FOOD SAFETY IN DEVELOPING COUNTRIES: AN OVERVIEW

A learning resource for DFID Livelihoods Advisers

Delia Grace, October 2015

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Contents

Figures

Tables

Boxes

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Acronyms and Abbreviations

ASF	Animal Source Foods
CAST	Council for Agricultural Science and Technology
DALY	Disability Adjusted Life Year
DFID	Department for International Development (UK)
DRC	Democratic Republic of Congo
ECDC	European Centre for Disease Prevention and Control
EFSA	European Food Safety Agency
EU	European Union
FAO	Food and Agriculture Organization
FBD	Foodborne Disease
FERG	Foodborne Disease Epidemiology Reference Group
GAP	Good Agricultural Practice
FORHEAD	Forum on Health, Environment and Development (China)
GDP	Gross Domestic Product
GFSF	Global Food Safety Forum
HACPP	Hazard Analysis and Critical Control Points
HIV	Human Immunodeficiency Virus
IHME	Institute for Health Metrics and Evaluation
ILRI	International Livestock Research Institute
INFOSAN	International Network of Food Safety Authorities
ISID	International Society for Infectious Diseases
NAFDAC	National Agency for Food and Drug Administration and Control (Nigeria)
NGO	Non-Governmental Organisation
NSAC	National Sustainable Agricultural Coalition (USA)
PACA	Partnership for Aflatoxin Control in Africa
PAH	Polycyclic Aromatic Hydrocarbons
PPD	Plant Protection Department (Ministry of Agriculture and Rural Development Vietnam)
UN	United Nations
Unicef	United Nations Children's Fund
USA	United States of America
VNS	Vietnam News Service
VVM	Vaccine Vial Monitor
WHO	World Health Organization
WSH	Water Sanitation Hygiene
YOMPI	The Young, the Old, the Malnourished, the Pregnant, and the Immune compromised

Symbols

%	Per cent
+	Positive – used to denote strength of evidence

Measurements/Currency

$	US dollar
ha	hectare
kg	kilogram

OVERVIEW

Take home messages

Foodborne diseases (FBD) can be defined as any illness caused by ingesting contaminated food or drink. The most common clinical presentation of foodborne diseases is gastrointestinal symptoms, but foodborne diseases can also lead to chronic, life-threatening symptoms including neurological, gynaecological or immunological disorders as well as multi-organ failure, cancer and death.

Foodborne disease matters for development. It is a major public health problem. It presents a barrier to countries that wish to export and to smallholder farmers who wish to sell produce in high value domestic markets. It is also a major concern of consumers.

Most of the known health burden of foodborne disease is caused by parasites, protozoa, bacteria and viruses in fresh animal source foods and vegetables. There are also major concerns, but major evidence gaps, on the health impacts of chemicals and fungal toxins in food.

Foodborne disease is probably increasing in developing countries. This is the result of:

- increased consumption of the most risky perishable foods;
- the intensification of agriculture that can encourage the spread of disease and can result in more contamination of food; and
- the failure to establish effective food safety systems for domestic markets.

Problems are especially noticeable in South East Asia and urban South Asia and Africa. Solutions to improve food safety require an enabling policy environment as well as systems that recognise and reward value chain participants for producing safe food.

The growth of food exports from developing countries, and the successes (albeit limited) of initiatives to improve food safety in informal markets, suggest that foodborne disease is a problem that can be solved.

The full health effects and the full economic costs of unsafe food are not known, but the global impact on health, trade, and development is considered enormous. Worldwide, hundreds of millions of cases of foodborne disease occur each year costing billions of dollars.

The material presented in this resource reviews foodborne disease in developing countries. It covers the following:

- the likely burden of foodborne disease;
- the importance of foodborne disease to developing countries;
- the causes of foodborne disease and the most risky foods;
- trends in foodborne disease; and
- the management of foodborne disease.

The resource has been put together to help livelihoods advisers and other interested development professionals critically think through the issues highlighted above. Our aim is to engage readers unfamiliar with the subject and to refresh and update knowledge on food safety for others. We hope the material will provide 'non-food safety experts' with a good understanding of foodborne disease within the broader context of 'development' discussions. It is assumed that readers already have a solid grasp of international development contexts, and current development discourse.

By reading this resource we hope that development professionals will become more confident in asking further questions or proposing and developing innovative and relevant approaches that consider the implications of foodborne disease in a changing global context.

The key debates, evidence, and messages outlined in this resource should provide 'food for thought' for future programme design or policy advice. At the very least, it is hoped that the evidence, messages and questions presented will stimulate thinking about narratives, and the assumptions we often hold about foodborne disease and food safety.

Finding your way through the material

The material has been presented in three main sections:

1. Foodborne disease and its impact
2. Interventions for managing food safety
3. Trends and drivers that affect food safety

Part 1 will help readers to understand what is meant by foodborne disease and its impact. It summarises current best evidence and knowledge gaps on foodborne disease in developing countries. It shows that:

- there is reasonable evidence that FBD has major impacts on developing countries;
- from a global perspective, developing countries bear the brunt of FBD;
- developing country consumers are concerned about FBD;
- most of the known burden of FBD disease comes from biological hazards. For example, we show there is evidence that:
    - Foodborne parasites (gastro-intestinal worms and protozoa) are an important known cause of foodborne disease causing millions of illnesses and around 18 million Disability Adjusted Life Years (DALYs) lost each year globally.
    - Microbial pathogens (bacterial and viral pathogens) also impose high health burden, causing millions of illnesses each year, but less is known of their burden. Conservatively assuming only 10% of the diarrhoeal burden is due to these pathogens, and the non-diarrhoeal burden is equivalent to this, around 18 million DALYs are lost each year globally.
    - Aflatoxins impose a moderate health burden of around 100,000 cases of liver cancer and 1-2 million DALYs a year but health impacts may be greater. In particular, aflatoxins are strongly associated with stunting and immune suppression.
    - Other toxins. Marine toxins cause tens of thousands of FBD cases a year, methanol and plant toxins hundreds of cases but the global health burden for these is not well established.
- Chemicals of major health concern can be transmitted through food but there is little quantified evidence of health burden (except for arsenic which has been recently reviewed). Arsenic, cadmium, mercury, dioxins and highly hazardous pesticides are chemicals of especial concern.
- Most foodborne disease is the result of consumption of fresh, perishable foods sold in informal markets.

Look out for symbols in the text. These will guide you to further information presented as Factsheets. Read these if you want to find out more on:

- measuring health burden caused by disease;
- foodborne parasites – what they are and what they do; and
- foodborne bacterial and viral pathogens.

We hope that after reading this section you come away understanding the complex nature of foodborne disease and why it is so important in terms of health burden, distribution, trends and cost.

Part 2 summarises some of the interventions for managing food safety and gets us thinking about the "so what" questions. It shows that foodborne disease is preventable. The material suggests that large scale formal food production and processing are not the only answers to reducing foodborne disease. We look at consumer demand for food safety, a promising way of driving up quality, but highlight three types of important challenges to consider –practical, ethical and economic. We review capacity building initiatives to combat foodborne disease, exploring Good Agricultural Practices and training of market actors. Finally we take a look at the technology interventions and policy approaches to managing food safety.

If you want to find out about or explore in further detail food trends, drivers that affect food safety in developing countries then go to Part 3. This section helps us think through:

- what the implications for agricultural intensification might be;
- the changes that are taking place in food consumed;
- the changes to how food is sold; and
- what potential shocks there might be to food systems.

We also review the geography of food safety and how this impacts on people who are poor. We look at what food safety means for: small farmers, export industries, women, the most vulnerable people, and for nutrition.

The conclusions presented at the end capture what the current best evidence is telling us:

- Food safety has been neglected in developing countries. There is growing evidence that foodborne disease may be an important contributor to gastrointestinal disease.
- Foodborne disease has been increasing in developed countries and is likely to increase in developing countries.
- Foodborne disease is not just a health issue. Already a major determinant of export market access, it is increasingly affecting domestic markets.

For more information

If you want to explore the material further we have also put together an annotated bibliography that lists recommended further reading. You may also find the stocktake note on what food safety initiatives are underway helpful. The glossary and our factsheets are designed as standalone quick refreshers.

As a starting point, click on the icon to read our Food Safety Fast Facts.

A note on the Evidence Criteria used in this material

Recent decades have seen increasing emphasis on the need to justify decisions on good evidence. The different evidence reviewed in this paper has been graded. Look out for the "+" symbols as you read the material.

+++ indicates **Good Evidence** - many good quality studies that consistently show an effect.

++ indicates **Suggestive Evidence** - several good quality studies that preponderantly show an effect and/or several studies that consistently show an effect but have less rigorous methodologies.

+ indicates **Weak Evidence** - supported by one or two studies; several weak studies; grey literature; unknown sources; and/or expert opinion.

1: FOODBORNE DISEASE IMPACTS

Nature and extent of food safety risks in developing countries

This section provides a useful summary of current best evidence and knowledge gaps on foodborne disease in developing countries. It shows that:

- there is reasonable evidence that FBD has major impacts in developing countries;
- from a global perspective, developing countries bear the brunt of FBD;
- developing country consumers are concerned about FBD;
- most of the known burden of FBD disease comes from biological hazards; and
- most FBD is the result of consumption of fresh, perishable foods sold in informal markets.

Developing countries probably bear most of the burden of foodborne disease

The full burden of FBD in developing countries is not known but experts believe that developing countries bear the brunt of FBD (Käferstein, 2003 +; UN, 2013 +). This is plausible given that:

- high levels of hazards are often reported in developing country food (Grace et al., 2010 ++);
- high prevalences of potentially foodborne pathogens are found in hospital and community surveys of children and adults with diarrhoea (Fletcher et al., 2013 +++);
- a lack of clean water for washing food and utensils is common (around 750 million people do not have access to clean water (WHO/UNICEF, 2014 +++); and
- the use of human sewage or animal waste for horticulture production is common in developing countries.

The burden of FBD is more challenging to estimate than the burden of single diseases such as malaria or tuberculosis. The most common manifestation of FBD is diarrhoea, but most cases never get a laboratory diagnosis.

You can read more in our factsheet on health impacts of FBD. It provides a simple explanation of why FBD is under reported and therefore under estimated.

Even if a laboratory diagnosis is provided, there is often no way of telling if the pathogen detected was acquired from food, water, the environment or another person. Moreover, in many countries there is no requirement to report FBD. Even if there is a requirement the reporting system may not be adequate. As a result, for most countries, stakeholders do not know the level of FBD or what issues are most important. For example, in China, reporting of sporadic FBD is voluntary but not required. A population based study in Gansu province estimated 30 million cases of acute intestinal illness occur each year, requiring 22 million medical consultations and 20 million courses of antibiotics. Just 400 cases were sent to the health reporting system (Sang et al., 2014).

On the other hand, in Malaysia it is a requirement by law to notify all cases of cholera, typhoid, paratyphoid, dysentery, and food poisoning. During 1990-2006, annual notifications for these diseases ranged from 2,934 to 10,416 cases. In contrast, a community study estimated at least 13 million episodes of acute diarrhoea annually; most of which are likely to be the result of these notifiable diseases. The figures indicate that cases of acute diarrhoea in Malaysia are grossly under-reported, with less than 0.1% of cases being captured by the national surveillance system annually (Gurpreet et al., 2011).

Many strands of evidence suggest FBD may be higher in developing countries than in high income countries (Nguyen et al., 2007; Ellis & Turner, 2008; Greenwood et al., 2008; WHO, 2014; FAO, 2014)

A first global and comprehensive estimate of the burden of FBD by the Foodborne Disease Epidemiology Reference Group (FERG) initiative of the World Health Organization (WHO) was published in late 2015 (http://www.who.int/foodsafety/areas_work/foodborne-diseases/ferg/en/) . This assessed the burden of 31 hazards. The estimates are conservative, and the key results are set out in Box 1 (next page).

Box 1: Findings from WHO Foodborne Disease Epidemiology Reference Group (FERG)

- The overall burden of FBD was estimated at 33 million DALYs (95% uncertainty interval 25-46). This is comparable to that of major infectious diseases such as HIV/AIDS, malaria or tuberculosis.
- The African and south east Asian regions had the highest burden.
- Although children under 5 years make just 9% of the population, they bore 40% of the FBD.
- Microbial pathogens were responsible for most (79%) of the burden: 584 million cases of illness, around 450,000 deaths and 26 million DALYs each year. The most important pathogens were Salmonella spp., toxigenic Escherichia coli, Norovirus and Campylobacter in that order.
- Foodborne macro-parasites were responsible for around 13 million cases, 45,000 deaths and a burden of 6 million DALYs each year. Most important were the tapeworms responsible for cysticercosis; fish associated fluke (common in south-east Asia); and roundworms, which are sometimes foodborne and are widespread in poor countries.
- Chemicals were responsible for 3% of the overall burden (220,000 cases, 20,000 deaths and 1 million DALYs), of which 900,000 DALYs were associated with aflatoxins, 240,000 DALYs with dioxins and 18,000 with cassava cyanide.

http://www.who.int/foodsafety/areas_work/foodborne-diseases/ferg/en/

The structure of the food sector in developing countries compounds the problem. Food systems are heterogeneous and fragmented with large numbers of actors, many of them small-scale and most operating in the informal sector.

In China food production is said to be dominated by "elephants and mice": that is, sprawling, monopolistic enterprises (who have incentives to escape or game regulation) and tiny household producers (who are difficult to monitor) (Alcorn & Ouyang, 2012). In Kenya, it is said "there is nothing between the cartel and the corner shop" (personal communication). These structural challenges are compounded by a generally poor capacity to enforce regulation in many developing countries.

Stakeholders cite the following governance challenges for food safety regulation:

- inadequate policy and legislation;
- multiple organisations with overlapping mandates;
- out-dated, fragmented or missing legislation;
- inappropriate standards;
- lack of harmonisation and alignment of standards;
- failure to cover the informal sector;
- limited civil society involvement; and,
- limited enforcement (FAO, 2005).

Developing country consumers show a high concern over foodborne disease

National surveys in Europe and North America show that public concern over food safety is high, rising, yet not always rational. For example, chemicals cause less illness than microbes but are more feared (Eurobarometer, 2010; Petrun et al., 2015). In developing countries, there are few nationally representative surveys of food safety concerns. However, smaller studies show high levels of worry and that the priorities of developing country citizens are similar to those in the USA and Europe. For example, a collection of studies from seven countries, found food safety was always a concern for consumers and often the single most important concern about food (Jabbar et al., 2010). Peoples' actions confirm this. 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). Similarly, assessments conducted in the context of Rift Valley fever outbreaks in Kenya found that consumers asked to see butchers' certificates and demand for ruminant meat dropped as consumers switched to poultry (ILRI, 2007).

Food safety has become an issue of enormous public concern in China (Garnett & Wilkes, 2014). This is not surprising given the food safety scares reported in the Chinese media (see examples in Box 2 below).

One survey found Chinese people reported FBD was the second greatest risk they faced in daily life (after earthquakes), and 92% of respondents said they expected to soon become a victim of food poisoning (Alcorn & Ouyang, 2012).

Box 2: What the public sees: thirteen years of food safety scares in Chinese media

2003 Ever Fresh Hams: small producers of Jinhua hams operated out of season to produce hams during warmer months, by treating their hams with pesticides used for crop fumigation to prevent spoilage and insect infestation.

2006 Duck Egg of Doom: China culled more than 5,000 ducks that farmers have fed with a cancer-causing dye to make their eggs look redder and fresher.

2008 Melamine Milk Scandal: six infants were killed and 300,000 were left sickened after consuming infant formula contaminated with the industrial chemical melamine.

2009 Formaldehyde Pudding: inspectors found that pork blood pudding in Wuhan was manufactured with formaldehyde, corn starch, industrial grade salt, artificial food colourings, and a variety of other additives.

2010 Pesticide Beans: more than 3.5 tonnes of "yard-long" green beans contaminated with the banned pesticide isocarbophos, were destroyed after being discovered on sale in the central city of Wuhan.

Cadmium Rice: It was reported that up to 10 per cent of rice sold in China was contaminated with heavy metals, including cadmium.

2011 Glow In the Dark Pork: pork sold in Shanghai glowed iridescent blue when the lights were turned off and customers remained suspicious despite reassurances from the Health Department who said pork was contaminated by a phosphorescent bacteria but safe to eat if well-cooked.

2013: Cross Dressing Meat: Chinese officials arrested 904 people who allegedly sold adulterated and mislabelled meat products treating rat, mink, and fox meat with chemicals in order to pass them off as beef and mutton.

2014 Gutter Oil: this is the name given to illicit cooking oil originating from restaurant fryers, sewers and waste oil that is then passed off as fit for human consumption.

2015 Forty Year Old Meat: Chinese authorities seize more than 100,000 tonnes of smuggled meat - some of it more than 40 years old, according to state media.

(Source: various online media sources)

The causes of foodborne disease: biological, chemical and physical hazards

Foodborne diseases can be caused by many different agents or hazards. In risk analysis[1] terminology these hazards are categorised as:

- **Biological:** living organisms such as viruses, bacteria, and parasites which are pathogenic (harmful);
- **Chemical:** substances such as: heavy metals, pesticides, insecticides, disinfectants, which can cause harm;
- **Physical:** solid objects that can cause harm such as glass shards or nails.

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

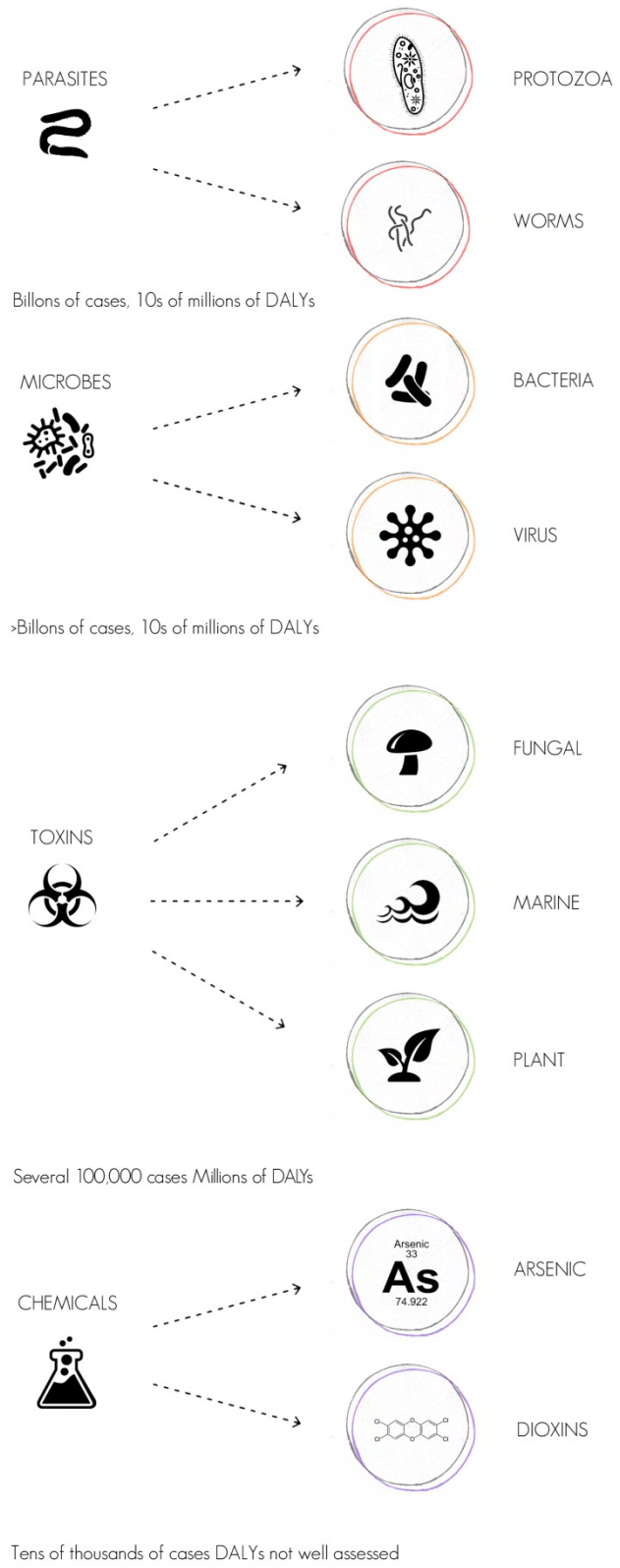
Our factsheet on the "Burden of Illness" explains DALYs and provides a "Do it Yourself" example. Click the icon to read this Factsheet.

Disease burden estimates are based on large-scale systematic reviews, but as for all health information from developing countries, they are prone to error and under-estimation. Indeed, estimates for neglected tropical diseases have varied considerably over the past decade and may continue to for many years to come (Hoetz et al., 2014).

