NIGERIA

INTEGRATED ANIMAL AND HUMAN HEALTH MANAGEMENT PROJECT

DRAFT REPORT

Assessment of risks to human health associated with meat from different value chains in Nigeria: using the example of the beef value chain

ILRI
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Preface

The World Bank is preparing a project on Integrated Animal and Human Health Management for Nigeria. The project will have four components to be implemented by the Federal and State Departments of Veterinary Services and Public Health. The State Departments will implement community-level activities in selected Local Government Areas (LGA).

The strategic framework of the proposed project has four objectives:

1. Build capacity to search for, identify and prevent newly emerging diseases.
2. ***Strengthen food safety and thereby break infection chains that promote the transfer of pathogenic organisms to humans.***
3. Develop effective, integrated animal and public health management infrastructures (including small-farm biosecurity, grassroots surveillance, rural food safety and sustainable health services) at the federal, state and LGA levels to minimize disease threats.
4. Reduce the impact of re-emerging livestock diseases that seriously affect the livelihoods of rural populations and thereby have a pro-poor objective.

To provide a reliable basis for determining returns to investment in the proposed project, the International Livestock Research Institute (ILRI) was invited to assist in investigating the extent of contamination along the meat chain in Nigeria and costs of food poisoning from consuming poor microbial quality meat. ILRI is a member of the Consultative Group on International Agricultural Research with a global mandate for research on livestock issues affecting poor people in developing countries.

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Abbreviations

ALOP	Appropriate Level of Protection
cfu	Colony-forming Unit(s)
DALY	Disability-adjusted Life Year
DNA	Deoxyribonucleic acid
EAEC	Enteroaggregative *Escherichia coli*
EHEC	Enterohaemorrhagic *Escherichia coli*
ELISA	Enzyme-linked Immunosorbent Assay
EPEC	Enteropathogenic *Escherichia coli*
ETEC	Enterotoxigenic *Escherichia coli*
FAO	Food and Agriculture Organization of the United Nations
FBD	Food-borne Disease
FSO	Food Safety Objective
GBD	Global Burden of Disease
GHP	Good Hygiene Practices
GMP	Good Manufacturing Practices
GoN	Government of Nigeria
HACCP	Hazard Analysis Critical Control Point
HIV	Human Immunodeficiency Virus
ICC	Intra-cluster Coefficient
ILRI	International Livestock Research Institute
KAP	Knowledge, Attitude and Practices
LGA	Local Government Area
MAT	Microscopic Agglutination Test
MC	Marginal Cost
MR	Marginal Revenue
NTS	Non-typhoidal *Salmonella*e
PO	Performance Objective
QMRA	Quantitative Microbial Risk Assessment
QRA	Quantitative Risk Assessment
RVF	Rift Valley Fever
SPS	Sanitary and Phytosanitary
TB	Tuberculosis
TEC	Toxigenic *Escherichia coli*
TSB	Tryptic Soy Broth
TSI	Triple Sugar Iron
UB	Urea Broth
USD	United States Dollar(s)
VSL	Value of a Statistical Life
WHO	World Health Organization
WTO	World Trade Organization
XLD	Xylose Lysine Desoxycholate

Executive summary

The study built on a series of logical steps starting with a stakeholders' workshop which was followed by an extensive review of available literature on key meat-borne hazards in Nigeria; with both activities indicating greater concern over the risk of consuming contaminated beef. Beef value chain and hospital surveys were then conducted for hazard identification, understanding the socioeconomic aspects of beef safety and determining costs associated with treatment of diarrhoea. Information from these primary and secondary sources fed into the quantitative risk assessment (QRA) model to estimate the risk of illness associated with the consumption of contaminated beef by people differentiated by sex, age class and health status. Finally and based on inputs from the foregoing, the cost of treatment and lost productivity was estimated using Monte Carlo stochastic simulation to take into account uncertainty and variability that might have been introduced by the quality of data. We then used data from the Global Burden of Disease (GBD) to estimate additional costs from loss of statistical lives based on the concept of Disability-adjusted life years (DALY).

