry.	Further res aforement
Climate-resilient cowpea	A little	n/a		
Integrated pest management (IPM)	Essential	<p>About 40% of crop is lost due to pests and diseases.</p> <p>In recent years, increase in spread of invasive species is causing havoc to crop production. Examples: South American tomato leaf miner, <i>Tuta absoluta</i>, papaya mealybug and Panama wilt of bananas.</p> <p>Viral diseases of various crops require management solutions as there are no chemicals available to control them.</p>	<p>Development of IPM packages for crops. Use of <i>Trichoderma</i> for control of soil-borne fungal diseases. Grafting on resistant rootstock to manage soil-borne bacterial wilt disease of tomato and eggplant. Use of <i>Pseudomonas fluorescens</i> and <i>Bacillus subtilis</i> to induce resistance in plants. Adoption of pheromone traps for area-wide management of pests as well as monitoring them. Recommendation of biological and botanical pesticides to replace synthetic chemical pesticides. Promotion of classical, augmentative and conservation biological control.</p>	<p>Identificati developme component packages f vegetable Bangladesh Nepal, Ethi and Tanzar chickpea in maize in Et and Tanzar Cambodia and for dra mango, lyc longan in V addition, w modelling South Ame leaf miner world and miner in Af working on change and in Nepal by weather st transects f assessment m altitude Terai to hig We are als unique tec transfer m</p>

				regional co
Nutrition	Very important	<p>Mycotoxin contamination of food supply: link to health/nutrition. Potential contributor to poor birth outcomes and compromised linear growth of infants.</p> <p>Consumer perception of food safety and quality related to aquaculture and horticulture and resulting purchasing behaviour.</p>	<p>Birth cohort studies (Nepal, Uganda) to determine extent of human exposure to aflatoxins and socio-economic correlates includes (Nepal) farmer awareness of mycotoxin problems and related household behaviour.</p> <p>Panel survey in Bangladesh that considers consumer behaviour when considering local market purchases of fish and/or fruits and vegetables.</p> <p>Collaboration with other Innovation Labs on toxin contamination of soil in Nepal.</p> <p>National assessment of aflatoxin blood exposure in Timor Leste.</p>	<p>Greater fo consumer mycotoxin perception safety.</p> <p>Possible co perception consumers</p> <p>Possible su mycotoxin Mozambiq Madagasca</p>
Livestock	Very important	<p>Livestock Disease Management and Food Safety is one of the four Areas of Inquiry for the Livestock Systems Innovation Lab (LSIL). In particular, we aim to improve the safety of animal-source foods [ASF] (e.g. reducing pathogens, aflatoxins and undesirable residues in meat and milk).</p> <p>As part of the research priority setting in the six LSIL target countries, the following issues were mentioned:</p> <p>Improve milk and meat safety from production to processing and handling: Understanding hazards in the food systems and assessing the possible associated risks.</p> <p>Improve food safety at the household level (including ASF-producing households).</p> <p>Promote prudent antibiotic use and reduce antimicrobial resistance.</p> <p>Improve poorly developed food safety regulation systems which lack or have limited infrastructure and testing capacity and limited overall food safety regulatory framework and implementation.</p> <p>Reduce environmental contamination with enteric pathogens from livestock to prevent environmental enteric dysfunction in young children.</p>	<p>Five out of 13 funded research projects in three target countries deal directly or indirectly with food safety:</p> <p>Ethiopia:</p> <p>One large (4-year) research project addresses food safety at the abattoir level, looking into establishing baselines for the presence of foodborne pathogens within abattoirs and developing and implementing strategies to mitigate the burden of foodborne pathogens within abattoirs.</p> <p>One small (1-year) research project looks into improving handling practices and microbiological safety of milk and milk products in Borana pastoral communities.</p> <p>Rwanda:</p> <p>One small (1-year) research project looks into milk production practices and udder health and their impact on milk quality, safety and processability.</p> <p>Lastly, two small research projects (1-year) in Rwanda and Ethiopia conduct research on animal feed safety; in particular, these studies are surveying feeds around the country for their mycotoxin concentrations. Discussions are ongoing to add testing the milk in those areas for aflatoxin to their experiments.</p>	<p>The Reque Application Cambodia ongoing – safety relat projects m In addition publish the Application Faso and N near future these two some proje dealing wit may be fur</p>
Soy food	Important	<p>Soy food Innovation Lab works with soy food entrepreneurs in developing areas of South America and Africa. We see food safety as an essential part of a food enterprise, whether or not it sells soy foods. Practising food safety enables a business to avoid food spoilage and foodborne illness, which can reduce customers’ trust in your business’s product. Maintaining a food safety system in a soy food operation also enables you to</p>	<p><i>Packaging:</i> Perishable foods such as soy milk and soy yoghurt should be packaged in order to maximize their shelf life.</p> <p><i>Soybean storage:</i> Soybeans must be stored so that they are kept dry and clean and free of foreign matter.</p> <p><i>Sterilization:</i> Soy food products must be cooked to ensure harmful bacteria are</p>	<p>We are alw new resear and welcom</p>

		<p>apply for and receive certification from your country's Food and Drug Administration. This certification allows you to brand your product and distribute it to a wider customer base.</p>	<p>killed.</p> <p><i>Sterile production room:</i> The facility, equipment and workers all must be kept clean while making the product.</p> <p><i>Limited resources:</i> Small-scale soy food processors in under-developed areas often work with fewer resources, which can make practising food safety more difficult.</p>	
Sustainable intensification	Essential	<p>Foodborne pathogen mitigation (specifically considering livestock and ASF production, as well as mixed/integrated crop-livestock systems, which is a major goal of sustainable intensification)</p> <p>Toxin mitigation (biological and chemical)</p> <p>The interaction between human health and human nutrition</p>	<p>We have a sub-award in Senegal that has a food safety component, particularly focusing on ASF. Dr Jessie Vipham is an assistant professor in global food systems and nutrition within our lab and her background is in food microbiology and food safety. Food safety has also be incorporated into the Sustainable Intensification Innovation Lab nutrition framework as an important aspect of achieving positive human health and nutrition outcomes, as well as the Sustainable Intensification Indicator framework as a part of the human condition domain. http://www.k-state.edu/siil/whatwedo/indicators/index.htm</p>	<p>We do not have plans for food safety. However, Dr Vipham's research portfolio, co-engaged in and proposed food safety. This research focuses on pathogen mitigation in livestock and as in development education programs for in development contexts.</p>
Reduction of post-harvest loss	Essential	<p>Mycotoxins: We have conducted baseline surveys, established in-country lab/human capacity for testing and tested post-harvest interventions for reduction of mycotoxin contamination in Bangladesh, Ethiopia, Ghana, Guatemala and Afghanistan. We are or have focused on rice, maize, sesame, chickpea, wheat, tree nuts and raisins.</p>	<p>Baseline surveys, as well as drying and storage technologies for the reduction of mycotoxin accumulation is ongoing as described above.</p>	<p>We are conducting surveys and capacity building in Honduras a year. In the future we are interested in mapping to contextual</p>

		<p>Post-harvest mycotoxin contamination: See above.</p> <p>Risk communications: We have devised a phased risk communications plan tailored for different mycotoxin stakeholder groups, and are integrating this across our programming.</p>		<p>potential r accumulati and groun will also be and spices.</p>
--	--	---	--	--