For this paper, where estimates varied we took the higher value given that neglected tropical diseases and especially zoonoses are prone to under-reporting (Schelling et al., 2007). The WHO launched an initiative in 2006 to estimate the global burden of foodborne disease and the final report is due in December 2015. This will give the most authoritative estimate of the foodborne disease burden in developing countries and this paper will be updated at that time.

The next sections will review evidence on health burden, causes, prevalence, distribution and costs for the most important hazards: foodborne parasites; microbial pathogens (non-parasitic); fungal, marine and plant toxins; and, chemicals.

Figure 1: Outline of the major causes of foodborne disease and their impacts



[1] Risk analysis is the gold standard methodology for assessing and managing FBD.

Foodborne parasites

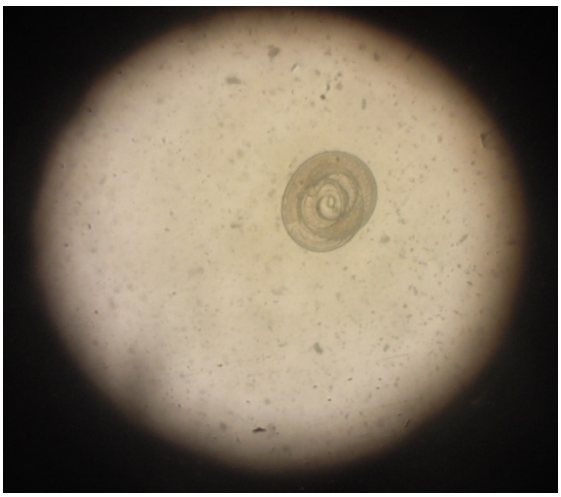
Foodborne parasites (gastro-intestinal worms and protozoa) are an important known cause of foodborne disease causing millions of illnesses and around 18 million DALYs each year globally.

Foodborne parasites are mostly infections by worms and protozoa acquired from food and other routes[2]. These parasites flourish in poor tropical countries. Infections are highest in children living in sub-Saharan Africa, followed by Asia and then South America and the Caribbean. The global burden of the top eight parasites is estimated at 1.7 billion cases and around 18 million DALYs each year (IHME, 2013; Torgerson et al., 2014; Hoetz et al., 2014 +++).

Large parasites

Some important foodborne parasites are large organisms, which are visible to the naked eye. These include roundworms, tapeworms (hosted by pig and sheep) and fluke. They are mainly eradicated from, or well controlled in, richer countries. Even within developing countries they often have a restricted geographical range. More than 90% of the global burden of hydatid disease (caused by a tapeworm for which sheep is a host) occurs in China (Torgerson et al., 2014 ++); fishborne fluke are found mainly in East and in South East Asia; and, tapeworms for which pigs are a host are found mainly in poor, pig-keeping communities in Latin America, Africa and North East India.

Roundworm infections are common in developing countries while tapeworms and fluke are less common but can cause more serious illness. One quarter of people in Asia are infected with one or more roundworms. Around 56 million people in South East Asia are infected with fishborne fluke. Tapeworm diseases are less common than roundworm diseases, affecting around 2 million people, but cause more serious illness.



© ILRI: https://goo.gl/ObUzlc

Photo: Larva of the roundworm Trichinella viewed through a microscope. Trichinella is the smallest human nematode parasite and people can get infected with its larvae through eating undercooked pork (photo credit: ILRI/Kristina Roesel)

The burden of tapeworms and fluke do not appear to be decreasing overall, although there has been progress with control in some areas (Fürst et al., 2012; IHME, 2013). Roundworm infections appear to be decreasing as the result of better sanitation and treatment.

The global cost of hydatid (sheep) tapeworm was estimated at more than US$1 billion in human health costs and US$2 billion in livestock production losses annually (Budke et al., 2006 ++). Economic studies from Peru, Cameroon, South Africa and Mexico all put the cost of pig tapeworm at tens of millions of US dollars a year ++. For some zoonotic parasites, a substantial part of this cost is loss to the livestock industry (Carabin et al., 2006; Praet et al., 2009).

For more information read our “Bad Bugs – Foodborne parasites” factsheet.

[2] The exact proportion of disease attributable to food is not fully known, but food has an important role in the transmission of all these parasites and hence they are called “foodborne parasites”.

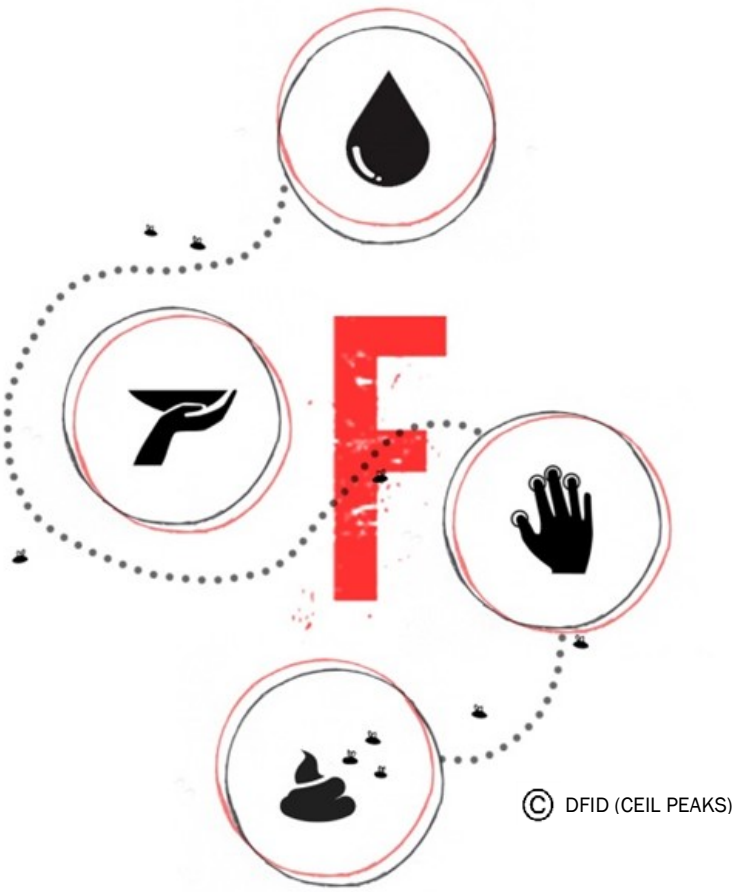
Small parasites

Other important foodborne parasites are microscopic organisms called protozoa. These include: Toxoplasma, Giardia, Amoeba and Cryptosporidium.

Globally, around one third (33%) of people are infected with *Toxoplasma*, 11% of people with *Giardia*, 4% with *Amoeba* and 4% with *Cryptosporidium*. Many of these infections will have no or mild symptoms. *Cryptosporidium*, *Toxoplasma* and *Giardia* have impacts worldwide. In contrast, nearly all the burden of *Amoeba* is in developing countries.

The burden of *Toxoplasma* and *Cryptosporidium* appears to be decreasing as a result of better sanitation and treatment for worm infections (IHME, 2013). However, *Toxoplasma* would be expected to increase where consumption of meat is growing rapidly as prevalence is higher where meat consumption is high. The lack of good monitoring systems for FBD makes trends difficult to detect.

Figure 2: Microbial pathogens and their pathways to foodborne disease (the four 'Fs'- faeces, fingers, food, fluids)



Microbial pathogens

Microbial pathogens also impose high health burden, causing millions of illnesses each year +++ but less is known of the full burden. However, based on extrapolation, microbial pathogens probably are responsible for at least 18 million lost DALYs a year +.

Diarrhoea is the most common manifestation of FBD. Most diarrhoea that is caused by microbial pathogens occurs when pathogens shed in animal or human faeces are ingested by the human victim through fluids (unsafe water or drinks), food, or fingers (when fingers touch contaminated objects/environment and then make contact with the mouth). Food may contain pathogens because the animal producing food was infected or because food was subsequently contaminated by unsafe fluids, flies, dirty fingers or utensils.

The proportion of diarrhoea due to food in developing countries (as opposed to fluid and fingers) is not known. In 2015, the WHO will publish the results of an initiative to estimate the global burden of foodborne disease, which should provide more authoritative estimates.

Microbial pathogens can also have non-intestinal, and/or chronic health impacts. These include: septicaemia, reactive arthritis, paralysis, abortion and birth defects. Although these impacts are less common than intestinal disease, the DALYs from these are much higher, reflecting both the greater severity of symptoms and the longer duration of illness (Gkogka et al., 2011; Havelaar et al., 2012; Gibney et al., 2014 ++).

There are few studies on foodborne diarrhoea in developing countries, with most coming from South East Asia and relying on the opinion of victims to determine if disease is foodborne[3]. The studies that exist find acute gastro-intestinal disease is common (around one in two people a year) and around one third of cases (12-55%) were attributed to food (Bureau of Epidemiology, 2004; Ho et al., 2010; Chen et al., 2013; Sang et al., 2014). We have better information on the global burden of diarrhoea but even for this, different estimates exist: 89,513,000 DALYs for 2010 (IHME, 2013); 99,728,000 DALYs for 2012 (WHO, 2014) and 2.7 billion cases in 2013 (IHME, 2013).

Important microbial pathogens (viral and bacterial)

For more information read our "Bad Bugs – Foodborne bacterial and Viral pathogens" factsheet.

Globally, the Institute for Health Metrics and Evaluation (IHME, 2013 ++) found that the most important viral and bacterial causes of diarrhoea were, in descending order: rotavirus, toxigenic *Escherichia coli*, *Campylobacter*, *Shigella spp.*, non-cholera *Salmonella* and cholera. The first systematic review of diarrhoeal pathogens in different world regions had similar findings: bacteria were relatively more important in developing countries and viruses less important (Fletcher et al., 2013 ++). Most studies (summarised in Belderock et al., 2011) find the Indian sub-continent has highest incidence of diarrhoea followed by Africa then other developing regions.

Photo: An ILRI-Wellcome Trust laboratory in Busia, western Kenya. A project here is investigating the disease pathogens circulating in both people and animals in the farming communities nearby (photo credit: ILRI/Pye-Smith).

In the absence of any conclusive data, this paper conservatively estimates at least 10% of the diarrhoeal burden is due to FBD resulting from bacteria and viruses. This is compatible with the lower end of the two reports from Asia; evidence from Water Sanitation Hygiene (WSH) studies (suggesting perhaps 40% of diarrhoea not attributed to water, sanitation or hygiene); and, good evidence on attribution of diarrhoea from developed countries (which finds 20-40% of diarrhoeal disease attributed to food). This diarrhoeal burden (10% of the global total) is around 9 million DALYs each year. There is reasonable evidence that the burden from non-intestinal health impacts is at least as great as the burden from intestinal disease, adding an additional 9 million DALYs from non-intestinal impacts.

[3] Self-diagnosis is indicative but far from conclusive and probably over-estimates the importance of food as a cause of diarrhoea.

Distribution

Microbial pathogens are problems in developed and developing countries. The countries with most diarrhoea deaths are in descending order: India, Nigeria, Democratic Republic of Congo (DRC), Pakistan, and Ethiopia. The high ranking of these countries is the result of both high incidence of diarrhoea and large populations. Countries with highest rates of diarrhoea are in descending order: Angola, DRC, Central African Republic, Chad and Somalia. They are mostly African countries with on-going or recent conflict and this likely reflects a high incidence of diarrhoea combined with poor health care (WHO, 2014).

Trends

In developed countries, FBD associated with microbial pathogens increased for several decades (from the 1970s to 1990s) and is now mainly stable (Crim et al., 2015; EFSA, 2015). Some (developed) countries have reduced certain pathogens (such as Salmonella in Europe) as the result of targeted campaigns, but other FBD (for example Vibrio in the USA) continue to increase. In developing countries, FBD due to microbial pathogens are probably increasing driven by more consumption of risky foods and changing supply chain structure. However, the lack of any solid data on FBD incidence at different time periods makes estimations of trends speculative.

Costs

There are few estimates of the cost of FBD due to intestinal illness in developing countries. The Asian Development Bank estimates that food-related disease in China costs the country US$14 billion annually in lost lives and healthcare costs (Ellis & Turner 2008 +). Estimates in Nigeria amounted to US$3 billion in 2010, or about 1.25 % of GDP (ILRI, 2011 +). In developed countries with better estimates, costs vary from billions to millions (US$78 billion in the USA, US$2 billion in the UK, US$1.3 billion in Australia, US$234 million in the Netherlands, US$171 million in Sweden) (Scharff, 2012; Abelson et al., 2006; Mangen et al., 2014; Toljander et al., 2012 ++). This reflects differences in population size, incidence of FBD, year of the study, value of costs, and, which costs were included. Some studies include costs of protozoal parasites. Lost exports are important costs for some countries.

For example, the 1991 cholera outbreak in Peru, caused water and seafood to be contaminated by *Vibrio cholerae*, which resulted in more than US$700 million in lost exports of fish products. More recently, in 2005, malachite green (a controversial compound that has been used as a parasiticide and antibacterial in commercial aquaculture) was found in Chinese eels resulting in export losses of at least US$860 million (Ellis & Turner, 2008).

Fungal toxins

Aflatoxins impose a moderate health burden of around 100,000 cases of liver cancer and 1-2 million DALYs a year +++ but health impacts are not fully known and aflatoxins may contribute to stunting.

Aflatoxins are naturally occurring toxins produced by some species of the *Aspergillus* fungus. They are widespread in crops in tropical and sub-tropical regions, especially in maize and groundnuts, and are also found in dairy products and traditionally fermented foods. Ingestion of large amounts of toxin can cause death. Chronic exposure to aflatoxins leads to liver cancer; it is also strongly associated with stunting and immune suppression, but a causal link has not yet been established. Aflatoxins are one of many kinds of mycotoxin. Some other mycotoxins have adverse impacts on human health but the global burden has not been calculated. They are probably less important than aflatoxins (Wu et al., 2014).

Burden

The first global estimate of DALYs due to aflatoxins suggested that there were 25,200–155,000 cases a year (Liu & Wu, 2010). A second study by the same team based on literature from high aflatoxin areas (China and sub-Saharan Africa) suggested aflatoxins were responsible for 17% of hepato-cellular carcinoma (liver cancer) or 88,400 cases (72,800-98,000) equivalent to 1.1 million DALYs. Another meta-analysis estimated 23% of liver cancer cases could be due to aflatoxin exposure (Liu et al., 2012). Hepatitis B infection appears to worsen the effects of aflatoxins and nearly two thirds of cases are in hepatitis B positive people (Liu et al., 2012).

It is difficult to understand the full health burden of aflatoxins (see Box 3 overleaf).

Box 3: Why it is so difficult to understand the full health burden of aflatoxins

Childhood stunting has been shown to be strongly associated (that is, correlated) with aflatoxin consumption in some but not all studies. Correlation does not imply causation and epidemiology provides a set of tools to help understand whether association is causal or due to confounding. In the case of aflatoxins, epidemiologists look for:

- A temporal relationship in which the exposure precedes the development of disease. Most studies on aflatoxin and stunting have been cross-sectional and so it is not possible to see which came first. Two studies have shown exposure to aflatoxins came before stunting.

- Biological plausibility as suggested by laboratory and animal studies. Many studies do show that aflatoxins have pathological effects on cells (including human cells) and metabolism. However, it is not known if the amounts consumed by children are enough to result in the proposed growth impairment effects. In toxicology, the dose makes the poison and a toxin that has pathological effects at one dose, may have no adverse effects or even positive effects, at a lower dose

- Animal studies showing health impacts. A large number of experimental studies have shown that aflatoxins lead to reduced weight gain and other health problems in animals. However, in most of these studies aflatoxins were administered every day at high to very high doses over short periods of time. This is different from the type of exposure children typically get. Moreover, there is a very wide species variation in susceptibility to aflatoxins. For example, mature chickens can tolerate aflatoxin at hundreds of times the amount that sickens day old ducks. It is not clear where humans are in terms of relative susceptibility.

- Exposure that exceeds the thresholds necessary for effect (again, the dose makes the poison). Most animal studies show a threshold below which effects are not seen but this is not constant across different studies. Species, strain, sex, age, diet, exercise and length of exposure all influence the threshold at which no effects are seen and the tolerance to higher doses. We do not know if the amount of aflatoxins consumed by children is over or under a threshold necessary to cause growth impairment.

- A dose-response relation. Animal studies have shown a clear dose-response effect on weight gain, but only over a relatively high range of doses. Some studies even find that at extremely low doses, aflatoxins stimulate growth.

- Replication over studies. Several studies show associations between aflatoxins and growth outcomes but some do not.

See Grace et al., 2015 for further discussion and references.

Distribution

Liu & Wu (2010) estimate 40% of cases of aflatoxin-induced liver cancer are in Africa, 27% in South East Asia, 20% in the Western Pacific and 10% in the Eastern Mediterranean region.

Trends

There has been a rapid reduction in liver cancer in China: an aetiological study attributed this to reduced exposure to reduced exposure to aflatoxins and increased hepatitis B vaccination coverage. Reduction in exposure was driven by rapid economic growth that allowed people to switch from maize to rice and to diversify their diets. Little improvement has been seen in Africa (Sun et al., 2013).

Costs

Annual economic costs of mycotoxins to the US agricultural economy were estimated at US $1.4 billion (CAST, 2003). The cost of aflatoxins to the poultry and pig sectors in Indonesia, Thailand and the Philippines was estimated at $156 million Australian Dollars (Lubulwa & Davis, 1994) and the human health effects at $500 million Australian Dollars.

A later study from Thailand estimated the costs to the agriculture sector at $6.9 million or $100 million USD per year (based on low and high contamination hypotheses). Most of these losses were borne by the livestock industry (Lubulwa et al., 2015).

In 2001, a study estimated that African food exporters lost US$670 million USD per year by not meeting EU safety standards alone (Otsuki et al., 2001). Others conclude the EU standards had no significant impact on groundnut and trade is more constrained by domestic supply issues rather than by limited market access (Xiong & Beghin, 2011). In Kenya in 2010, The Government estimated that 10% of the maize harvest was contaminated by aflatoxin equivalent to US$100 million (PACA, undated). Newspaper reports suggested a much smaller amount was actually condemned and much of the condemned maize found its way back onto the market. A large part of the costs in developed countries is for testing and compliance with regulations. In the USA, the annual cost of regulatory enforcement, testing and other quality control measures for mycotoxins was US$466 million annually (CAST, 2003).

Figure 3: A quick introduction to aflatoxins

Other food related toxins: marine, methanol and plant

Marine toxins cause tens of thousands of FBD cases a year, methanol and plant toxins hundreds of cases. The global health burden for these is not well established.

Marine toxins

Seafood poisoning from marine toxins is increasing because of climate change, pollution, coral reef damage and transport of algae by ships. Algae produce chemicals that give rise to marine toxins when taken up by fish. Ciguatoxins are marine biotoxins found in contaminated tropical reef fish that cause ciguatera poisoning. This is the most common marine toxin disease worldwide with 10,000 to 50,000 cases a year (EFSA, 2010 ++). Paralytic shellfish poisoning is most common in colder waters. The algae producing the toxin cause red streaks to appear in the ocean called "red tides". Diarrhetic shellfish poisoning is common in Europe but found worldwide (FAO, 2004). Scombrotoxic fish poisoning is a syndrome resembling an allergic reaction caused by eating fish with high levels of histamine produced by bacterial spoilage. It is most associated with consumption of scombroid fish (e.g. tuna, mackerel).

Methanol

Illicit or unrecorded alcohol constitutes about 30% of all alcohol consumed globally, with poorer countries consuming a higher proportion of illicit alcohol (Rehm et al., 2014). Illicit alcohol may contain methanol due to incorrectly managed distillation processes, but more commonly, as the result of deliberate addition to fortify drinks. As reported in the published literature, methanol poisoning is responsible for fewer than 1,000 deaths in any given year. In India, around 2,000 deaths have occurred since independence (Bodwal, 2014). As such, methanol deaths seem to be primarily individual or regional tragedies rather than a global public health problem.

Plant toxins

Plants contain some chemicals that are known to be toxic to both animals and humans. Some of these chemicals evolved in plants to protect them from pests or herbivores. Lathyrism, a neurological disease caused by consumption of some types of pulse (*Lathyrus spp.*) has been a problem in South Asia and Ethiopia. Few cases are reported currently, for reasons that are not fully known (Mishra et al., 2014), but probably linked to increasing income, better health care and more diverse diets. Konzo (an acute paralytic illness) and tropical ataxic neuropathy (a chronic illness characterised by sensory deficits) are caused by high dietary cyanogen consumption from insufficiently processed bitter cassava combined, in the case of konzo, with a protein-deficient diet.

Around 2,000 cases of konzo have been reported in the last 20 years but unofficial reports suggest there may be tens of thousands of unreported cases (Nzwalo & Cliff, 2011). Plant toxins are mainly local problems but have caused major outbreaks (thousands of cases or more) in times of famine or war. Deaths from plant cyanogens appear to be declining.