The study estimated the total cost associated with food-borne diarrhoea at US$3.6 billion; and the cost associated with beef-borne diarrhoea at US$156 million. DALY lost from diarrhoea are estimated at 67,712, corresponding to a statistical value of US$2.7 billion; while the DALYs lost from beef-associated disease correspond to 13,542 with a statistical value of US$542 million.

We discuss the other aspects of cost of beef-borne illness which were not captured because of inadequate data but which are likely to be similar or greater to the costs calculated. Chronic and non-gastrointestinal illness associated with food-borne disease is less common than gastrointestinal illness but more severe, and experts consider it to have an equivalent cost. Other costs of beef-borne disease, which were not quantified, include reduced animal productivity, costs of control and trade impacts.

This initial estimate suggests beef-borne disease is costing Nigeria US$854 million per year. Furthermore, a reduction of between 20-70% in beef-borne disease is feasible.

Recommendations are then given on risk-based approaches for reducing beef-borne disease in Nigeria.

Key points

- There is a lack of information on the risk to human health, cost of illness, the relative importance of different hazards, or risk factors for food-borne diseases in Nigeria.
- However, evidence indicates there are high levels of zoonotic and food-borne disease in Nigeria, likely to impose a huge burden of health on consumers as well as all actors involved in food value chains.
- It appears that bacterial pathogens are the biggest problem and the most important of these, as elsewhere in the world, are zoonotic.
- There is a high and unacceptable risk of illness from toxigenic *E. coli* or *Salmonella* from beef consumption each year and a high level of consumer concern over the quality of the meat they buy. Consumers who have less concern are most likely to report gastrointestinal illness.
- Information asymmetries between beef sellers and consumers may result in value chain failures in delivering safe meat.
- Abattoirs appear to be a key point where contamination occurs.
- Traditional approaches to food safety centred on infrastructure provision and command-and-control regulation have not led to sustainable improvements in food safety.
- Newer approaches based on risk rather than hazard, and taking into account incentives for behaviour change as well as governance structures, are 'better bets' for sustainably improving the safety of beef value chains.
- Because gender influences engagement in all aspects of the 'farm to fork' risk pathway, gender-aware strategies are likely to be more effective.
- Marked and significant differences between regions implying food safety interventions should be targeted for regions.

Report structure and chapter summaries

Chapter 1: Introduction

The first chapter sets out the justification for the study, describes the approach used (risk analysis and socio-economic analysis) and sources of data.

Chapter 2: Stakeholder engagement

The second chapter describes the process of engaging stakeholders in the assessment and getting their perspectives on food-safety issues. An initial workshop confirmed that experts, academics and practitioners in veterinary public health, as well as the private sector are concerned over food safety in Nigeria. Beef was seen as an important value chain in all parts of Nigeria. Participants identified 21 important hazards (biological and chemical) and considered *Salmonella* spp., toxigenic *Escherichia coli* and *Mycobacterium bovis* to be key hazards. They also endorsed a risk-based approach to assessing, managing and communicating food-borne hazards. After the field work, a second stakeholder consultation was conducted and comments and suggestions incorporated in the final version of the report.

Chapter 3: Literature review

Chapter 3 consists of a literature review on food-borne disease in Nigeria. The main conclusion was that in Nigeria, as in most developing countries, we lack accurate information on the prevalence and impact of food-borne disease. However, we know that diarrhoea, the most common manifestation of food-borne disease is a major cause of sickness and death. Studies agree that the most important causes of diarrhoea are toxigenic *E. coli*, *Salmonella* spp., rotavirus and *Shigella* spp. Bacterial causes of diarrhoea (most of which are zoonotic) appear to be of relatively high importance in Nigeria and diseases associated with toxigenic *E. coli* and non-typhoid salmonellosis are high and increasing confirming the identification of these as key hazards by stakeholders.