Chemicals

Chemicals of major health concern can be transmitted through food but there is little quantified evidence of health burden.

The World Health Organization has prioritised ten chemicals as being of major health concern. For two of these (cadmium and dioxins), food is the major exposure route while for three others food is an important (arsenic, mercury, fluoride) or possibly important (highly hazardous pesticides) exposure route. For the other four chemicals of major concern, food is not an important route (air pollution, asbestos, benzene, lead). Although food is a potentially important exposure route for six chemicals of major health concern, the health burden has only been calculated for arsenic and as this is based on only one study it is less reliable than estimates based on multiple studies (see Table 1).

There is a high level of concern among the general public about the presence of chemicals in food. Chemicals of most concern to the general public include: pesticides, growth promoters, chemicals added to food during processing, chemicals added to adulterate food, and, toxins produced by cooking (polycyclic aromatic hydrocarbons and acrylamides). We briefly look at some of these in the sections that follow.

Chemical	Associated health problems	Known food related health burden or risk	Reference
Cadmium	Kidney dysfunction and bone problems	Incomplete data	Prüss-Ustün et al., 2011
Dioxins	Thyroid dysfunction and reduced sperm count	Incomplete data	Prüss-Ustün et al., 2011
Arsenic	Bladder, lung and skin cancer	70,000 additional cancer cases in developing countries each year	Oberoli et al., 2014
Mercury	Prenatal exposure leads to mild retardation	Elevated risk among seafood consumers in the coastal regions of SE Asia, the W Pacific and the Mediterranean	Sheehan et al., 2014
Fluoride	Bone problems	Incomplete data	Prüss-Ustün et al., 2011

Table 1: Chemicals that can be transmitted in food and the food related health burden

Agricultural chemicals

In developed countries, chemicals in food are strictly controlled. There is little evidence for major health impacts from chemical hazards, although there is concern about impacts not adequately detected with current technology. In developing countries, there is no credible, comprehensive, quantified evidence on the impact of agricultural chemicals in food on human health (Prüss-Ustün et al., 2011; Käferstein 1997), but there is solid evidence that some health impacts occur, and suspicion that these could be substantial.

Various studies have found high levels of agricultural chemicals in marketed food and widespread use of obsolete, cheaper and more hazardous chemicals in developing countries. For example, in Ghana 19% of produce (fresh fruit and vegetables) had pesticide residues above maximum permitted levels compared to typical values of less than 5% in developed countries (Bempah & Donkor, 2011). A survey in Vietnam found 2,500 kg of banned pesticide in use (PPD, 2000). In developed countries, there are more residues found in foods imported from developing countries than domestic foods (EFSA, 2013).

Food adulteration

Food adulteration to increase profits has led to several high profile outbreaks of food poisoning. In Cambodia, in 1996 and 1998, 70 deaths were linked to drinking rice wine mixed with pesticides to make it stronger. Problems with Sudan Red (an illegal food dye), melamine in formula milk and malachite green have been reported from China (Ellis & Turner, 2008). There are also occasional reports of malicious poisonings. In China, 38 school children died from rat poison when a baker contaminated products of a rival seller to obtain commercial advantage (ISID, 2002). Accidental contamination may be more common in developing countries as a result of lack of stringent health and safety protocols and these incidents are occasionally reported in the media. For example, in India in 2013, at least 22 schoolchildren died after eating a free school lunch contaminated with insecticide[4].

Toxins produced by cooking

Polycyclic aromatic hydrocarbons (PAHs) and acrylamide[5] can be formed by smoking, grilling, roasting and frying food. Smoked and barbecued meats and fish may contain high levels of PAHs as a result of the smoking process. PAHs are irritating and very high levels may cause death; PAHs and acrylamide are also carcinogens. There has been limited investigation of PAHs and acrylamide in developing countries but one study from Côte d'Ivoire is illustrative (Box 4).

Box 4: *Polycyclic aromatic hydrocarbons in fish – an example from Côte d'Ivoire*

More than 80% of the fish landing in Côte d'Ivoire is traditionally smoked for sale in the local market and for export. Smoked fish accounts for 0.73% of the total export volume (which corresponds to 2.3% of foreign exchange), and the sector employs approximately 70,000 people who feed another 400,000. In 2007, PAH was discovered in smoked fish from Côte d'Ivoire destined for export to Europe. In Europe the main purchasers of these fish products are the West African diaspora. A recent study found 71% of smoked fish in local markets was contaminated and levels were five times higher than EU permitted levels. Most of the people smoking fish were women (90%) without secondary education. High-risk practices were noticed like the use of resinous wood (branches of rubber trees) and high smoking temperatures (Roesel & Grace, 2014).

4 See: http://www.bbc.co.uk/news/world-asia-india-23353017, accessed September 2015.

5 Acrylamide: a chemical produced naturally in food as a result of cooking starch rich food at high temperatures.

Most foodborne disease comes from fresh, perishable foods sold in wet markets

In countries where good data exist, most FBD results from consuming animal source foods (ASF) (i.e. fresh meat, milk, eggs, fish) and produce (i.e. fresh fruits and vegetables).

In developing countries, less fresh food (animal source foods and produce) is eaten, but the fresh food (animal source foods and produce) eaten is more contaminated.

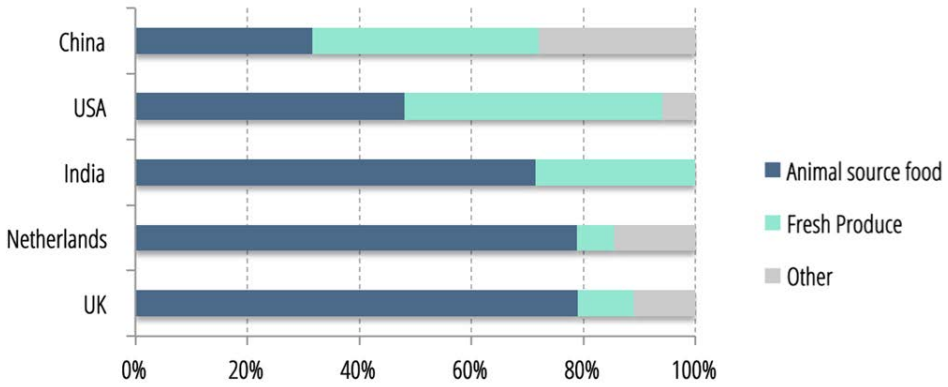
Figure 4 (below) shows the foods implicated in FBD from three large, comprehensive national studies in the UK, USA and Netherlands, one small study in India, and one small, self-reported study from China (Painter et al., 2013; Sudershan et al., 2014; Mangen et al., 2014; Tam et al., 2012; Sang et al., 2014).

Meat consumption is a strong predictor of foodborne disease mortality. In a cross-country study, for every additional metric tonne of meat consumed per 100 people, foodborne disease mortality increased by 6% (Hanson et al., 2012).

The parasitic and microbial pathogens responsible for most of the health burden come from animal source food and vegetables. Pesticides are often transmitted through vegetables and fruit but are also commonplace in animal source foods in developing countries. Comparing the problem of FBD in developing countries to the much better studied problem of FBD in developed countries, it is likely that:

- the burden of microbial FBD is higher in developing countries than in developed countries;
- it is caused by similar pathogens; but, bacteria are relatively more important than viruses; and
- microbial FBD makes up less of the overall burden of FBD because parasites, mycotoxins and chemicals are mostly uncontrolled in developing countries.

Figure 4: Animal source foods and fresh produce are responsible for most foodborne illness



Knowledge Gaps: For developing countries, we have no accurate data on the prevalence or impact of foodborne disease. We don't know how much diarrhoea can be attributed to food. We suspect a link between aflatoxins and stunting, but it is not proven. There is high concern about chemical hazards such as pesticides, yet minimum investment in understanding the health burden. In the absence of evidence, it is difficult to target resources to key problems amenable to solutions. Where issues create major concerns but evidence on health impacts is lacking, then generating evidence on the actual importance should be a priority (e.g. pesticides in food or traditional smoking of food using resinous wood). On the other hand, for issues where there is already good evidence that health burdens are high, the priority should be developing, testing and implementing control measures (e.g. for foodborne parasites and microbial pathogens).

2: FOOD SAFETY SOLUTIONS

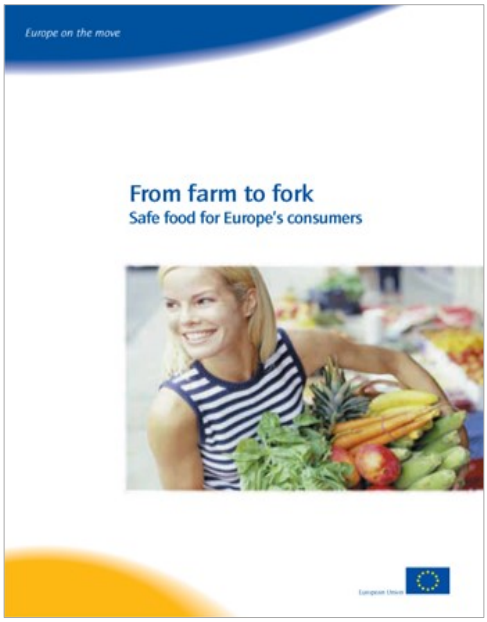
Impact and cost-effectiveness of different tools and approaches for managing and controlling food safety issues

The previous section presented evidence that the known burden of FBD is high and the unknown burden of concern. We are fairly sure that foodborne parasites, microbial pathogens in food, aflatoxins, arsenic, and contaminated fresh food sold in wet markets cause substantial health burdens in developing countries.

This section summarises some of the interventions for managing food safety in developing countries and the successes and challenges encountered. We should not expect a large body of evidence on food safety interventions. To draw from a related health issue, enormous development efforts have been dedicated to water, sanitation and hygiene (WSH) interventions over the past decades, and much greater efforts have been extended to WSH than to food safety. Yet systematic reviews find it has been difficult to estimate accurately the impacts of WSH on diarrhoea reduction (Cairncross et al., 2013). Therefore, for the neglected area of food safety improvements, it is not surprising that there is even less evidence on interventions and their impacts. This chapter summarises the scarce literature that is currently available.

Foodborne disease is preventable and prevention starts on the farm

Several developed countries have succeeded in reducing foodborne disease over relatively short periods. The UK reversed an epidemic of *Salmonella* through legislation, food safety advice, and an industry-led vaccination programme in broiler-breeder and laying poultry flocks (O'Brien, 2013). In Iceland, measures at production, retail level and in the household resulted in *Campylobacter* declines of more than 70% in broiler flocks and in human infections (Stern et al., 2003). Denmark reduced *Salmonella* by up to 95% in eggs, poultry and pork, by monitoring herds and flocks, eliminating infected animals, and differential processing depending on *Salmonella* status. This resulted in savings of US$25.5 million (Wegener et al., 2003). In all three of these success stories, control was along the value chain, with an emphasis on reducing disease in the animal reservoir rather than the retailed product. Although these control approaches are mainly applicable to industrialised countries with modern intensive farming systems and good enforcement capacity, the "farm to fork approach" (which as the title suggests takes a value chain approach), is likely to be useful in developing countries also.



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 & 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.

Caution in assuming that shifts to large scale, formal sector food production and retail will necessarily reduce foodborne disease

There is a common belief that many problems of food safety and disease can be ameliorated by transiting to 'modern' agro-food systems. For example, in China, wet markets have been singled out as major sources of poultry disease and there have been several attempts to ban them (Scoones & Forster, 2008). In Vietnam the plan for modernisation of agriculture aims to encourage large-scale intensive farms and reduce smallholder production. Although developed countries do have lower burdens of FBD compared to developed countries, the health outcomes from encouraging modern food systems[6] in poor countries are not well known.

Few studies have compared the safety of food in the formal and informal markets. Those that do often find that food sold in the formal sector is no safer than that sold in the informal sector. For example, in the case of milk in Assam, Kenya, and Tanzania and meat in Vietnam and Kenya the food sold in the formal sector was no better (and sometimes worse) at meeting standards than food sold in the informal sector (Roesel & Grace, 2014). Several studies also show use of agricultural chemicals is higher in large-scale production (e.g. antibiotic use appears to be higher in intensive farms (Grace, 2015)).

The intensive sector has been associated with emergence of new diseases including: swine influenza in Mexico; Nipah virus[7] infection in Malaysia; and, poultry salmonellosis and 'mad cow disease' in the UK (Jones et al., 2013).

Informal sector sellers usually give a higher price to the producer than the formal sector can offer, but at the same time informal sector sellers are able to sell to the consumer at a lower price than the formal sector does. This makes the informal sector the preferred buyer for farmers and the preferred seller for consumers.

Investment in formal dairy processing facilities, both in private and public sectors, has often failed, leading to underutilised capacity (Sirohi et al., 2009) so the sustainability of interventions based on supporting the formal sector should be factored into investment decisions as well as likely impacts on food safety, food availability and equity. At the same time, intensification of agriculture and growth in the formal retail sector is a response to greater demands for food and changes in behaviour resulting from development. Many argue that intensive, agro-industry is required to meet food demand. For example, the FAO states "*As it stands, there are no technically or economically viable alternatives to intensive production for providing the bulk of the livestock food supply for growing cities*" (FAO, 2011).

What does this mean? There is a trend for large-scale formal sector production and retail to increase. Promoting this on food safety grounds is not currently justified. Policy or investments to encourage large, formal sector agro-food industries should be reviewed and monitored for impacts on food safety, poverty, equity, environment and nutrition. These impacts should be factored into donor or government support of agro-food industry relative to other options for producing, processing and retailing food (e.g. smallholders, traditional processing and informal retail). Where the large-scale, formal agri-business is growing rapidly, its performance on food safety should be monitored.

Caution in assuming provision of infrastructure to the informal sector will necessarily reduce foodborne disease

A common approach to improving food safety in the informal sector is the provision of processing and marketing infrastructure. This is often linked with increasing formalisation (e.g. selling packaged and labelled products through modern retail outlets). These types of intervention are expensive and the impact has been surprisingly weak. For example, in developing countries most large slaughterhouses have very poor standards of hygiene, in contrast to better hygiene

[6] Large-scale, intensive farming, modern supply chains, or formal sector, 'supermarket-style' retail.

[7] A newly emerging zoonosis that causes severe disease in both animals and humans. The natural host of the virus are fruit bats of the Pteropodidae Family, Pteropus genus.

outcomes from small slaughter slabs (Roesel & Grace, 2014). Some examples:

- During the bird flu epidemic in the 2000s, there were many attempts to close or upgrade wet markets. Most were unsuccessful in improving hygiene or only covered a tiny proportion of birds sold.
- In China, modern beef slaughterhouses were established, but because demand for their services was low, they were not profitable. Presumably as a result, operators used illegal measures to increase profitability, such as infusing fat into muscle in order to mimic marbled beef and injecting water to increase weight (Waldron et al., 2010).
- In Lusaka, street sellers were moved to a new ultra-modern market funded by US $2.7 million grant from the European Union after consultation with vendors and other stakeholders. Yet many vendors returned to selling on the streets as they found they made more money by being closer to customers (Ndhlovu, 2011).

The World Health Organization (WHO) and FAO have developed numerous programmes to improve the safety of street-vended food but these have been difficult to implement, particularly in regard to the provision of infrastructure (Infosan, 2010).

What does this mean? Better infrastructure is needed in most developing country food processing and retail. However, infrastructure provision, though necessary, should not be seen as a sufficient response to poor food safety. Investments that require radical changes in how food is processed, sold, or consumed are often favoured by stakeholders who wish to move to systems they perceive as modern and safe. However, these major changes to food system infrastructure have often not been successful. Incremental improvements may be more useful (for example, organising a milk collection point in a remote rural area rather than building a milk cooling plant with a generator). The most expensive, best practice technologies will be more difficult to maintain than lower-level technologies and when viewed in this way, the best can be the enemy of the good. 'Appropriate', intermediate technologies should be emphasised unless there is clear evidence that more complex and expensive approaches are warranted.

What is a wet market?

"A wet market is a market selling fresh meat, fish and produce, distinguished from dry markets which sell durable goods such as flour, dried legumes, cloth and electronics. Wet markets often have wet floors, where sellers dose produce with water to keep produce looking fresh: hence the name. Animals are often slaughtered and meat butchered in wet markets".

Click the video thumbnail below to watch a short film about wet markets.

Caution in leveraging consumer demand for food safety

Many (10-20) studies have found that consumers in developing countries say they are willing to pay more for safer foods. For example, studies from seven countries found consumers expressed willingness to pay an additional amount for safe food that ranged from 5% to more than 100% of the cost (Jabbar et al., 2010). However, most 'willingness to pay' studies have been based on *ex ante* assessments (i.e. before an event) that may not reflect what customers will do when faced with real world choices over time. We should also note that there are practical, ethical and economic challenges to using consumer demand for safe food to drive improvements in the safety of retailed food.

- Practical considerations. For most food safety challenges, consumers have no way to identify whether food is safe and, in developing countries, there are few examples of credible third party safety assurance of food safety (outside niche export and premium markets). This verification problem could be overcome by development of cheap, rapid diagnostics for food safety, which could be used by consumers and other value chain actors. As an example, a lactometer is a device like a thermometer; only instead of reading temperature it reads density. By putting a lactometer in milk, consumers can see if water has been added, and if they prefer their milk pure, refuse to buy it.

- A fundamental problem concerns the ethics of selling food as 'more' and, by implication, 'less' safe. In nearly all countries, it is illegal to sell food, which does not meet standards and is unsafe to eat. Retailers in developed countries do not use safety higher than standards as a marketing tool and have stated it is not ethical to compete on food safety *"Food safety" should not be a competitive marketing food-trait, lest the most vulnerable people end up with access to only the least safe food, or simply fewer choices" (NSAC, 2011).*

- Economic explanations for the reluctance to use food safety as a marketing tool, are:

  - consumers expect food to be safe and hence will not pay a premium;
  - supermarkets maximise profits by not separating products according to safety; and
  - competing on food safety will undermine consumer confidence in all types of the food sold, reducing the market for that food (Russo et al., 2011).

What does this mean? Supporting segmented markets for safe food may be difficult and unintentionally work against poor people so they should be explored with caution. Low-cost diagnostics that allow value chain participants to directly verify the safety of food would be a powerful tool for improving food safety, even for poor consumers, as has been the case, for example, in the use of low cost technologies that show if a vaccine has been kept at the correct temperature (Box 5). This would allow 'pushing quality control down the supply chain' as traders could also test their suppliers to ensure consumers' demands for safety are met.

Box 5: Using low-cost diagnostics to leverage consumer demand for improved safety

Imagine the challenge of getting the extremely heat-sensitive polio vaccine from a pharmaceutical company in Europe to a remote village in Ghana. In the past, heat-damaged vaccines were sometimes unknowingly delivered to children, or good vaccine was thrown out because health workers feared it had gone bad. To address this "cold chain" problem, PATH (an international health NGO) found a technology originally used by the food industry to label perishable products and worked to adapt it. The resulting product—the vaccine vial monitor, or VVM—is a small sticker that adheres to the vaccine vial and changes color as the vaccine is exposed to heat, letting the health workers know whether the vaccine can be safely used for immunisation. Today, VVMs are available for all vaccines used in immunisation programmes in developing countries, and UNICEF requires them on all vaccines they purchase.

http://www.path.org/publications/files/TS_vvm_case_study.pdf

Training farmers, extension services, and 'Good Agricultural Practices' likely to be useful

Few capacity-building initiatives focus only on improving food safety. But, hygiene, quality and especially, safe use of chemicals and drugs, are often part of farmer training and extension initiatives. There have been many reports of small scale or pilot training and these often show improvements in practices and hygiene (Omore & Baker, 2011).

However, there is less evidence for success at large scale: an illustration of the saying "pilots never fail, and pilots never scale". A recent systematic review of Farmer Field Schools, which had a strong emphasis on integrated pest management and reducing pesticides, showed that farmers in the programme had higher yields and used less pesticide, but there was no evidence to show that benefits were either sustained or scalable (Waddington & White, 2014).

While some small farmers have been able to comply with Good Agricultural Practices (GAP) required for export, there is less information on domestic GAP programmes and uptake. However, the limited literature suggests impact of domestic GAP is low. For example, a national GAP programme that started in 2009 in Vietnam succeeded in certifying just 491 hectares of the total 823,700 hectares available for vegetable cultivation as VietGAP by 2013 (VNS, 2013). In Thailand, farmers who follow the public GAP have no better pesticide use or outcomes, than those who don't (Schreinemachers et al., 2012).

So what does this mean? Training farmers in GAP seems to be most useful when there are clear incentives for changing practices. For example, GAP can help access export markets. Interventions like GAP should be encouraged where they offer livelihood opportunities to farmers, whilst recognising that there is little evidence (so far) that they will improve food safety for domestic consumers.

Training informal sector agents likely to be useful

Approaches that are based on working with the existing situation and gradually improving it, have shown success (Infosan, 2010). A well-documented initiative working with butchers in wet markets of Ibadan promoted "positively deviant practices"[8] and peer-to-peer training. The initiative led to 20% more meat samples being of acceptable quality. The intervention cost US$9 per butcher but resulted in savings of US$780 per butcher per year from reduced cost of human illness (Grace et al., 2012).

There have been many other successful training initiatives with informal sector food workers that have improved food safety (Von Holy & Makhoane, 2006; Donkor et al., 2009; Campbell, 2011). 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 (Soon et al., 2012).

Photo: CARE extension officers Faustino Jose and Feliciano Majesso train a mixed producer group on gender issues related to income sources, household expenditures and decision taking. The training was organised by the imGoats project in Mozambique (photo credit: ILRI/Birgit Boogaard).

[8] Practices that are good (positive) but used only by a minority of butchers (deviant).

In Kenya and Assam, initiatives to train milk traders and provide an enabling environment have been effective, economically attractive, scalable and sustainable. An estimated 6.5 million consumers are currently benefiting from safer milk as a result of these interventions (Kaitibie et al., 2010; Lapar et al., 2014). Decisions to train informal sector actors are based on the assumptions that:

- many workers are well intentioned but ill-informed and will change some of their behaviours if given information and instruction;
- some of the behaviours promoted will also have other, obvious benefits (such as less food spoilage), which can encourage adoption;
- new institutions can be introduced such as branding or licensing which will act as an incentive for behaviour change.

An important incentive for changing behaviour is to obtain certificates or other legitimacy which can reduce the cost associated with illegality (e.g. fines, bribes) or improve status in society. However, it cannot be assumed that training alone is sufficient to change behaviour, or that short-term improvements in behaviour will persist. In the few cases where long term effects have been shown, there have been other monetary or social incentives for behaviour change (Kaitibie et al., 2010).

Box 6: Safe food, street food in South Africa

Until the late 1990s street-vended foods in South Africa were perceived as unsafe and most decision makers believed that they should be outlawed. Research showed that street food vendors could produce safe foods, with low bacterial counts, although there was still a need for proper hygiene conditions and access to basic sanitary facilities. The Department of Health of South Africa, when coordinating an FAO project, drew similar conclusions. Through a combination of evidence, policy advocacy, and programmes to improve hygiene opinion shifted: food vending was no longer perceived as a nuisance by health authorities who instead promoted and improved street food vending as a way to support livelihoods and nutrition (Von Holy & Makhoane, 2006).

So what does this mean? Training informal sector agents in food hygiene can be effective especially when linked with incentives for behaviour change.

Technologies are likely to be useful

Where value chain actors are not using food safety technologies, simple innovations such as food grade containers or chlorinated water can result in substantial improvements to food safety and quality. Other technologies are effective and affordable but are not used, for example, adding lactoperoxidase[9] to preserve milk or using chlorine washes to reduce bacteria on chicken carcasses, or adding mycotoxin binders[10] to animal feeds. In several of these cases, technologies are not used in Europe or other developed countries because of secondary considerations which may be relevant to rich countries but are less so to poor countries. For example, aflatoxins are carcinogens, and many developed countries would not consider it acceptable to use aflatoxin binders because of food safety concerns about the presence of carcinogens in food. (People would not easily accept that food or feed has carcinogens plus something that inactivates the carcinogens by binding them.) Developed countries tend to follow this approach, although a risk assessment might suggest that where malnutrition is a problem, and half or more of food is contaminated with carcinogens, it is better to add binders to reduce the effect of the carcinogens than to attempt to incinerate the contaminated food.

As we have outlined earlier, a major constraint to improving food safety is that consumers and value chain actors have no affordable way of evaluating food safety. Cheap, rapid, diagnostic tools would allow stakeholders to directly ascertain the safety of food. Medical technologies such as vaccines for diarrhoea and hepatitis B have high success in reducing rotaviral diarrhoea and liver cancer from aflatoxins (Sun et al., 2013) and while they are costly, they can be more cost effective than agricultural solutions.

So what does this mean? Situational analyses can identify which technologies are not being

9 An enzyme that functions as a natural antibacterial agent.

10 Substances that when added to feeds contaminated with mycotoxins, interact with the mycotoxin reducing its harmful affects.

used but have potential to improve food safety (e.g. water disinfection, lactometers). From these analyses it might be feasible to introduce appropriate technology at farm or processing level. Easy 'stroke of the pen' policy reforms can be encouraged to legalise technologies known to be safe but not allowed because of secondary considerations (e.g. lactoperoxidase for milk preservation, mycotoxin binders in livestock feed). A mid to long term recommendation might be to consider investing in development, adaptation and dissemination of new technologies that include vaccines, therapeutics and diagnostics.

Policy approaches

There is general consensus that most developing country governments are not able to ensure the safety of most food consumed in domestic markets. Currently, neither the formal or informal market can consistently provide food that meets the standards in place in most developing countries. Although most developing countries have adopted the Risk Analysis, Farm to Fork and 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.

For an understanding of Risk Analysis and HACCP approaches to food safety see our factsheet.

Clearly, new policy and implementation approaches are needed. In many developing countries, multiple agencies are in charge of assuring food safety with overlapping mandates and inadequate resources. There has been interest in re-structuring food safety governance. A single unified structure or an integrated system is likely to be more effective, but when it 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).

Rational food safety governance systems are important, but experience has shown that even when policies and regulations are good, they are rarely translated into implementation. However, notable achievements have been seen when policy-makers champion food safety (see Box 7).

So what does this mean? Policy reform is important, but not sufficient to improve food safety in domestic markets, and needs to be accompanied by regulatory impact assessment and followed by close monitoring to track and adjust the actual implementation. Supporting champions and changing culture are some of the most powerful ways of changing governance.

Box 7: A champion for food safety

Nigeria had severe challenges with safety of food and drugs; in the 1980s more than 50% of drugs sampled did not meet standards. In 2001, under the leadership of Dr Dora Akunyli the National Agency for Food and Drug Administration and Control (NAFDAC) underwent dramatic restructuring and reform and the next decade saw substantial improvements in food and drug safety and governance. For example, a reduction in substandard drugs of 80% was achieved. This campaign would not have been possible without the political leadership of the head of NAFDAC, who barely survived two assassination attempts, not to mention several death threats. Some NAFDAC officers were severely beaten and their vehicle destroyed when they confronted drug sellers, and NAFDAC buildings and labs were burned down or vandalised. (Akunyili, 2005).

Knowledge gaps: While many pilots show success, there are few studies that have looked at the sustainability and scalability of food safety initiatives. Little is known about the unanticipated risks of increasing unsafe food consumption among the most vulnerable people, by initiatives to improve food safety. For example, if the markets most used by the rich impose strict standards, the food that fails to meet these standards will end up in the markets used by the poor where standards are less observed. There are opportunities to improve food safety through technologies and restructuring of food safety governance, but the feasibility and effectiveness of these is not well understood.

3: FOOD SAFETY TRENDS AND DRIVERS

In this section we look at some of the trends and drivers that affect food safety in developing countries and the geography of food safety. We also look at what food safety means for:

- small farmers
- export industries
- women
- the most vulnerable people and
- nutrition.

Because there is inherently more uncertainty about predictions into the future, in this section we do not use the strength of evidence markers.

Trends in food safety

Despite considerable investments in food safety, the EU and USA have seen an increase in the number of cases of most foodborne diseases over the last five (EU) or ten (USA) years (EFSA, 2013; ECDC, 2012). A notable exception is salmonellosis in Europe, which is declining, largely due to vigorous control in poultry (EFSA, 2012). There is no accurate reporting of foodborne disease in developing countries and it is therefore more difficult to monitor trends. In the US and Europe, food safety was an issue of intense concern during the periods of most rapid industrialisation and urbanisation, and this concern is now reflected and evident in the more rapidly developing countries. 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.

Most experts believe that the emerging market economies will eventually converge with the richer countries (Perry et al., 2011). Panic over food safety can be a driver for improvement. From this perspective, the situation in China where a widely publicised finding is that half of food retail establishments are failing inspection may be more positive than the situation in India where there are no reports on food safety inspection or results are not publically available (Grace & McDermott, 2015).

Drivers of foodborne disease in developing countries

We look at four main drivers of FBD in developing countries as: agricultural intensification, changes in food consumed; changes in the retail sector, and potential shocks to food systems.

Agricultural intensification

Populations will continue to increase but nearly all the productive land has already been exploited so to feed the future, agriculture must intensify. Agricultural intensification can be viewed positively. It can, but does not always, lead to:

- increased profits;
- growth of off-farm income;
- a reduction in greenhouse gases per unit of animal source food produced; and
- higher biosecurity.

But, intensive agricultural units have also been linked to negative health impacts:

- increases in salmonellosis and campylobacteriosis have been linked to intensification of poultry, pigs and cattle (O'Brien, 2013);
- increases in use of inputs such as pesticides, resulting in greater risk of contamination of vegetables and fruit with pesticide residues, are commonly seen as horticulture intensifies;
- higher, and sometimes excessive, use of fertilisers is seen which can result in eutrophication in water, thus decreasing the quality of ground and public water;
- crowding of animals has led to the increased use of antibiotics, which in turn leads to emergence of antibiotic resistant bacteria;
- historical analyses show a clear link between livestock intensification and the emergence of novel diseases such as bird flu and mad cow disease (Jones et al., 2013); and
- intensification with poor biosecurity can lead to rapid disease spread.

In developing countries where intensification is occurring rapidly in a context of poor governance and limited transparency, food safety problems are likely to worsen because it is not easy to identify and hold to account the farmers responsible for excessive use of agricultural inputs, pollution and spread of disease.

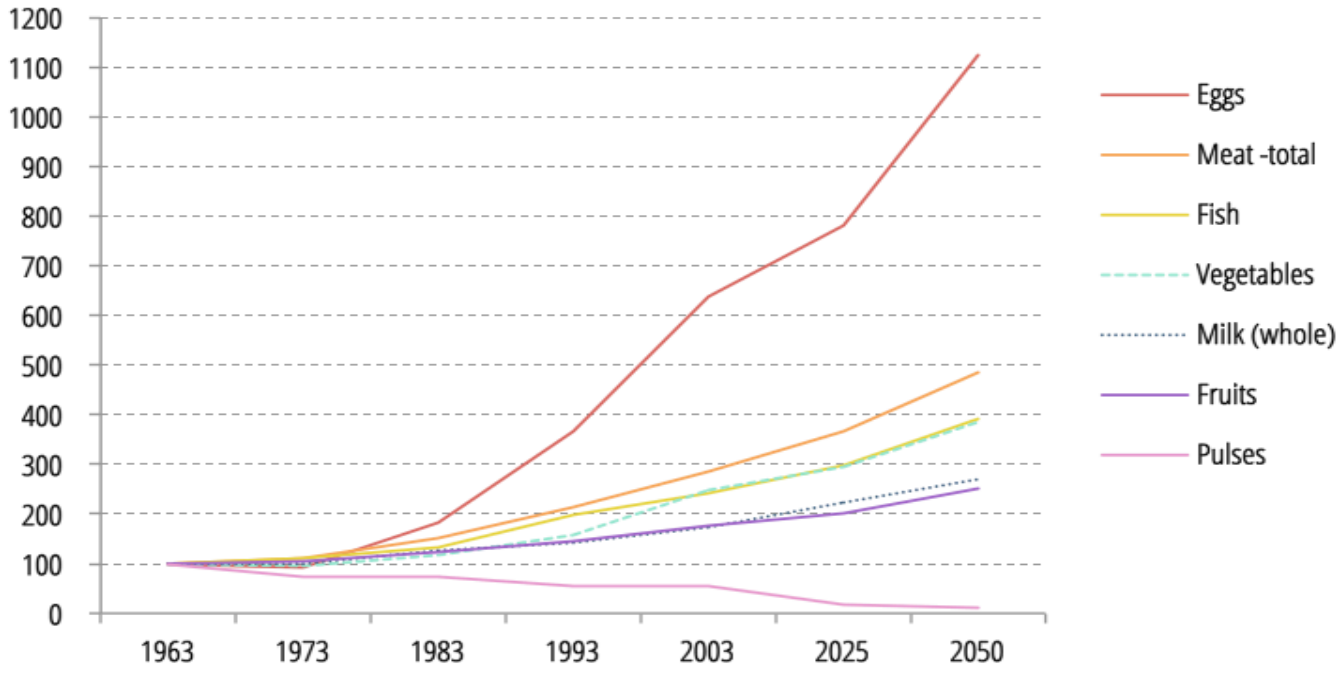
Changes in foods consumed: fresh food and processed food

Fresh food

The consumption of fresh foods is growing rapidly (see Figure 5). This rapid growth is driven by: increasing population, rises in income, urbanisation and globalisation (through increased export / import of fresh foods). In East and South Africa, per capita expenditure on perishable foods is set to quadruple by 2040 and the total market size increase by a factor of eight (Tschirley et al., 2014). In developed countries, fresh produce is increasingly sourced from other countries and this has led to several FBD outbreaks.

Preference for fresh, ready to eat foods in and out of season is established in developed countries and growing in developing countries. The global market for vegetables, fruit, meat, and ethnic foods is increasing. Whilst this offers export opportunities it may have catalytic effects on domestic food production (see next section). Supplying increasing global and domestic demand can expose risk. For example, it can increase exposure to microbes and in particular microbes that can survive at low temperatures (e.g. *Listeria monocytogenes* the bacterium that causes listeriosis, a serious infection). Another example mentioned previously, in Abidjan, Côte d'Ivoire, a problem of chemicals in smoked fish was not discovered until fish was exported to diaspora populations in France. This led to the identification of food safety problems in domestic markets (Roesel & Grace, 2014).

Figure 5: Increase in per capita consumption of perishables and pulses in developing countries with 1963 as index year (FAO, 2009)



As well as an increase in demand for fresh produce and animal source food, there is also an increased demand for processed, convenience and snack food. Anecdotally, repeated scares over fresh food safety are prompting switches to packaged and processed food.

Processed food

Processed food is less likely to contain biological hazards, which are the greatest cause of known FBD in developing countries. However, processed food may be more likely to contain chemical hazards. There is also a clear association between consumption of processed foods and obesity.

Additives are used in processed food to increase aesthetic appeal, extend product life and increase weight or apparent nutritional content. In recent years in China there have been reported incidents of:

- using melamine to increase the apparent protein level of baby milk;
- using ink to colour noodles; and
- using sodium borate to make cheap pork resemble beef (GFSF, 2011).

All of these are food safety risks. Xue and Zhang (2013) carried out a meta-review of studies of acute food poisoning sourced from Chinese academic databases for the period 2000-2010, covering 2,387 individual incidents of acute foodborne illnesses. Overall, food additives were responsible for 9.9% of incidents, 3.5% of illnesses and 11.6% of deaths in studies they reviewed.

Changes in the retail sector: food chains, supermarkets and street food

Emerging economies have rapidly changing food systems with urbanisation creating bigger markets and longer and more complex food chains. Lengthening of the food chain gives more opportunities for microbial growth while bulking foods from different sources allows cross contamination and makes tracing back through the food chain difficult. Mature and well-governed value chains may be able to reduce FBD by insisting on high standards along the value chain and conducting testing. However, in developing countries the expansion of value chains is happening in advance of effective governance and this increases risk. In China and Vietnam, changing industry structure, rapid market development, rapidly changing prices of products and inputs, low profit margins, lack of bargaining power in key players and lack of government support to stabilise markets all put high pressure on value chain actors to cut corners and sacrifice food safety (FORHEAD, 2014).

The number of supermarkets are rapidly increasing in developing countries. In Mexico, Central America and South East Asia their share is 10-50% of the retail market while in sub-Saharan Africa (outside South Africa) and South Asia the share is less than 10%. In India supermarkets would have to grow at rates of 20%, for 20 years to reach just 20% of market share (Tschirley et al., 2010) suggesting the near term food safety priority should be on informal markets rather than the formal sector.

In developing countries street food is becoming an important component of the diet in cities. This can be a significant source of income, especially for women who dominate street food trade in many countries. At the same time, street food is often contaminated because of inadequate training of vendors and lack of infrastructure (e.g. clean water and sanitation, solid waste removal).

Photo: Produce for sale in a large supermarket in Maputo, Mozambique (photo credit: ILRI/Mann)

Two other trends and potential shocks to food systems: climate change and food defence

Climate change can increase foodborne disease by bringing novel vectors and pathogens into temperate regions or by temperature-associated changes in contamination levels. A recent extensive literature review concluded that:

- campylobacteriosis and salmonellosis were most likely to increase as air temperature increases;
- campylobacteriosis and non-cholera vibrio infections increase as water temperature increases;
- cryptosporidiosis followed by campylobacteriosis were likely to increase with increased frequency of rainfall; and
- cryptosporidiosis followed by non-cholera vibrio were likely to increase as heavy rainfall events increase.
- Listeriosis can survive well at low temperatures but in this review, outbreaks were not associated with temperature thresholds, extreme precipitation events, or temperature limits (ECDC, 2012).

Food defence is a relatively new trend and is concerned with preventing intentional food contamination by malicious/ terrorist individuals or organisations. There have been several documented cases of deliberate contamination of food (e.g. salmonellosis in USA) (Torok et al., 2007). Intentional food contamination is likely to continue to be monitored.

Geography of food safety

In the least developed economies, FBD is probably common but under-reported. The poorest consumers are to some degree protected from foodborne disease by:

- their limited access to the most risky foods (animal source foods and fresh produce);
- the short value chains for these products; and
- indigenous practices that mitigate risk such as fermentation and lengthy cooking.

Conversely, the poorest people are more at risk from hazards associated with staple foods such as aflatoxins because their diet is more dependent on staples and because the staples they consume are often of poor quality. Important to note is that although aflatoxins are not visible, there is a positive correlation between mouldy and damaged cereals and the presence of aflatoxins. We also need to be mindful that in the poorest countries it is difficult to disentangle foodborne disease from the complex of water-borne, vector-borne, contagious, filth associated and other diseases of neglect and poverty.

In countries where infrastructure is lacking, growth of cities stimulates urban and peri-urban production of perishable foods such as livestock products and vegetables. Emerging economies often have high levels of poorly regulated intensification, high levels of concern over food safety, a relatively advanced ability to detect food contaminants, and a high ability to communicate food scares through mass and social media. It is not surprising then that some of the most serious and widely publicised food safety problems are now occurring in and being reported within emerging market economies (Grace & McDermott, 2015).

Food safety as a market barrier for small farmers

Food safety for export markets is largely controlled by the private standards that importers require. There is a wide range of standards, although with increasing convergence: GlobalGAP[11] is one of the better known. These standards may improve agricultural practices in countries where regulation is weak or lacking and may also prevent dumping of sub-standard food in developing country markets (Grace & Unnevehr, 2013). Few studies have looked at the spillover health benefits of participating in export markets but a study in Kenya found that farmers who had been given training in food standards and monitored for compliance used safer chemicals and had fewer reported health problems. In contrast, a study found that workers participating in export seafood chains in Brazil did not receive any health benefits (Unnevehr & Ronchi, 2014).

Standards tend to ratchet upwards and are driven by the concerns of customers in importing countries. In most cases, this has increased production costs but only in a minority of cases has this improved efficiency (Unnevehr & Ronchi, 2014). International

[11] http://www.globalgap.org/uk_en/who-we-are/about-us/

trade studies have found evidence that the fixed costs of meeting standards tends to favour established exporters and leads to a greater reduction in developing-country exports relative to those in developed countries (Unnevehr & Rohnchi, 2014). Participation in export markets benefits some farmers but many do not benefit and there is a tendency for smaller farmers to drop out, as they lack the human and financial capital needed to participate in highly demanding markets. In the 2000s both Kenya and Uganda saw major declines (60% and 40% respectively) in small farmers participating in export of fruit and vegetables to Europe under Global GAP (Graffham et al., 2007). The situation is similar for supermarkets. The farmers who supply supermarkets usually benefit (often substantially) but it is hard for most farmers to enter these more demanding value chains (Andersson et al., 2015). Those who do benefit tend to be richer, better educated and geographically advantaged. There is also concern that growth of supermarkets is increasing the risks and reducing the rewards for local farmers, creating an environment similar to that seen in industrialised countries. For example, South African dairy farmers are facing declining terms of trade and increasing retail margins (from 1-5% under the Milk Board to 15-30%). This has led to a decline in producers, an increase in farm size and a decrease in prices paid to dairy farmers (Qeqe & Cartwright, 2005; Kirsten, 2009).

Food safety and gender

Women's participation in value chains is high but activities and resource use by women and men vary between cultures, systems and stage in the value chain. A review of 21 informal value chains in Africa and India (Grace et al., in press) found that men caught fish, shot game, slaughtered large animals and predominated in meat sales while women predominated in traditional processing, slaughter of chickens and in sale of fish and street food. In some countries they also predominated as meat sellers.