Studies on hazards in food show high levels of contamination, with meat being particularly problematic. Abattoirs are extremely unhygienic and appear to be a critical point for contamination. Non-diarrhoea associated zoonoses which can be transmitted by food, or are occupational hazards, are also important. In particular, there is strong evidence that tuberculosis, brucellosis, leptospirosis, cystic echinococcosis, anthrax, Q fever and Rift Valley fever (RVF) are endemic zoonoses which impose huge burdens on human health and the livestock economy in Nigeria.

While an extensive literature documents a wide range of hazards, there are few studies on risk to human health, cost of illness, the relative importance of different hazards, or risk factors. Moreover, most studies are local and little information exists on national prevalence.

Chapter 4: Hazard identification

Chapter 4 describes a survey of meat safety with the objective of generating up-to-date and representative information on bacteriological quality and risk factors. We collected 200 samples of meat and meat products in two regions. The majority of meat samples (80%) contained unacceptable levels of one or both of the two key hazards surveyed (toxigenic *E. coli* and *Salmonella* spp.). Results suggested that the dynamics of the two pathogens are different and further investigation would be needed to undertand transmission and identify control strategies.

Meat at the abattoir was highly contaminated and this is obviously a critical point for preventing contamination down the chain. Cooking is considered an important risk mitigating strategy, but although it halved the risk of contamination, the presence of pathogens was still unacceptably high (60% of samples were unacceptable despite cooking). An important finding was that a relatively small proportion of actors generated the majority of risk. This makes a risk-targeted strategy attractive where, by identifying the chains and actors where there is greatest potential for contamination, scarce resources can be allocated to where they will have most impact.

Chapter 5: Socio-economic aspects of beef safety

In this chapter, two recent case studies looking at socio-economic aspects of beef safety in Nigeria are summarized. The first looked at the social determinants of meat quality and the link between meat quality and self-reported illness. This study showed the importance of butchers' associations and suggests they may be good entry points for interventions to improve food safety. It also found that even under difficult conditions some groups could achieve better food safety and better health outcomes. Women butchers reported better practices and groups with a high proportion of women had better quality meat. This study showed a high proportion of butchers reporting gastrointestinal illness in the previous two weeks (47%) and a clear relation between meat of poor microbiological quality and higher incidence of gastrointestinal disease (23% more illness in groups with poor quality meat).

The second study looked at the knowledge, attitude and practices (KAP) of beef value chain actors in four sites (Abuja, Enugu, Ibadan and Kaduna). Risky practices were reported by only a minority of consumers but have potentially large impacts on health (e.g. eating cold left-overs; frying for less than 7 minutes; giving left-overs to animals; eating raw meat). False beliefs were common, for example, 88% of people believed that one can tell unsafe beef by its appearance and 96% that cooking beef makes it safe. Most customers (81%) had concerns about the meat they bought (especially hygiene and quality). Consumers who had concerns about safety reported much less illness, and those who believed price is more important than quality had much more. This study showed marked and significant differences between regions, implying food safety interventions should be targeted for regions.

Risk enhancing practices of beef sellers include: selling meat over a long period; retaining meat for sale the next day; tasting raw meat; inadequate washing of surfaces; and negligible use of disinfectants. Beef sellers reported more diarrhoea than customers, suggesting they are an at-risk group but also providing an incentive for them to change behaviour. There are belief asymmetries, with most beef sellers agreeing that 'price is more important than quality to consumers' but most consumers disagreeing; moreover, 92% of beef sellers agreeing that 'customers will complain if there are problems with beef' but only 45% of customers agreeing with the same statement.

Chapter 6: Risk assessment of key hazards (toxigenic *E. coli* and *Salmonella*)

This chapter reports an assessment of the potential risk of illness from the consumption of beef contaminated with toxigenic *Escherichia coli* and *Salmonella* spp. in a subpopulation in Nigeria. In the study, we used quantitative risk assessment (QRA) to collate and analyze data from different sources to estimate the risk associated with the consumption of contaminated beef. The effect of uncertainty and variability of the different parameters used in the model on the predicted risk of illness was evaluated using Monte Carlo simulation.