Across the value chains studied, both women and men consumed animal source foods but consumption patterns varied by gender. There are many taboos around consumption of food (especially nutritious food) that tend to disadvantage women. Worldwide, meat is the main target of taboos for pregnant women (Fessler, 2002). In Africa men have more access to meat because they predominate in bars that serve meat and alcohol (Roesel & Grace, 2014). Consumption in these places is associated with increased risk. A similar pattern is seen with fishborne disease in China, Vietnam and Korea. Men have more frequent eating opportunities at restaurants than women and have a significantly higher rate of fishborne fluke (Han et al., 2013).

Photo: Gender and Market-Oriented Agriculture (AgriGender 2011) workshop, 31st January to 2nd February 2011, Addis Ababa, Ethiopia (photo credit: ILRI/Apollo Habtamu).

Food systems are rapidly evolving in developing countries, and this may exclude women, unless additional efforts are made to retain or include them. For example, in South Africa preparing poultry for consumption is traditionally a female role. Privately run, modern poultry plants mainly employ male workers that exclude (perhaps unintentionally) women. But there are examples, where an inclusive approach was deliberately taken: in Mali a milk processing venture deliberately included women in the enterprise because it is women who traditionally process milk. By intentionally including women a high participation of women were retained in the milk value chain (Roesel & Grace, 2014).

Gender roles are important determinants of health risk and biological differences are also relevant. Pregnant and lactating women are especially vulnerable to a range of pathogens, especially *Listeria* spp. and *Toxoplasma*. Women are risk managers in the realms of food consumption, preparation, processing, selling and, to a lesser extent, production, so gender analysis is important in designing interventions for improving food safety in informal markets.

Who are the most vulnerable to foodborne disease?

Answer: YOMPI – the young, the old, the malnourished, the pregnant, and the immune-compromised.

Why knowing this matters

In the UK, 24% of people are YOMPI and at higher risk from FBD (Lund & O'Brien, 2011). The proportions are less established in developing countries but a significant proportion of the population also fall in the high-risk categories. Immune-compromised people are especially vulnerable to FBD and people with HIV are more prone to many FBD as well as suffering more severe manifestations such as toxoplasmosis enteritis. Liver dysfunction can increase iron availability in the body and this can stimulate the growth of several foodborne pathogens. Immunosuppressant therapies for autoimmune disease or cancer can also increase risk. Salmonellosis and campylobacteriosis are three and four times more common, respectively, in patients with diabetes than in the general population.

In infants, the immune system is not fully developed. Exclusive breast-feeding for six months can protect infants from FBD. Infant formula or follow-on formula contaminated with *Cronobacter sakazakii* or *Salmonella* has caused serious infection in infants (Bowen & Braden, 2008). Infants are also vulnerable to botulism and honey has been the source in several cases. This is why honey is not recommended for infants under one year old. Age-related deterioration of the immune system also increases susceptibility to infection. Malnutrition is a major risk factor for susceptibility to FBD and FBD in turn is associated with malnutrition.

In developing countries, large numbers of people fall into the different categories of vulnerability but numbers are not known as categories overlap (young (579 million <5 years old); pregnant (185 million pregnant women), old (224 million >70 years old) immune-compromised (includes 32 million living with HIV), malnourished (805 million malnourished, 2 billion with micro-nutrient deficiency) (WHO, 2014; FAO, 2014).

Food safety and nutrition

There are potential trade-offs between food safety and availability. In most developing countries, the informal traditional markets are the major source for the risky, fresh foods that are also among the most nutritious foods: foods such as eggs, green leafy vegetables and fish. 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, pasteurisation is considered one of the most effective ways of making milk safe. However, the process adds cost to milk. Most pasteurised milk is sold in packages, which also add to the cost. In 2014 in Kenya the typical cost of a litre of pasteurised milk was US$1 while the typical cost of a litre of raw milk was US$0.5. Nairobi households drink

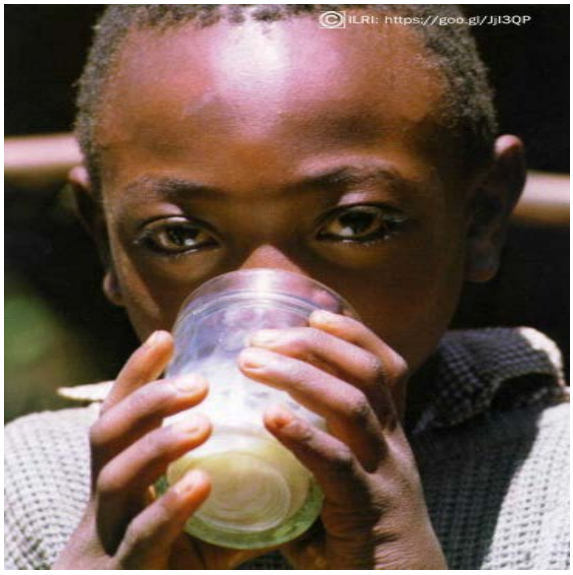


Photo: Kenya boy drinking milk (photo credit: ILRI).

most of their milk boiled in tea so there is little health benefit from pasteurisation and potentially large health impacts from lowered access to milk because of increased price and the small number of retail outlets that sell pasteurised, chilled milk (author's observation).

Wasting and stunting

Wasting, or extreme thinness (very low weight-for-height), is the result of short-term (acute) undernutrition or insufficient dietary energy intake. 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 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: a) contaminated or naturally hazardous food can cause diarrhoea; b) aflatoxins may directly contribute to stunting; c) ingestion of faecal material on food or in the environment may contribute to environmental enteropathy.

- Diarrhoea: One multi-country study found 25% of the stunting burden was attributable to repeated episodes of diarrhoea (Checkley et al., 2008). Each additional episode in the first 24 months of life increases the risk of stunting by roughly 5% (Black et al., 2008). Other studies found diarrhoea had a small but measurable affect on stunting (Richard et al., 2013). A recent meta-analysis suggested WSH interventions (some of the benefits of which are mediated through safer food) slightly but significantly increased growth in height in children < 5 years of age (Dangour et al., 2013). (The specific interventions, evaluated by randomised controlled trials, were solar disinfection of water, provision of soap, and improvement of water quality with an intervention time of 9 – 12 months.)
- Aflatoxins, produced by fungi that infest soil and staple crops, have also been associated with growth retardation, but a causal relation (though plausible) is not yet proven (Leroy et al., 2013).
- Environmental enteropathy is linked to stunting. This condition, characterised by a leaky gut, is probably the result of chronic exposure to faeces in the environment (human and animal). Recent studies in India have shown a strong correlation at state level between childhood stunting and open defecation (Spears et al., 2013). Animal faeces could have similar effects and exposure may be even more frequent. In Lima, Peru, infants in compounds with poultry ingested chicken faeces four times in 12 hours. In Zimbabwe chicken faeces were an important source of bacteria ingested by infants (Ngure et al., 2013).

Photo: Kadidja Kimba, demonstably malnorished with her hair turned red for lack of nutrition, pounds millet whilst caring for Khadi Boubacar (photo credit: ILRI/Stevie Mann).

Knowledge gaps: Current monitoring is not adequate to track changes in foodborne disease. We know food safety standards tend to exclude women and poor people from food systems, but not how best to build inclusive and affordable systems. There are important unanswered questions on the contribution of diarrhoea and aflatoxins to stunting.

CONCLUSION

There is reasonable evidence that developing countries bear the brunt of FBD; that developing country consumers are concerned about FBD; that most of the known burden of FBD disease comes from biological hazards; and, that most FBD is the result of consumption of fresh, perishable foods sold in informal markets. While we don't have good data on the burden of FBD in developing countries, microbial pathogens may contribute 18 million lost DALYs a year, foodborne parasites around 18 million, aflatoxins 1-2 million and known chemical hazards 1-2 millions. However, the burden of chemical hazards is not well assessed.

Food safety has been neglected in developing countries, where most efforts have focused on water, sanitation and hygiene. However, these interventions and improvements still leave a large proportion of diarrhoeal disease unmanaged and evidence is growing that FBD may be an important contributor. There is limited evidence on effective, sustainable and scalable food safety interventions but some promising approaches. Building on the existing food system may be more successful than attempting to impose completely new systems. There are opportunities to improve food safety through technologies, vaccinations and restructuring of food safety governance, but the effectiveness and feasibility of these is not well understood.

Foodborne disease has been increasing in developed countries and is likely to increase in developing countries. These changes are led by massive increases in the consumption of risky foods (livestock and fish products and produce) and by lengthening and broadening value chains bulking more food and increasing the distance between production and consumption. Livestock and fish intensification is a risk as is urban and peri-urban vegetable production relying on wastewater and untreated human and/or animal waste.

Foodborne disease is not just a health issue. Already a major determinant of export market access, it is increasingly affecting domestic markets. Currently, informal markets dominate and offer many opportunities for smallholders and women as well as selling nutritious foods more cheaply than formal markets. Formal domestic and export markets tend to be less equitable, but inclusiveness can be improved by intentional investments. Supporting informal markets to produce safer food, and supporting small farmers and women to engage in emerging formal markets can achieve multiple outcomes of improved health, better livelihoods, enhanced nutrition and equity.

Photo: Informal sales of raw milk in Yopougon Lièvre rouge site. Abidjan, Côte d'Ivoire (photo credit: ILRI/Sylvain Gnamien Traoré).

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BIBLIOGRAPHY OF KEY PAPERS AND FURTHER READING

The safety of perishable foods in informal markets is arguably one of the most important food safety issues in developed countries, and certainly, it is one of the most under-studied issues. The lack of a mature literature on food safety in developing countries makes it difficult to select a comprehensive bibliography. The papers that we signpost here are a selection of resources that help answer broader development questions about the relevance of food safety and provide further information on areas that have been discussed in the accompanying overview paper (produce, parasites, aflatoxins, export, social issues). The papers that we have selected are a mixture of reviews and research. They are all written by experts and are credible sources of further information.

Haagsma et al., 2013, Systematic review of foodborne burden of disease studies: Quality assessment of data and methodology

How are foodborne disease burdens estimated and how accurate are they? Can we trust the foodborne disease estimates?

The concept of using health burdens to set priorities has revolutionised approaches to health care in developing countries. Big burden diseases receive more investment than small burden diseases. But how are foodborne disease burdens estimated and how accurate are they? It is challenging to estimate the burden of foodborne diseases because many diseases can be transmitted by several routes (for example by food, water or direct contact). This paper systematically reviews the methods used to calculate foodborne disease. It provides readers with more information on how the burdens are estimated. It shows:

- Foodborne diseases are a growing public health concern worldwide.
- The burden of disease studies relevant to foodborne disease can be subdivided into: agent-based (e.g. burden due to salmonella or aflatoxins); outcome-based (e.g. burden due to diarrhoea); and risk factor-based (e.g. burden due to pork consumption or to unsafe water).
- Data may be derived from 1) laboratory-confirmed cases, 2) cohort or cross-sectional data, 3) syndrome surveillance data and 4) exposure data.
- Considerable variation exists in methodology (e.g. disability weights, discounting, age-weighting).

Newell et al., 2010 Food-borne diseases — The challenges of 20 years ago still persist while new ones continue to emerge

We know that most infectious diseases are in decline, is this true also of foodborne diseases? Will foodborne disease continue to be important?

The last century has seen a marked decline (sometimes called an epidemiological transition) in infectious disease rates and an increase in the importance of non-communicable disease. This started in the developed world but is now increasingly seen in developing countries. While improvements in wealth, income, knowledge, infrastructure and health systems would be expected to reduce foodborne disease there are other factors that might result in foodborne disease remaining high or even increasing. This paper argues:

- The burden of diseases caused by foodborne pathogens remains largely unknown, with data limited to a few industrialised countries.
- Evidence for a decline in foodborne disease is limited.
- Pathogens are continuously evolving to exploit new niches and so new foodborne diseases can be expected.

Tschirley et al., 2014, The rise of a middle class in East and Southern Africa: Implications for food system transformation, WIDER Working Paper 2014/119

The supermarket revolution has been a popular topic in recent years. What are the current and consumption and purchasing patterns in East and Southern Africa and what are the trends towards 2014? Will informal wet markets continue to matter or are they a thing of the past?

Food safety initiatives in developing countries have focused mainly on export and formal markets. Some believe that the rapid transition to supermarkets seen in America, Europe and to a lesser extent in Latin America and parts of South East Asia will spread to the rest of Asia and Africa. The overview paper summarises evidence suggesting that the greatest health burden comes from perishable animal source food and fresh produce sold in wet markets. There is ongoing research into the current and future importance of wet markets as there is little information about wet markets. This paper is based on large scale survey data and gives a good overview for East and South Africa. It highlights that:

- Wet markets are important: informal markets currently supply 85-95% of market demand and will still supply 50-70% of market demand by 2040.
- Wet markets will persist: traditional marketing systems will dominate East and Southern Africa food systems for decades to come, even with robust economic growth and expansion of the middle class.
- Supermarkets are anti-smallholder: Robust evidence indicates that smallholders are largely excluded from supermarket procurement in these regions.
- Imports are and will remain minor: food imports are currently small and are predicted to remain so at least to 2040.
- There will be more urban consumers: urban consumers are currently 52% of the food market and it is estimated that this will increase to 67% by 2040.
- There will be explosive growth in animal source foods: in the next 30 years the market for animal source perishables will increase by a factor of nearly eight.
- Processed food constitutes a high proportion of household budget spend and this is getting higher: processed foods constitute nearly 40% of the entire food budget across all households surveyed.

Jabbar M, A. et al., (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 No. 24. ILRI (International Livestock Research Institute), Nairobi, Kenya

It is sometimes said that people who are food insecure don't care about food safety. What is the demand for food safety and quality in developing countries? Is food safety important for clients of development?

There is a common perception that, in poor countries, food safety is not seen as an important problem by either decision makers or the public. This research report includes findings from surveys in seven countries about public perceptions on food safety. It finds that:

- Most meat and dairy products are purchased from wet markets.
- It is women in Asia and Africa who are mostly in charge of food purchasing decisions.
- Consumers are willing to pay higher prices for higher quality and safety in milk and meat, and this willingness is particularly strong among the more wealthy and urban consumers.
- Across all animal-sourced foods, freshness, absence of adulteration, fat content (milk) and fat cover (meat), and various aspects of appearance were found to be the quality attributes of major interest amongst consumers.

Lynch et al., 2009, The growing burden of foodborne outbreaks due to contaminated fresh produce: risks and opportunities

This paper provides more information on *foodborne diseases associated with fresh fruits and vegetables.*

The overview paper gives many examples on food safety problems in developing countries associated with animal source foods and aflatoxins. This is partly because the CGIAR system for developing country agricultural research has major activities in these areas. However, evidence from the literature shows that fresh vegetables (and to a lesser extent, fruits) are also important causes of foodborne disease. This paper discusses foodborne disease linked to fresh produce in developed countries. It is important because the upward trend and critical areas are equally relevant to developing countries. Important points in this paper:

- Foodborne outbreaks from contaminated fresh produce are increasingly recognised in developed countries. This is due to a number of factors including:
  - an increase in the consumption of fresh produce;
  - changes in the production and distribution of fresh produce; and
  - a growing awareness amongst public health officials of food safety.
- Foodborne disease outbreaks are increasingly linked to imported food.
- Five areas are critical for safe fresh produce:
  - Quality of water in the supply chain.
  - Protection from contamination of human and animal faeces.
  - Ensuring washing and sanitising fresh products.
  - Management of time and temperature in the supply chain.
  - Protecting produce from contamination by handlers.

Unnevehr L and Grace D, 2013, Aflatoxins: Finding Solutions for Improved Food Safety, IFPRI 2020 briefs

This package of briefing papers provide more information on *Aflatoxins.*

Much research and programme investment has been carried out on the control of aflatoxins (fungal toxins mainly infesting maize and groundnuts) in developing countries. This set of 18 briefing notes summarise current knowledge on health and agriculture. They show that:

- Chronic exposure to aflatoxins leads to liver cancer (the risk of which is much higher in the presence of hepatitis B infection). Aflatoxins are associated with stunting and immune suppression in children but a causal link has not been shown.
- Markets in developing countries generally do not reward reduced aflatoxins in crops because it is difficult to discern aflatoxin contamination or its risks.
- A wide range of control methods exist including cultivation practices and postharvest handling. There are also limited means for mitigating effects of exposure. Control methods are not in wide use in developing countries due to cost, logistics, and lack of incentives.
- Differences among countries in aflatoxin standards (and ability to meet standards) tend to reduce international trade or to divert low-quality exports to lower-value markets.
- Diagnostic tools would facilitate both public monitoring for aflatoxins as well as the development of commercial markets for improved-quality grain.
- Aflatoxins have adverse effects on animal growth, health and productivity. The livestock revolution will exert demand for aflatoxin safe animal feeds.

Torgerson et al., 2013, The global burden of foodborne parasitic diseases: an update Trends in parasitology, 30(1), pp.20–6

This paper provides more information on *foodborne parasites.*

Recent years have seen marked improvement in our understanding of the burden of foodborne parasites, thanks to work by the WHO Foodborne Disease Epidemiology Reference Group and others. This paper summarises current knowledge and includes important updates.

- The WHO launched an initiative in 2006 to estimate the global burden of foodborne diseases in terms of Disability Adjusted Life Years (DALYs).
- Intestinal protozoa were reviewed: *Giardia* appeared to have the highest global prevalence (median = 10.8%), followed by *Entamoeba* (median = 4.3%), and Cryptosporidium (median = 4.0%).
- Toxoplasmosis is mainly foodborne and congenital toxoplasmosis costs 1.2 million DALYs. Other health impacts have not been quantified.
- Foodborne trematodiasis, echinococcosis and cysticercosis impose large burdens. There is little evidence for effective control.

Unnevehr & Ronchi, 2014, Food Safety and Developing Markets, IFPRI discussion paper 00000

There has been a lot of concern over food safety as a barrier to market access by small farmers and women. This paper provides more information on *food safety and market access*. It shows that:

- Most studies have looked at horticulture exports to the EU and other sectors are under-studied.
- Food safety standards often exclude small firms and farms from export markets but there are some examples where they have been successfully included.
- Technical assistance, subsidies for certification costs and managerial support can promote market participation of small farmers.
- Intensive farmer monitoring, training, input provisions and farmers groups are successful mechanisms for including small farmers in export markets.
- Food safety standards impose costs on exporting firms: in some, but not all, cases adoption of standards leads to improved efficiency that can partially offset costs.
- Farms and firms that do participate have clear benefits of market access with emerging evidence on poverty reduction and health.
- Technical assistance and government and donor support has positive impacts on compliance.
- It is difficult to manage food safety through purely public regulation and public-private partnerships (co-regulation) have untapped potential.
- Higher standards for exports can be catalysts for improvements in the domestic industry

Quinlan, 2013, Foodborne Illness Incidence Rates and Food Safety Risks for Populations of Low Socioeconomic Status and Minority Race/Ethnicity: A Review of the Literature, Int. *J. Environ. Res. Public Health* 2013, *10*, 3634-3652

Provides more information on f*oodborne disease and equity.*

Foodborne diseases are not usually considered from an equity perspective. This review summarises evidence from mainly developed countries on how foodborne disease risks vary by socio-economic status and ethnicity. It shows that:

- Low income people and minorities appear overall to suffer higher rates of foodborne disease.
- High incidence of listeriosis among pregnant Hispanic women is an example of where a food culture (consumption of fresh Mexican style cheese) contributes to increased rates of a foodborne illness.
- The high incidence of yersiniosis among African American infants has been linked to the seasonal production of chitterlings (boiled large intestines of pigs following removal of fat and faecal material).
- Lower household income and lower level of parental education are also associated with greater exposure of children to raw products that are often unsafe sources of food.
- Higher microbial loads were found on produce from markets in low socio-economic status areas.
- Plate counts (a measure of bacteria) were significantly higher in milk samples from low socio-economic status and Hispanic tracts when compared to milk samples from higher socio-economic status tracts.

Grace, 2015, Food Safety in Low and Middle Income Countries, Int. *J. Environ. Res. Public Health* 2015, *12*, 10490-10507

A peer-reviewed paper was based on the literature review conducted for this paper "FOOD SAFETY IN DEVELOPING COUNTRIES: AN OVERVIEW". It summarises the information presented in this paper, provides some additional references, and as a peer-reviewed paper has undergone additional checks for accuracy and relevance.

A STOCKTAKE OF WHAT IS 'GOING ON' IN FOOD SAFETY: WHO IS WHO AND WHAT THEY ARE DOING

Many organisations and initiatives have an interest in food safety in developing countries. This note summarises some of the most relevant and provides a good stocktake of who is who and what they are doing. It is divided into three sections:

- The 'Three Sisters' and their food safety initiatives
- Other international initiatives
- Regional and national initiatives

Links to further information and training material have been included at the end of this note.

The 'Three Sisters' and their food safety initiatives

The 'three sisters' can refer to the three sister organisations with a mandate for global health (WHO, OIE and FAO) or to the three standard setting organisations recognised by the World Trade Organisation (the Codex Alimentarius Commission, OIE and International Plant Protection Convention). Food safety initiatives involving WHO, OIE and FAO are summarised below.

World Health Organization

The Department of Food Safety and Zoonoses (FOS) aims to strengthen health security and promote sustainable development of Member States. Its mandate is:

- to develop independent, international scientific advice;
- improve international cross-sectoral collaboration on food safety; and
- lead and assist in the development of risk based, integrated national food safety systems.

WHO initiatives on food safety include:

Foodborne Disease Epidemiology Reference Group (FERG). In 2006 the WHO launched the FERG as an initiative to estimate the global burden of foodborne diseases to provide Member States with data and tools to support policy-makers and other stakeholders to set appropriate, evidence-informed priorities of food safety at country level.

Global Environment Monitoring System - Food Contamination Monitoring and Assessment Programme, GEMS/Food. Since 1976, GEMS/Food has been informing Governments, the Codex Alimentarius Commission (see FAO below) and other relevant institutions, as well as the public on: levels and trends of contaminants in food; their contribution to total human exposure and their significance with regard to public health and trade.

The Global Foodborne Infections Network is a capacity-building programme that promotes integrated, laboratory based surveillance and inter-sectoral collaboration among human health, veterinary and food-related disciplines.

International Food Safety Authorities Network (INFOSAN). Through INFOSAN, WHO assists Member States in managing food safety risks, ensuring rapid sharing of information during food safety emergencies to stop the spread of contaminated food from one country to another. INFOSAN also facilitates the sharing experiences and tested solutions in and between countries in order to optimise future interventions to protect the health of consumers.

The WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance (WHO-AGISAR) was set up in 2008 to minimise the public health impact of Antimicrobial Resistance associated with the use of antimicrobial agents in all food-producing animals. WHONET is a downloadable, Windows-based database software which is used for the management and analysis of microbiology data, with a special focus on the analysis of antimicrobial susceptibility test results.

The Antimicrobial Resistance Information Bank (AR InfoBank) provides access to policy-makers and health care workers to information about drug resistance and resistance surveillance networks. It is collaboration between WHO and WHO Collaborating Centre for Electronic Disease Surveillance, INSERM, Paris, France.

Food and Agriculture Organization of the United Nations

The Food Safety and Quality Programme within FAO coordinates activities in collaboration with other concerned technical divisions and FAO Regional Offices.

Codex Alimentarius Commission

The Codex Alimentarius Commission, established by FAO and WHO in 1963, develops harmonised international food standards, guidelines, and codes of practice to protect the health of the consumers and ensure fair practices in the food trade. The Commission also promotes coordination of all food standards work undertaken by international governmental and non-governmental organisations.

JECFA - Joint FAO/WHO Expert Committee on Food Additives

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) is an international expert scientific committee administered jointly by FAO and the World Health Organization. JECFA serves as an independent scientific committee which performs risk assessments and provides advice to FAO, WHO and the member countries of both organisations. The requests for scientific advice are for the main part channelled through the Codex Alimentarius Commission (CAC) in their work to develop international food standards and guidelines under the Joint FAO/WHO Food Standards Programme.

JMPR - Joint FAO/WHO Meetings on Pesticide Residues

While not officially part of the Codex Alimentarius Commission structure, the Joint FAO/WHO Meetings on Pesticide Residues provide independent scientific expert advice to the Commission and its specialist Committee on Pesticide Residues. FAO and WHO maintain separate websites highlighting the work of the JMPR from the points of view of the two parent organisations.

JEMRA - Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment

While not officially part of the Codex Alimentarius Commission structure, the Joint FAO/WHO Expert Meetings on Microbiological Risk Assessment provide independent scientific expert advice to the Commission and its specialist Committees. FAO and WHO maintain separate websites highlighting the work of the JEMRA from the points of view of the two parent Organizations.

World Animal Health Organization (OIE)

OIE is working with relevant organisations to reduce foodborne risks to human health due to hazards arising from animal production. In this context, a hazard is defined as a biological, chemical or physical agent in food with the potential to cause an adverse health effect in humans, whether or not it causes disease in an animal. Key areas of focus are:

- antimicrobial resistance;
- the role of state veterinary surgeons in food safety;
- meat inspection; and
- Good Agricultural Practices for livestock production.

Other international initiatives

CGIAR programme on Agriculture for Nutrition and Health

The CGIAR research programme on Agriculture for Nutrition and Health (A4NH) is designed to fill the existing gap between agricultural development and its unfulfilled health and nutritional benefits. The starting point is that agricultural practices, interventions, and policies can be better adapted to maximise health and nutrition benefits and reduce health risks. It has four components or flagships, one of which is addressing food safety issues. Around half the research portfolio is on aflatoxins in staple crops and animal source food, and the other half on food safety issues in informal, domestic markets.

Global Food Safety Partnership (GFSP)

The World Bank is facilitating the establishment of a multi-stakeholder GFSP for food safety capacity building. The partnership's main goal is to promote and coordinate capacity building for improved food safety systems, agri-food value chains, and public health outcomes. The GFSP serves as a platform in which concerned international organisations, public sector agencies, private sector producers, processors and retailers, technical service providers, leading academic institutions, consumer groups, and other stakeholders can convene to work out synchronised, collaborative approaches to food safety issues rather than working separately and independently.

Global Food Safety Curricula Initiative (GFSCI)

The International Union of Food Science and Technology (IUFoST) has been commissioned to lead an initiative by academia and other partners to identify gaps in food safety curricula, build capacity, and establish and harmonise core competencies at university and graduate levels.

Global Food Safety Initiative (GFSI)

The GFSI is an industry-driven initiative providing thought leadership and guidance on food safety management system controls necessary to assure the safety of the food supply chain. This work is advanced through collaboration between the world's leading food safety experts from retail, manufacturing and food service companies, as well as international organisations, governments, academia and service providers to the global food industry. It includes large supermarkets e.g. Carrefour, Walmart, Tesco and others.

GlobalGAP

The GlobalGAP sets voluntary standards for the certification of agricultural products around the globe. It started in 1997 as EurepGAP, an initiative by retailers to harmonise their own standards and procedures and develop an independent certification system for Good Agricultural Practice (GAP). The EurepGAP standards helped producers comply with Europe-wide accepted criteria for food safety, sustainable production methods, worker and animal welfare, and responsible use of water, compound feed and plant propagation materials. Harmonised certification brings savings for producers, as they no longer need to undergo several audits against different criteria every year.

World Trade Organization and Sanitary and Phytosanitary Measures

The World Trade Organization (WTO) is the only global international organisation dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and signed by the bulk of the world’s trading nations and ratified in their parliaments. The goal is to help producers of goods and services, exporters, and importers conduct their business.

The Agreement on the Application of Sanitary and Phytosanitary Measures, also known as the SPS Agreement, is an international treaty of the WTO. Under the SPS agreement, the WTO sets constraints on member-states' policies relating to food safety (bacterial contaminants, pesticides, inspection and labelling) as well as animal and plant health (phytosanitary) with respect to pests and diseases that might enter a country through trade. WTO members should base their SPS methodologies on the three standard setting organisations: Codex Alimentarius Commission (Codex), World Organization for Animal Health (OIE) and the Secretariat of the International Plant Protection Convention (IPPC).

Regional and national initiatives

ASEAN Food Safety Network (AFSN)

AFSN was established in 2003 to be a channel for ASEAN Member States to exchange information relevant to food safety.

African Union

The African Union (AU) is reported to be planning to establish a food safety authority as well as a rapid alert system for food and feed, based on European models, to prevent the spread of foodborne diseases and facilitate trade in foodstuffs.

The Partnership for Aflatoxin Control in Africa (PACA) is a collaboration that aims to protect crops, livestock, and people from the effects of aflatoxins. By combating these toxins, PACA will contribute to improving food security, health, and trade across the African continent.

FAO Regional Commissions

Regional Commissions are entities created by agreement between FAO member countries and established under the FAO Constitution. They are forums enabling member countries to take a direct voting position on technical issues relating to their mandates. Commissions are also active on ongoing projects both at member country level and at regional level. The Commission on Livestock Development for Latin America and the Caribbean and The Animal Production and Health Commission for Asia and the Pacific (APHCA) have both conducted initiatives on food and feed safety.

WHO Regions

The WHO regions also conduct food safety activities.

Useful links to further information and training material

Want to know more?

Here are some useful links to further information and training material

- The Codex e-learning course explains the organisation, management and procedures of the Codex Alimentarius Commission (CAC) and its subsidiary is available here: http://www.fao.org/food/food-safety-quality/capacity-development/participation-codex/codex-course/en/
- The European Food Safety Authority is an independent European Agency funded by the European Union. The website features EFSA publications including the EFSA journal. http://www.efsa.europa.eu
- FoodRisk.org is a collaboration by the University of Maryland, USA the Food and Drug Authority and the United States Department of Agriculture. It houses datasets, tutorials, tools, and links to numerous sources of information on risk assessment but also other aspects of food safety. http://foodrisk.org
- The Food Standards Agency is responsible for food safety and food hygiene across the UK. It also commissions and publishes research related to food safety in the UK. http://www.food.gov.uk
- The International Association for Food Protection is a non-profit association of food safety professionals. With members from over 50 countries, it provides information through two journals and an annual meeting. Its website has publications, information and food safety icons. http://www.foodprotection.org
- Safe Food International is a project designed by and for consumer organizations that aims to unify and focus the efforts of consumer organizations worldwide. It is an initiative of the Center for Science in the Public Interest. http://www.safefoodinternational.org
- The US Center for Disease Control and Prevention (CDC) has a website on food safety. The site has information on burden, trends and causes of foodborne illness. http://www.cdc.gov/foodborneburden/estimates-overview.html
- The US Food and Drug Administration (FDA) publishes the “Bad Bug Book” on line which provides current and accessible information about the major known agents that cause foodborne disease. http://www.fda.gov/Food/FoodborneIllnessContaminants/CausesOfIllnessBadBugBook/
- The World Health Organization (WHO) has a site on food safety. This has fact sheets, technical information and publications including the “Five Keys” a simple tool for improving food safety, and information on food safety in the WHO regions. http://www.who.int/topics/food_safety/en/
- The CGIAR Research Program on Agriculture for Nutrition and Health has a website on agriculture associated disease which features articles on food safety research. https://aghealth.wordpress.com

GLOSSARY OF FOOD SAFETY TERMS

This list of words, phrases and food safety terms has been put together to help with understanding the material presented in the text and other related readings on food safety. For ease we have listed terms alphabetically. You may also find our series of factsheets helpful. In particular the factsheets on:

- Bad bugs – foodborne parasites
- Bad bugs – microbial pathogens
- Disability Adjusted Life Years

Acute diseases or illnesses are of sudden onset and/or short duration.

Aflatoxins are a group of metabolic products formed by species of fungus, especially, *Aspergillus flavus* and *A. parasiticus*, in several agricultural commodities, including corn or maize.

Amoebiasis is caused by the protozoan parasite *Entamoeba histolytica* and its transmission occurs via the feacal-oral route either directly by person-to-person contact or indirectly by eating or drinking faecally contaminated food or water. Disease ranges from diarrhoea and dysentery to fulminant colitis, peritonitis and extra intestinal amoebiasis.

Animal source foods are food items that can be obtained from animals such as meat, eggs, milk, cheese and yoghurt.

Antimicrobial resistance is resistance of a microorganism to an antimicrobial drug that was originally effective for treatment of infections caused by it.

Ascariasis is an infection of the small intestine caused by *Ascaris lumbricoides*, a large roundworm. The eggs of the worm are found in soil contaminated by human faeces or in uncooked food contaminated by soil containing eggs of the worm. A person becomes infected after accidentally swallowing the eggs. The eggs hatch into larvae within the person's intestine. The larvae penetrate the intestine wall and reach the lungs through the blood stream. They eventually get back to the throat and are swallowed.

Biological hazards most of the known burden of foodborne disease comes from biological hazards. They include foodborne parasites and microbial pathogens.

Biosecurity, as defined by FAO, offers a strategic and integrated approach to analyse and manage risks in food safety, animal and plant life and health, and biosafety. It provides a policy and regulatory framework to improve coordination and take advantage of the synergies that exist across sectors, helping to enhance protection of human, animal and plant life and health, and facilitate trade.

Burden of disease can be thought of as a measurement of the gap between current health status and an ideal situation where everyone lives into old age, free of disease and disability.

Campylobacter spp. are bacteria that are pathogenic for domestic animals or humans. Most human illness is caused by one species, *C. jejuni*, which grows best at 37°C to 42°C, the approximate body temperature of a bird (41°C to 42°C). It seems to be well adapted to birds who carry it without becoming ill. These bacteria are fragile. They cannot tolerate drying and can be killed by oxygen. They grow only in places with less oxygen than the amount in the atmosphere. Freezing reduces the number of *Campylobacter* bacteria on raw meat.

Chronic Diseases are a long-lasting condition that can be controlled but not cured.

Clostridium perfringens is a bacterium that is found in many environmental sources as well as in the intestines of humans and animals. *C. perfringens* is commonly found on raw meat and poultry. It prefers to

grow in conditions with very little or no oxygen, and under ideal conditions can multiply very rapidly. Some strains of *C. perfringens* produce a toxin in the intestine that causes illness.

Cryptosporidium is one of the most widespread intestinal parasites and a common cause of severe diarrhoea in immunocompromised people and young children. *Cryptosporidium* can be found in surface and groundwater sources susceptible to flooding or faecal contamination, and may be present in piped "improved" drinking water systems that use these water sources. Opportunistic infections with *Cryptosporidium* can cause cryptosporidiosis, a potentially severe and life-threatening illness.

Cysticercosis is a tissue infection caused by the larvae of a tapeworm. Adult tapeworm live in people and immature forms (cysticerci) are found in pigs. However, if a human eats a tapeworm egg shed by themselves or another human, the immature form can develop inside the human body in a number of tissues such as the muscles, subcutaneous tissues, eyes and brain; those that are located in the central nervous system cause neurocysticercosis, the most severe form of the disease.

Disability adjusted life years are the sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.

Disease vectors are organisms that transmit pathogens and parasites from one infected person (or animal) to another, causing serious diseases in human populations.

Echinococcosis is a parasitic disease caused by tapeworms of the genus *Echinococcus*. Humans are infected through ingestion of parasite eggs (shed by the canine host) in contaminated food, water or soil, or through direct contact with animal hosts. Echinococcosis is often expensive and complicated to treat, and may require extensive surgery and/or prolonged drug therapy.

Emerging infectious diseases are defined as infections that have newly appeared in a population or have existed previously but are rapidly increasing in incidence or geographic range.

Environmental enteropathy also known as tropical enteropathy is a subclinical condition caused by constant faecal-oral contamination resulting in blunting of intestinal villi and intestinal inflammation. It may cause chronic problems with absorbing nutrients resulting in malnutrition and growth stunting in children.

Farm to Fork refers to the stages of the production and movement of food. Stages include: planting/breeding, harvesting/slaughtering, storage, processing, packaging, sales, and consumption. Farm-to-table is another common term used often when describing the process of producing food locally and delivering that food to local consumers.

Foodborne diseases are illnesses that result from the ingestion of pathogenic bacteria, viruses, parasites, chemical or natural toxins (e.g. aflatoxins) that contaminate food.

Foodborne parasites are parasites acquired from food.

Foodborne trematode infections, or foodborne trematodiases, are a group of parasitic infections caused by trematodes (flatworms or "flukes") that are acquired through ingestion of food contaminated with the larval stages of the parasite. Transmission is linked to human behaviour patterns related to methods of producing, processing and preparing foods.

Giardiasis is an infection of the digestive system caused by protozoan parasites called *Giardia*. *Giardia* is a microscopic parasite that causes the diarrheal illness known as giardiasis. *Giardia* is found on surfaces or in soil, food, or water that has been contaminated with faeces from infected humans or animals.

Good Agricultural Practices (GAP) in the context of foodborne disease are a set of principles applied to on-farm production and post-production processes, that result in safe and healthy food and non-food agricultural products, and take into account economic, social and environmental sustainability. GAPs may be applied to a wide range of farming systems and at different scales.

Hazard Analysis and Critical Control Paths (HACCP) is a management system which identifies, evaluates, and controls biological, chemical, and physical hazards from raw material production, procurement, and handling, to manufacturing, distribution, and consumption of the finished product.

Hazards are agents or conditions that can cause injury, harm or illness.

Health burden is the impact of a disease problem as measured by financial cost, mortality, morbidity, or other indicators. It is often quantified in terms of quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs), both of which quantify the number of years lost due to disease.

Hyperendemic refers to disease organisms that are present in its host population at a very prevalence.

Informal The informal sector or informal economy is the part of an economy that is not taxed, monitored by any form of government or included in any gross national product (GNP), unlike the formal economy. Examples are barter and gift economy. In the food sector, informal often refers to the traditional, small-scale sector which do not pay tax, lack effective sanitary inspection, but are often recognised by authorities and pay municipal and other fees.

Intensification can be technically defined as an increase in **agricultural** production per unit of inputs (which may be labour, land, time, fertilizer, seed, feed or cash).

Intestinal illness is a broad term that describes conditions with chronic or recurring immune response and inflammation of the gastrointestinal tract.

Macroparasite are parasites that can be seen with the naked eye. They grow in one host but reproduces outside of the host. They include helminths (e.g. nematodes and flatworms). Immune responses evoked by macroparasites are transient and depend on the parasite load. The key epidemiologic measure is the number of parasites per host.

Microbial pathogens are microscopic organisms such as bacteria, viruses and parasites that cause disease in their host.

Norovirus is cluster of associated, single-stranded ribonucleic acid viruses of the family *Caliciviridae* that are very contagious. Virus can be transmitted from an infected person, contaminated food or water, or contaminated surfaces to uninfected person. The virus causes inflamed stomach or intestines (acute gastroenteritis).

Produce is a generalised term for farm-produced crops and goods, including fruits and vegetables (i.e. meats, grains, oats, etc. are sometimes considered as produce). The term often implies that products are fresh and in the same state as where they were harvested.

Protozoan parasites are microscopic, one-celled organisms that can be free-living or parasitic in nature. They are able to multiply in humans, which permits serious infections to develop from just a single organism. Transmission of protozoa that live in a human's intestine to another human typically occurs through a faecal-oral route (for example, contaminated food or water or person-to-person contact). Protozoa that live in the blood or tissue of humans are transmitted to other humans by an arthropod vector (for example, through the bite of a mosquito or sand fly).

Public health is the science of protecting and improving the health of families and communities through promotion of healthy lifestyles, research for disease and injury prevention and detection and control of infectious diseases.

Reactive arthritis is an inflammation of the joints (e.g. wrists, knees, and ankles) that develops in reaction to an infection in another part of the body).

Rift Valley fever is an acute, fever-causing viral disease most commonly observed in domesticated animals (such as cattle, buffalo, sheep, goats, and camels), with the ability to infect and cause illness in humans.

Risk Assessment, is the scientific evaluation of known or potential adverse health effects resulting from human exposure to foodborne hazards. The process consists of: hazard identification, hazard clarification, exposure assessment and risk characterisation.

Rotavirus is a contagious virus that can cause inflammation of the stomach and intestines. The related symptoms include severe watery diarrhoea, often with vomiting, fever, and abdominal pain. Infants and young children are most prone to rotavirus disease. They can become severely dehydrated, may need to be hospitalised and can die.

Salmonella spp. is a genus of rod-shaped bacteria that are a major cause of foodborne illness. The genus belongs to the same family as *Escherichia*, which includes the species *E. coli*. Salmonellae are found worldwide in both cold-blooded and warm-blooded animals, and in the environment. The bacteria are generally transmitted to humans through consumption of contaminated food of animal origin, mainly meat, poultry, eggs and milk. They cause illnesses such as typhoid fever, paratyphoid fever, and food poisoning with symptoms such as fever, abdominal pain, diarrhoea, nausea and sometimes vomiting.

Taeniasis is an intestinal infection caused by two species of tapeworms. The most important human infections are caused by *Taenia solium* (pork tapeworm) and *T. saginata* (beef tapeworm).Humans become infected with *T. saginata* when they consume beef which has not been adequately cooked. Taeniasis due to *T. saginata* usually has a minor impact on human health. Infection also occurs in humans when they eat raw or undercooked pork (*T.solium*). *T. solium* tapeworm infection is of significant importance as it can lead to cysticercosis – a serious disease.

Toxoplasmosis is one of the most common zoonoses worldwide. It is a disease caused by toxoplasma, transmitted chiefly through undercooked meat, soil, or in cat faeces. Symptoms of infection generally pass unremarked in adults, but can be dangerous to unborn children.

Traceability is the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stage of production, processing and distribution.

Value chain: the term "value chain" is used to characterise the interconnected, coordinated set of links and linkages that take place as products move along a continuum between primary production and the consumer.

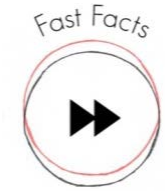
Wet market is a market selling fresh meat and produce.

The World Health Organization (WHO) is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries and monitoring and assessing health trends. In the 21st century, health is a shared responsibility, involving equitable access to essential care and collective defence against transnational threats.

Willingness to pay (WTP): the amount individuals are prepared to pay for goods and services.

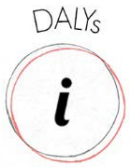
Zoonoses are any diseases or infections that are naturally transmissible from vertebrate animals to humans and vice-versa. Zoonotic diseases can be caused by viruses, bacteria, parasites and fungi. They are common diseases. Scientists estimate that more than six out of ten infectious diseases in animals are spread form animals.

FACTSHEETS



Fast Facts

Health impacts of foodborne disease and why foodborne disease in developing countries is under-estimated



Burden of illness and Disability Adjusted Life Years

Bad Bugs: Foodborne parasites

Bad Bugs: Foodborne bacterial and viral pathogens

Risk Analysis and Hazard Analysis and Critical Control Point (HACCP)

FAST FACTS

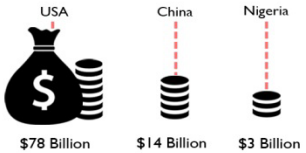
DIARRHOEA DEATHS

The countries with most diarrhoea deaths are in descending order: India, Nigeria, Democratic Republic of Congo (DCR), Pakistan, and Ethiopia. Most of these deaths are caused by contaminated food and/or contaminated water.

THE VULNERABLE

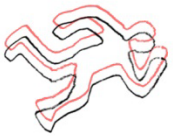
At least one quarter of people in developing countries are especially vulnerable to foodborne diseases. The types of people who are vulnerable include: infants, elderly, pregnant, malnourished and immune-compromised.

Lack of nutritious foods leads to micro-nutrient deficiency which affects around 2 billion people. Many of most nutritious foods which could prevent these deficiencies are also highly prone to contamination: meat, milk, fish, eggs and fruits and vegetables.



Foodborne disease is costly. In the USA foodborne disease is estimated to cost $78 billion per year; in Nigeria $3 billion per year and in China it costs $14 billion annually in lost lives and healthcare.

Foodborne disease can be serious. In a minority of cases, foodborne disease can have serious effects including epilepsy, septicaemia, arthritis, paralysis, kidney failure, abortion and death.



Food safety matters and will continue to matter as agriculture becomes more commercialised in a changing global context. Foodborne disease tends to increase with agricultural intensification and modern supply chains and retailing.

PATHOGENS

Some of the pathogens, which can cause foodborne disease, are very common and widespread. Worldwide, one in three people are infected with *Toxoplasma* and one in ten with *Giardia*. In poor, pig-keeping communities, almost one in three cases of epilepsy may be due to pig tapeworm cysts in the brain.

HAZARDOUS FOODS

Foodborne diseases are the result of eating contaminated or naturally hazardous foods. Examples of foodborne disease include: diarrhoea caused by bacteria in food, allergies to peanuts, poisoning from pesticides or heavy metals in food, and liver cancer resulting from fungal toxins (aflatoxins) in maize or groundnuts.

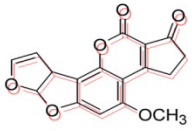
MARKETS

Most food in developing countries is sold in traditional or informal markets, which lack adequate inspection and control systems for foodborne disease. Informal or wet markets are often seen as a food safety problem. Yet most informal markets in developing countries are close at hand to poor people and sell affordable food. They also provide market access for small farmers.

Foodborne disease is common but often under-reported. In developed countries, where information is better than information we have from developing countries, we estimate that one in eight Canadians, one in four Britons and one in three Greeks fall ill each year from foodborne disease. Foodborne disease is probably even more common in developing countries.

IMPACT

Worldwide, the impact of foodborne disease on human health may be as great as the burden of tuberculosis or lung cancer.



AFLATOXINS

Aflatoxins are produced by moulds and are common in maize, groundnuts, sorghum and milk. Aflatoxins cause around 100 thousand cases of liver cancer each year. They may contribute to stunting and immune-suppression.

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Health impacts of foodborne disease and why foodborne disease in developing countries is under-estimated

Measuring Foodborne Diseases

Defining foodborne disease (FBD)

Foodborne diseases can be defined as those conditions that are commonly transmitted through ingested food. Foodborne diseases comprise a broad group of illnesses caused by microbial pathogens, parasites, chemical contaminants, toxins and other hazards.

Category		Clinical syndromes	Examples
Infectious disease (Biological hazards)	Acute	Gastroenteritis	*Campylobacter sp.* Non-typhoidal *Salmonella sp.* *Cryptosporidium sp.* Norovirus Bacterial toxins, marine biotoxins
		Meningitis	*Listeria monocytogenes* *Salmonella sp.*
		Septicaemia	*Brucella* *Salmonella sp.* *Listeria monocytogenes*
		Acute neurological symptoms	*Clostridium botulinum* Marine biotoxins
		Perinatal loss	*Listeria monocytogenes* *Toxoplasma gondii*
		Acute hepatitis	Hepatitis A, hepatitis E

Health impacts of foodborne disease (FBD)

The most common clinical presentation of foodborne diseases results in gastrointestinal symptoms, but foodborne diseases can also lead to chronic, life-threatening symptoms including neurological, gynaecological or immunological disorders as well as multi-organ failure, cancer and death. The tables that follows shows that foodborne diseases can result in many different clinical signs.

Category		Clinical syndromes	Examples
Infectious disease (Biological hazards)	Acute	Reactive arthritis	*Salmonella sp.* *Campylobacter sp.* *Yersinia sp.*
		Guillain Barré syndrome	*Campylobacter sp.*
		Irritable bowel syndrome	*Campylobacter sp.* *Salmonella sp.*
		Epilepsy	*Taenia solium*
		Retinopathy	*Toxoplasma gondii*
		Renal failure	Toxigenic *Escherichia coli*
		Cancer	*Helicobacter pylori* *Opisthorchis vivemini*
		Multi-organ failure	*Trichinella spiralis* *Mycobacterium bovis*

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Category		Clinical syndromes	Examples
Chemical	Acute	Gastroenteritis	Organophosphates
	Chronic	Neuro-developmental disorders	Lead Methylmercury
		Cancer	Aflatoxin, Acrylamide, Dioxins, Arsenic
		Renal disease	Cadmium

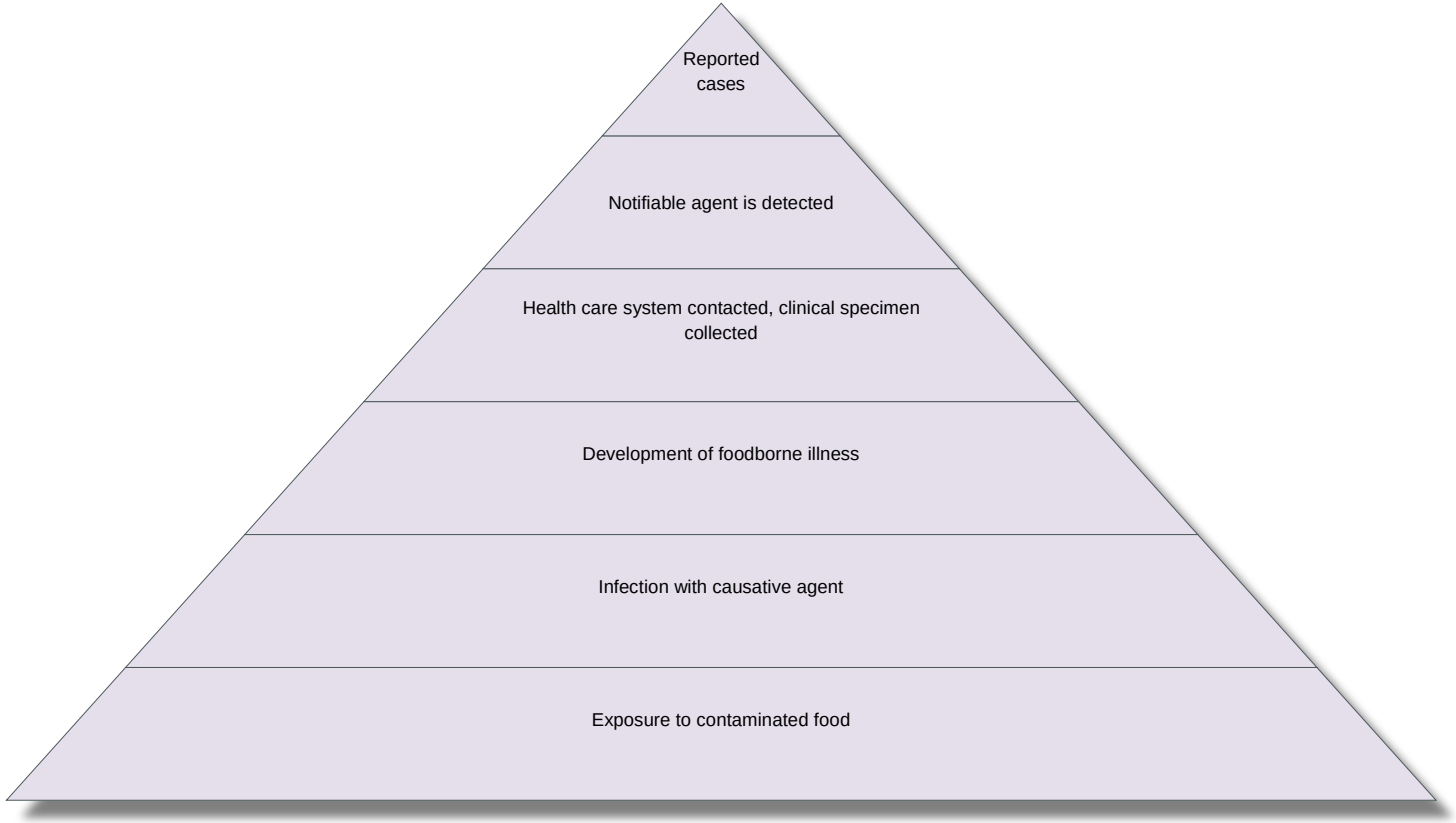
There is remarkably little information on foodborne disease in developing countries. The most common manifestation of FBD is diarrhoea, but most cases never get a laboratory diagnosis. Even if they do, there is often no way of telling if the pathogen detected was acquired from food, water, the environment or another person. As a result, for most countries stakeholders do not know the level of FBD or what issues are most important.

Only a fraction of foodborne diseases that occur are ever reported

Reported cases usually only represent a small proportion of the actual number of clinical cases (See The Surveillance Pyramid that follows overleaf). In developing countries many victims go untreated, or get treatments from unqualified people. Even if treated at a hospital or clinic, there is often no collection of a stool sample for laboratory examination. When laboratory tests are required, they may not cover all potential causes. In many, sometimes most cases, no pathogen is identified. Even if a pathogen is identified, it is not possible to know where the pathogen came from without further investigations (e.g. finding a genetically identical pathogen in food) or evidence (e.g. multiple people report eating the same food before becoming ill).

FACT SHEET

Health impacts of foodborne disease and why foodborne disease in developing countries is under-estimated



Surveillance Pyramid for Foodborne Diseases

FACT SHEET

Burden of illness and Disability Adjusted Life Years

Source: https://en.wikipedia.org/wiki/Disability-adjusted_life_year

This fact sheet discusses how the burden of illness can be measured. The most common measure for disease burden is the Disability Adjusted Life Year (DALY). Use this fact sheet to:

- explore and understand the DALY;
- find out about its history and its utility as a health metric;
- get to grips with some of its criticisms; and
- work through an example to help understand how DALYs are calculated.

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Burden of illness and Disability Adjusted Life Years

DALYs

What is a DALY?

The most widely used and accepted global metric of human sickness and death is the Disability Adjusted Life Year (DALY).

One DALY can be thought of as one lost year of "healthy" life. They are negative and as such should be minimised.

DALYs combine the burden of death and sickness into a single number. It is the primary metric used by the World Health Organization and the Institute for Health Metrics and Evaluation to assess the global burden of disease. It is also a primary metric used to quantify the cost-effectiveness of different disease control programmes. DALYs are increasingly used to assess and monitor health within populations and to set priorities within health sectors.
The sum of DALYs across a population, also called the burden of disease, is a measure of the gap between current health status and the ideal health situation where the entire population lives to an advanced age, free of disease and disability.

How the DALY came about and why it is used as a health metric

The DALY was developed for the World Health Organization as part of its *Global Burden of Disease* project in 1990. It has several advantages as a health metric:

- it combines mortality and morbidity (sickness and death) in a single measure.
- it allows comparison of different diseases.
- it facilitates prioritisation and targeting of scarce resources to where they will have most impact.
- it facilitates cost-effectiveness assessments and allows different interventions to be compared.
- it facilitates monitoring progress of attaining health goals.

Health Economics

Public versus private goods: The earliest attempts to redefine appropriate roles for private suppliers and government led initiatives used the distinction between 'public' and 'private' goods. Public goods and services, once provided to one person, are available to others at no extra cost, and at scale can potentially have a big impact. An example would be a radio programme on food safety. Private suppliers of goods and services tend to be reluctant to supply public goods as they cannot ensure people will pay for them.

In cases where the benefits of the goods exceed their costs, there is a strong argument for state intervention. Controlling diseases at a population level by co-ordinated action such as vaccination campaigns or fluoridation of drinking water has strong public good aspects. Choices made by individuals for disease prevention on the other hand would be determined as private goods. For example, we might think that refrigerators have an important role in reducing foodborne disease because they keep food fresh and that it makes sense that everyone should have access to a refrigerator. Economists, whilst appreciating this fact, might think that the supply of private goods is best left to the market. It would be highly unlikely therefore that a development programme is designed to supply and deliver refrigerators to reduce foodborne disease.

Diseases associated with externalities or side effects: Many diseases are due to risky behaviours which people choose to do because they derive enjoyment or utility from them. Examples might include, diseases linked to obesity or alcohol. Economists might argue that public investments should prioritise those DALYs, which are not lifestyle related but are the result of something which did not bring any offsetting benefit (e.g. infectious disease).

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Burden of illness and Disability Adjusted Life Years

Are development investments driven too much by DALYs?

As a numerical value that can be compared across nations, diseases, and interventions the use of DALYs has become widespread in policymaking, academia and nonprofit work. Yet it is not without criticism.

Common criticisms include:

- DALYs are too subjective and making small changes in assumptions can result in big changes to burdens;
- DALYs do not reflect preferences about allocating health care resources;
- there is economic justification that not all disease burdens are equivalent.

Subjectivity and sensitivity: Deciding the severity to be assigned to sickness is to some extent subjective and when diseases are very common (for example, worm infections) a small change in the severity assigned makes a very large difference to global burden.

Preferences about health care: Intuitively, people do not tend to think that all aspects of disease and death can be combined in a single metric.

Economic reasons: There are arguments that diseases should be treated differently depending on whether their control is a private or public good, and whether the actions that led to disease had positive externalities. These terms are explained in the box to the right.

Let's look at two different scenarios to illustrate these points.

Scenario 1: Which intervention from the two choices given would you rather invest in:

a) an intervention that reduces the length of diarrhoea from four weeks to two for 4,000 children;
or
b) an intervention that saves the life of one child?

If you were basing your decision on DALYs you would probably prefer the first option (a). Yet many people might think it is better for 4,000 children each to bear the discomfort of an additional two weeks of diarrhoea than for one child to die.

Scenario 2: Now consider where you would rather direct $10 million of donor investments. Given the choice would you invest $10 million to:

a) provide hospital beds for Ebola victims in Uganda during an outbreak;
or
b) produce campaigns to reduce smoking in Uganda.

If you were basing your decision on DALYs you might prefer the second option (b). Yet many people think public investments should be directed to deal with diseases that occur outside someone's control than common diseases that are the result of lifestyle choices.

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Burden of illness and Disability Adjusted Life Years

DALYs for foodborne diseases: a do-it-yourself example

DALYs are a complicated concept but are a cornerstone to measuring disease burden. Despite the criticisms, they are likely to remain an important health metric. A good way to understand DALYs is to work through an example of how DALYs are calculated.

For this example, we will calculate the DALYs associated with Campylobacter infections, which are often acquired from chicken and other foods. Campylobacter infections most often result in diarrhoea. However, a small proportion of cases may be followed by Guillain-Barré syndrome which causes sudden onset paralysis.

How DALYs are calculated in four steps

Step 1

To work out how many years are lost from disease, we first need to estimate how many years would be lived in the absence of disease. The highest life expectancy observed for any nation - 82.5 years life expectancy of women in Japan - is typically chosen as the starting point and will be used in this example.

Step 2

Next, information is gathered on disease incidence, symptoms and sequelae (that is, after-effect) by age, sex and geographic region. This statistical information summarises impacts across many people. For example, two infections of Campylobacter may result in very different symptoms:

- Edmund, a 20 year old man suffers with diarrhoea for two weeks as the result of Campylobacter infection.
- Wachira, a 40 year old woman suffers with diarrhoea for one week and then goes on to develop Guillain-Barré syndrome as the result of Campylobacter infection. She is paralysed for two years and then recovers.

Step 3

Judgements are made on the disutility of the disease (that is, how bad the disease is) compared to a year lived with perfect health. A judgement on the disutility of the disease can be given by experts and can also be obtained using surveys. We know that one of the after-effects of campylobacteriosis is paralysis. A survey may ask the question: “Imagine two people – the first person is paralysed, and the second person has diarrhoea. Who is healthier overall?" After the decision (which would likely be that paralysis is worse), then further questions would be asked as an attempt to decide how much worse it is.

Surveys and experts can estimate how much disability is associated with an outcome when the weight assigned to death is 1 and to perfect health is 0. For example they may estimate:

- A year lived with paralysis has a disability weight of 0.9 – a year with paralysis is considered to be a week lived with 10% or 1/10 of normal health. 0.9 years of normal health are lost due to the year lived with paralysis.
- A year lived with diarrhoea has a disability weight of 0.2 – a year with diarrhoea is considered to be a year lived with 80% of normal health. 0.2 years of normal health are lost.

Step 4

The DALYs related to the disease are calculated. In this example of Campylobacter infection the results for Edmund and Wachira would be as follows:

- Edmund has lost two weeks (or 0.04 years) at a disability weight of 0.2. The total DALYs is 0.04 x 0.2 = 0.008 DALYs or years of normal health lost as a result of being infected.
- Wachira has lost one week (or 0.02 years) at a disability weight of 0.2 = 0.004 DALYs from diarrhoea. In addition she has lost two years with a disability weight of 0.9 or the equivalent of (2 x 0.09) or 1.8 DALYs from paralysis. In total 1.8004 DALYs.

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Disease burden

If the DALYs are calculated for all the population at risk, an estimate can be obtained of the burden. For example, in the Netherlands, the disease burden associated with Campylobacter infections was estimated at 1,200 DALYs per year. Globally, the burden of Campylobacter infections is 7.5 million DALYs.

In practice, the calculation is not always so straightforward.

Additional methods used might include:

- Discounting (giving less value to) health years lost in the future (3% is a common discount rate). This means if a disease causes a lifetime of illness, the disutility (badness) of the years spent ill in the distant future would count for less than the years in the present and near future.
- Age weighting DALYs: very young or older ages receive less weight (this is less common). This means a year of life when someone is 80 might count for less than a year of life when someone is 40. So in effect, diseases of old people would count less than diseases of young people.
- Monetising by giving DALYs a monetary value.

FACT SHEET

Bad Bugs: Foodborne parasites

More than a thousand living organisms, from visible to sub-microscopic, can cause human disease. The diseases caused can vary from the rare and trivial to common and deadly. Putting diseases into categories brings order to this huge array of pathogens[1]. A common categorisation is to divide pathogens into parasites, bacteria and viruses. This fact sheet gives information on **parasites.** [2]

Many parasites are multi-cellular and macroscopic. This means that their bodies are made up of many cells and they can be seen without a microscope. They can be detected in the bodies and excreta of animals and humans quite easily. Other parasites are uni-cellular and can only be detected with a microscope, protozoa are an example.

Defining foodborne parasites

An FAO/WHO expert group has developed a comprehensive list of 95 human parasites for which food might be an important transmission pathway. From this list the 24 most important have been identified (FAO/WHO, 2012). The Parasitic Disease Taskforce of the Foodborne Disease Epidemiology Reference Group (FERG)[3] also identified foodborne parasites that were likely to have a substantial health burden. Some of the more important are described below under the main groups of protozoa[4] and worms.

Protozoa

- **Intestinal protozoa:** are microscopic parasites with faecal-oral cycles. Infections occur when protozoal cysts are passed in faeces of people or animals, and then are ingested through food, fluids, or fingers that touch contaminated surfaces. Numerous protozoa normally live in the human gut. Under certain circumstances, some cause severe disease.
  - *Giardia lamblia* is found worldwide. It is the most common protozoa found in stools and causes an estimated 200 million cases of illness a year. Globally, 10.8% of people are infected with Giardia.
  - Amoebic dysentery is caused by *Entamoeba histolytica*. There are an estimated 50 million cases of illness and 100,000 deaths a year. Globally 4.3% of people are infected with Entamoeba.
  - *Cryptosporidium* is a common cause of diarrhoea and are especially serious in people who are immune compromised. It is responsible for around 20% of diarrhoeal episodes in children in developing countries and up to 9% of diarrhoeal episodes in developed countries. Some strains are exclusive to humans and others are zoonotic[5]. Globally 4% of people are infected with *Cryptosporidium*. Infection levels are highest in Africa and lowest in South East Asia.
  - *Cyclospora* the cause of several outbreaks of foodborne disease associated with produce imported from South and Central America and *Isospora* are related pathogens.

- **Other protozoa**: *Toxoplasma gondii* has a predator-prey type cycle. Cats become infected after eating rodents or prey that have cysts in their tissues. People become infected when they ingest cysts passed in cat faeces or eat under-cooked meat. Pregnant women can also become infected from sheep, but this is rare. Around one third of humans are infected and in healthy adults symptoms are mild. However, if pregnant women are exposed for the first time, it can cause foetal defects. In immune-compromised people, it can cause fatal encephalitis.

[1] Pathogen: a bacterium, virus, or other microorganism that can cause disease.
[2] Parasite: An organism that lives off or in another organism, obtaining nourishment and protection while offering no benefit in return.
[3] For more on FERG, read our information sheet 'What's Going On in Food Safety'
[4] Protozoa: A parasitic single-celled organism that can divide only within a host organism.

[5] Zoonotic: Pertaining to a zoonosis: a disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans.

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FACT SHEET

Bad Bugs: Foodborne parasites

Worms

Fluke worms (trematodes) are small flat worms. Blood flukes (schistosomiasis) are acquired through contact with water. Fluke which can be foodborne include.

- ***Liver fluke infection (fascioliasis, opisthorchiasis, and clonorchiasis)*** is common in Asia and Eastern Europe. Infections are acquired from eating raw or undercooked fish, or in the case of sheep fluke, from contaminated water plants.
- ***Lung fluke infection (paragonimiasis)*** is found in East Asia, West Africa and Central America and is acquired from eating crabs and crayfish or drinking contaminated water.
- ***Intestinal flukes*** are found in Asia, the Middle East, and elsewhere. They are acquired by eating food that contains or consists of vegetation, snails or fish harbouring the parasite.

Round worms (nematodes). Some types of roundworm infection are acquired when larvae penetrate the skin (e.g. hookworm) or are spread by insects (e.g. river blindness). In this factsheet we discuss only the diseases which can be transmitted by food.

- ***Ascariasis (often called roundworm)*** affects over one billion people mainly in developing countries. Ascarids moving through the body can cause a variety of symptoms and ascarids in the gut can cause diarrhoea and pain. The numbers infected have been estimated to range from 807 to 1,221 million. Infection is acquired directly from soil or from vegetables grown in contaminated soil.
- ***Whipworm (trichuriasis)*** infection affects around 500 million people, mainly children in tropical areas. Severe infection causes chronic diarrhoea and anaemia.
- ***Pinworm (enterobiasis)*** unlike most foodborne parasites, this is common in temperate countries. It can cause intense itching of the anus.
- ***Capillariasis*** is endemic in the Philippines and Southern Thailand where infection is acquired by eating raw or undercooked fish.
- ***Trichinosis (trichiniasis)*** infection occurs when people eat meat (particularly pork) that is undercooked. It is found in Asia. It causes gastrointestinal symptoms as well as muscle swelling and pain.

Tapeworms (cestodes) can grow up to 30 feet and are mainly acquired by eating eggs in food or water that contains cysts.

- ***Pork tapeworm (taeniasis)*** is acquired from eating undercooked pork with tapeworm larvae. If the eggs of the tapeworm are eaten the larvae can infect the human host (cysticercosis). This is a major cause of epilepsy. Across a number of studies in poor pig-keeping communities, 29% of all epilepsy was due to cysticercosis. The host for the adult worm is humans and the usual host for the development stage is pigs.
- ***Beef tapeworm (taeniasis)*** is acquired from undercooked beef with tapeworm larvae. It is not a major cause of illness. The host for the adult worm is humans and the usual host for the development stage is grazing animals.
- ***Fish tapeworm*** is acquired from fish, especially in the northern hemisphere but cases have been reported from Uganda and South America. The host for the adult worm is humans and junior stages are found in crustaceans and fish.
- ***Hydatid disease (cystic echinococcosis or CE)*** is caused by infection with the larval stage of a tapeworm through consuming eggs which are passed in dog faeces and can contaminate food, water, utensils or fingers. CE causes slow growing, harmful cysts in organs and occasionally other tissues. In Eastern Europe there have been considerable increases in human CE since the early 1990s. In South America, there has been some progress in control, but the disease remains high. China may have 40% of the global burden. CE is common in the Middle East and North Africa. Kenya, Uganda and Ethiopia also have hot spots. In endemic areas, 1-10% of people may be affected. The final host of the worm is dogs; sheep, cattle, goats, and pigs are hosts of a development stage of the worm.
- ***Alveolar echinococcosis (AE) disease*** is caused by infection with the larval stage of a different tapeworm found in foxes, coyotes, and dogs are final hosts, small rodents are intermediate hosts. It is found only in the northern hemisphere and over 90% of the global burden is in China on the Tibetan plateau. AE is a more serious disease than CE producing a slow-growing, tumour-like lesion usually in the liver.

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Burden of foodborne parasites

We used estimates from the literature to summarise the burden of foodborne parasites in the table below. For many of the foodborne parasites there are no global estimates of the health burden. However, there is information on the most important foodborne parasites.

Parasitic disease	Associated food	Disease	Cases	DALYs	Reference
Cysticercosis	Pork	Epilepsy, blindness, skin nodules	1,030,800	503,000	GBD, 2014, IMHE, 2015
Cystic echinococcosis	Produce	Large cysts	849,200	1,009,662	Budke et al., 2006 IMHE, 2015
Alveolar echinococcosis	Produce	Tumour like lesions	18,235	666,433	Torgerson et al., 2010
Ascariasis	Produce	Intestinal disturbance	804,370,100	1,355,057 (1.31 million)	WHO, 2014, Pullan et al., 2014, IMHE, 2015
Trichuriasis (whipworm)	Produce	Diarrhoea and anaemia	477,374,400	647,400	Pullan et al., 2014, IMHE, 2015
Foodborne trematodiasis	Fish, aquatic animals & plants	Intestinal disturbance or organ malfunction	80,194,500	1,875,000	IMHE, 2013; Furst et al., 2012, IMHE, 2015
Toxoplasmosis	Meat	Congenital defects, eye disease	7,500 (congentital)	1,200,000	Torgerson & Mastroiacovo, 2013
Cryptosporidiosis	Fresh produce, juice, milk	Diarrhoea		8,372,000	Hoetz et al., 2014
Giardiasis	Produce	Diarrhoea	280,000,000		Esch & Petersen, 2013
Amebiasis	Produce	Diarrhoea, liver abscess	5,000,000	2,237,000	Hoetz et al., 2014
				17,865,552	

FACT SHEET

Bad Bugs: Foodborne bacterial and viral pathogens

Bad Bugs Foodborne Pathogens

More than a thousand living organisms, from visible to sub-microscopic, can cause human disease. The diseases caused can vary from the rare and trivial to common and deadly. Putting diseases in categories brings order to this huge array of pathogens. A common categorisation is to divide pathogens into parasites, bacteria and viruses. This fact sheet gives information on **bacteria and viruses.**

Another commonly used medical term is microbes. Microbes are very small living organisms that can only be seen through a microscope; hence the name. Microbes include bacteria (e.g., *Vibrio cholera,* which causes cholera), viruses (e.g., influenza, which causes the flu), minute fungi (e.g., *Candida albicans*, which causes some yeast infections), and minute parasites (e.g., *Plasmodium falciparum*, which causes malaria).

Globally, the most important microbial causes of diarrhoea are, in descending order: rotavirus, toxigenic *Escherichia coli*, *Cryptosporidium, Campylobacter*, *Shigella spp.*, non-cholera *Salmonella* and cholera (IHME, 2013). The relative importance of different microbial pathogens varies with context. For example, *Vibrio parahaemalyticus* lives in coastal waters and is associated with seafood. It is an important cause of illness in Japan, but is rare in inland countries where raw seafood is not consumed.

1

Rotavirus causes severe diarrhoea and vomiting. It is acquired by ingestion of virus in small amounts of faeces, which may contaminate hands, vectors, food or water. It is the most common cause of gastro-enteritis in children under five worldwide, and is relatively more important in the developed world. If dehydration is not treated, it can be deadly. However, unlike some bacterial causes of gastro-intestinal disease, long-term health effects are not common. Rotavirus vaccine has been very effective in developed countries and moderately so in developing countries.

2

Toxigenic Escherichia coli: *Escherichia coli* are bacteria commonly found in the gastrointestinal tract of people and animals. People are infected when they come into contact with the faeces of an infected animal or person, either directly or indirectly. Major routes of infection are: eating contaminated food; drinking or swimming in contaminated water; directly contacting the faeces of an infected animal or person.

Many types of *E. coli* are harmless but some types of *E. coli* can produce toxins. These are called Shiga toxigenic *E. coli* (STEC) or verocytoxin producing *E. coli* (VTEC). There are various strains of STEC, e.g., *E. coli* O111 and *E. coli* O157. The reservoir of toxigenic *E. coli* is ruminant animals, such as cattle. Toxigenic infections cause a diarrhoeal illness. Sometimes infections can result in haemolytic uraemic syndrome, a severe condition characterised by kidney failure, bleeding and anaemia, which can be fatal.

3

Cryptosporidium is a microbial parasite and is discussed in the Fact Sheet on 'Foodborne Parasites'.

4

Campylobacter bacteria are a major cause of foodborne diarrhoeal illness in humans and are the most common bacterial cause of gastroenteritis worldwide. *Campylobacter* can be found in the intestinal tracts of wild birds and various other animals including pets. The main route of transmission is generally believed to be foodborne, via undercooked meat and meat products, as well as raw or contaminated milk. Contaminated water or ice is also a source of infection. A proportion of cases occur following contact with contaminated water.

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As well as causing diarrhoea, campylobacter may result in septicaemia, hepatitis, pancreatitis and miscarriage. Post-infection complications may include reactive arthritis (painful inflammation of the joints which can last for several months) and neurological disorders such as Guillain-Barre syndrome, a polio-like form of paralysis that can result in respiratory and severe neurological dysfunction or death in a small number of cases.

5 **Shigella** bacteria are closely related to *Escherichia* bacteria. They are a common cause of diarrhoea, including bloody diarrhoea. It is acquired either by direct contact with an infected person's stool or by eating or drinking contaminated food or water.

About 2% of persons who are infected with *S. flexneri*, the most common type of *Shigella* in developing countries, later develop reactive arthritis. Other rare complications are toxic megacolon (a paralysis of the colon preventing bowel movements) or haemolytic urinary syndrome.

6 **Non-cholera *Salmonella*** bacteria are widely distributed in domestic and wild animals. *Salmonellosis* in humans is generally acquired from meats and eggs, but also vegetables contaminated with animal faeces, and even dry foods like spices, chocolate and nuts. People can be infected via the stool of infected people or contact with animals.

Most people infected with *Salmonella* develop diarrhoea, fever, and abdominal cramps. In some people, the diarrhoea may be so severe that the patient needs to be hospitalised. In about 5% of cases, salmonella invade the blood stream, which can result in abscesses and internal infections. Between 2-15% of people may develop reactive arthritis following infection and there is some evidence salmonella infection increases the risk of developing irritable bowel syndrome.

7 **Cholera** is an acute diarrhoeal infection caused by ingestion of food or water contaminated with the bacterium *Vibrio cholerae*. The main reservoirs of *V. cholerae* are people and aquatic sources such as brackish water and estuaries, often associated with algal blooms. Recent studies indicate that global warming creates a favourable environment for the bacteria.

Large epidemics are often related to faecal contamination of water supplies or street vended foods. The disease is occasionally transmitted through eating raw or undercooked shellfish. There are two types of safe and effective oral cholera vaccines currently available.

Other important foodborne microbes that cause gastro-intestinal illness include:

- *Listeria monocytogenes* is often acquired from dairy products, meat and seafood and vegetables. It is rare but because infections are serious, it is a leading cause of death from foodborne illness. It can manifest as gastro-intestinal disease or septicaemia.
- *Yersinia* infections are often acquired from pork, milk and seafood.
- In addition to the *Vibrio* causing cholera, other types of *Vibrio* infections are often acquired from seafood.
- *Bacillus cereus* infections are often acquired from animal source and starchy foods.
- *Staphylococcus* bacteria are common in soil and water and can live in humans and animals. Infection is often acquired from animal source foods, produce and baked goods.
- Q fever, caused by *a Coxiella* is most commonly acquired by inhaling bacteria excreted by animals. Infections can also be acquired from dairy products or tick bites. Q fever is a flu-like illness and gastrointestinal symptoms may be present.
- Norovirus infections can be acquired from food and water but are also easily transmitted by person-to-person contact and contact with contaminated objects or surfaces.

Other important foodborne microbes that do not cause intestinal illness:

- Typhoid and paratyphoid fever are common in developing countries caused by types of Salmonella. Infection is mainly from contaminated food and water. Symptoms include high fevers, stomach pains, headache, enlarged spleen and clusters of pink spots on the skin. Paratyphoid fever is milder. Some patients become permanent carriers. A vaccine is available for typhoid which is 50-80% effective.
- *Streptococcus* infections can be acquired from food. A common symptom is pharyngitis (Strep sore throat).
- Botulism can be acquired from improperly processed, home preserved foods. It is rare but causes a paralysis that can be fatal if not treated. Infant botulism can be acquired from honey.
- Most types of tuberculosis are not foodborne but zoonotic tuberculosis can be acquired from dairy products.
- Brucellosis can be acquired from dairy products and causes undulant fever.
- Hepatitis A is a liver disease that can be acquired from food and water or contact with infected people or contaminated objects and surfaces. Hepatitis E is a similar disease, more common in developing countries. It has a wider host range and pigs and pork products may have a role in transmission.

We used estimates from the literature to summarise the burden of foodborne pathogens in the table overleaf.

Burden of foodborne Pathogens

For many of the foodborne pathogens there are no global estimates of the health burden. However, there is information on the most important foodborne pathogens.

Disease	Commonly associated food	Symptoms	DALYs	Reference
Rotaviral enteritis	Contaminated food and water	Diarrhoea and vomiting	18,650,000	IHME, 2013
Toxigenic *E. coli* infection	Beef, milk, fresh produce	Bloody diarrhoea	14,594,000	IHME, 2013
Campylobacteriosis	Poultry	Bloody diarrhoea, vomiting, fever	7,541,000	IHME, 2013
Shigellosis	Produce, poultry, dairy	Cramps, diarrhoea, fever	7,052,000	IHME, 2013
Other *salmonella* gastrointestinal infections	Eggs, meat, milk, fresh produce	Cramps, diarrhoea, fever	4,847,000	IHME, 2013
Cholera	Water and food	Diarrhoea	4,463,000	IHME, 2013
Other diarrhoeal diseases	Meat, fresh produce, water		21,916,000	IHME, 2013
Typhoid and paratyphoid	Contaminated food and water	Septicaemia	12,239,000	IHME, 2013
		Total DALYs per year in 2010	91,302,000	

FACT SHEET

Risk Analysis and Hazard Analysis and Critical Control Point (HACCP)

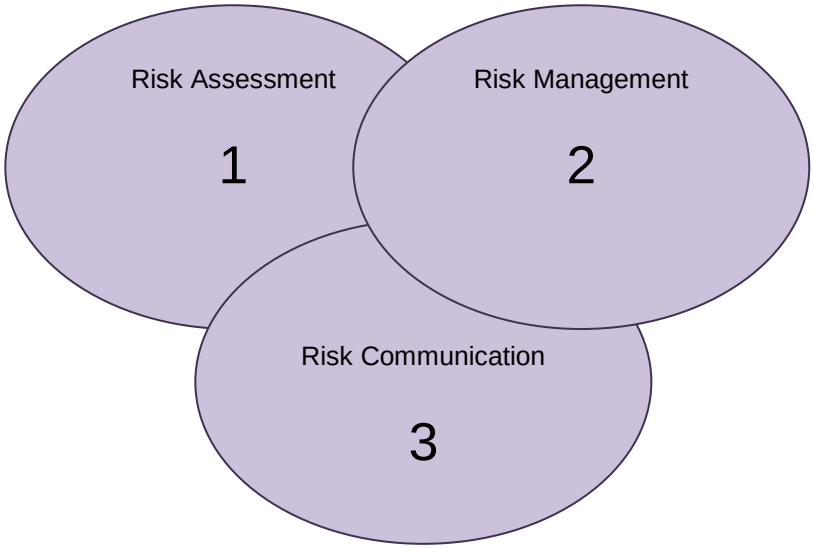
Risk analysis provides a way of measuring the harm associated with contaminated or naturally toxic food, identifying options for managing these problems, and making decisions about the best management option to choose.

Risk analysis addresses important concerns:

- Is it safe?
- Is it a big and important risk?
- What efforts should we make to reduce the risk?

- *Meaning of risk:* In risk analysis, risk is the potential for negative consequences. It can be considered a combination of the severity of health impacts and their likelihood of occurrence.
- *Meaning of hazard*: a biological, chemical or physical agent in, or property of, food that may have adverse health effects.
- Risk Analysis is a structured approach for dealing with risk. It has three essential elements: risk assessment, risk management and risk communication:

1. **Risk assessment** is a systematic evaluation of hazards and their possible effects. It is the process of identifying a hazard and estimating the risk it poses.
2. **Risk management** uses outputs from the assessment to put in place actions to control hazards. It is the process of evaluating and selecting alternative regulatory and non-regulatory responses to risk. The selection process necessarily requires the consideration of legal, economic, and behavioural factors.
3. **Risk communication** is the exchange of information, opinions and concerns about risk among interested parties (stakeholders).



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Risk Analysis and Hazard Analysis and Critical Control Point (HACCP)

Risk Analysis

Hazard Analysis and Critical Control Point

Regulators and industry officials agree that the most effective and economical way to identify and manage food safety risks is the use of Hazard Analysis and Critical Control Points (HACCP). This common sense approach relies on scientifically-based risk assessment and prevention rather than on detection of hazards.

The HACCP concept was developed in the early 1970s as a system to assure the safety of food for astronauts in the NASA space programme. HACCP is based on the recognition that manufacturers are responsible for determining the critical aspects of producing safe foods. It helps food manufacturers to improve the efficiency of control by providing a disciplined, systematic approach to the procedures for assuring food safety.

However, HACCP is not widely used in developing countries and many small and informal sector enterprises are not ready for HACCP.

A World Health Organization (WHO) consultation identified the key constraints to uptake of HACCP in developing countries:

- Lack of customer and business demand;
- Lack of government commitment;
- Absence of legal requirements;
- Financial constraints;
- Human resource constraints;
- Lack of expertise and/or technical support;
- Inadequate infrastructure and facilities.

Basic good practices (Good hygienic practice or HACCP pre-requisites) need to be in place before HACCP is introduced.

There are **seven** discrete activities that are necessary to establish, implement and maintain a HACCP plan, and these are referred to as the 'seven principles' in the Codex Guideline (1997).

Principle 1: Conduct a hazard analysis

Identify hazards and assess the risks associated with them at each step in the commodity system. Describe possible control measures.

Principle 2: Determine the Critical Control Points (CCPs)

A critical control point is a step at which control can be applied and is essential to prevent or eliminate a food safety hazard, or reduce it to an acceptable level. The determination of a CCP can be facilitated by the application of a decision tree.

Principle 3: Establish critical limits

Each control measure associated with a CCP must have an associated critical limit which separates the acceptable from the unacceptable control parameter.

Principle 4: Establish a monitoring system

Monitoring is the scheduled measurement or observation at a CCP to assess whether the step is under control, i.e. within the critical limit(s) specified in Principle 3.

Principle 5: Establish a procedure for corrective action, when monitoring at a CCP indicates a deviation from an established critical limit

Principle 6: Establish procedures for verification to confirm the effectiveness of the HACCP plan

Such procedures include auditing of the HACCP plan to review deviations and product dispositions, and random sampling and checking to validate the whole plan.

Principle 7: Establish documentation concerning all procedures and records appropriate to these principles and their application

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