The probability of illness for a healthy female from consumption of beef contaminated with toxigenic *E. coli* at a restaurant ranged from 7×10^{-3} to 28×10^{-2} depending on the amount of beef consumed. However, the risk for the same female eating at home was less (5×10^{-3} to 24×10^{-2}). The estimates of illness were three times higher for immunocompromised females exposed either at the restaurant or at home. We also evaluated the risk for healthy males being exposed at restaurants and their risk was higher than for females under a similar scenario (13×10^{-3} to 44×10^{-2}). A similar trend of reduced risk was observed for men exposed at home (9×10^{-3} to 32×10^{-2}). In the case of *Salmonella*, the respective probabilities of illness for healthy females eating at home and restaurants were (1.8×10^{-3} to 9×10^{-2}) and (1.2×10^{-3} to 6×10^{-2}), respectively while for healthy males they were (1.8×10^{-3} to 9×10^{-2}) and (2.7×10^{-3} to 13×10^{-2}), respectively. The risk of illness for immunosuppressed males and females from consuming contaminated beef is considerably higher.

This analysis suggested a high and unacceptable risk of illness*;* for people consuming beef once a week, the most optimistic scenario suggested healthy adults have around a one in three chance of falling ill from toxigenic *E. coli* or *Salmonella* each year. Although results are preliminary and require further research, these initial findings confirm stakeholder concern over the importance of these two hazards in beef.

Chapter 7: Cost of illness

The final chapter presents a cost of illness analysis using data from the systematic literature review and value chain survey (Chapters 3 and 4) as well as a hospital survey to estimate the cost of food-borne and beef-borne illness in Nigeria. Cost of treatment and lost productivity was estimated using Monte Carlo stochastic simulation to take into account uncertainty and variability. The total cost associated with food-borne diarrhoea was estimated at US$3.6 billion; and the cost associated with beef-borne diarrhoea at US$156 million. We then used data from the GBD to estimate additional costs from loss of statistical lives: DALYs lost from diarrhoea are estimated at 67,712, corresponding to a statistical value of US$2.7 billion; while the DALYs lost from beef-associated disease correspond to 13,542 with a statistical value of US$542 million. We discuss the other aspects of cost of beef-borne illness which were not captured because of inadequate data but which are likely to be similar to or greater than the costs calculated. Chronic and non-gastrointestinal illness associated with food-borne disease is less common than gastrointestinal illness but more severe, and experts consider it to have an equivalent cost. Other costs of beef-borne disease, which were not quantified, include reduced animal productivity, costs of control and trade impacts.

This initial estimate suggests beef-borne disease costs Nigeria US$854 million per year. Furthermore, a reduction of between 20-70% in beef-borne disease is feasible.

Chapter 8: Summary, conclusions and recommendations

As each chapter could be considered a standalone in some sense, this final chapter is included to summarize the overall findings and conclusions as well as present potential (risk-based) approaches to improve meat safety in Nigeria.

CHAPTER 1

1. Introduction

1.1 Justification for the study

Food safety is a significant and growing public health problem in Nigeria and food-borne disease is an important contributor to the huge burden of sickness and death caused by diarrhoea. The Federal Ministry of Health reported 90,000 cases of food poisoning in 2007, which is certainly a gross underestimate. The World Health Organization (WHO) estimates 200,000 deaths from diarrhoea each year in Nigeria (WHO 2008), as many as 70% of which may be attributable to contaminated food and water.

As elsewhere, animal-source foods are probably responsible for most of these cases of food-borne disease. Food safety is a problem from farm to fork. The national ruminant and pig herd and poultry flock have high levels of disease, some of which are transmissible through food. With the partial exception of large, commercial abattoirs, of which only a dozen exist in Nigeria, adequate meat handling practices at the country's thousands of village and town slaughter slabs are virtually absent. Most meat is sold fresh (warm) in markets with no refrigeration by butchers with no or inadequate training. At the consumer level, knowledge, attitudes and practices are not conducive to food safety.

The Government of Nigeria (GoN) recognizes the need for improvement in the implementation of its national food hygiene and safety policy in several areas:

- effective enforcement of the existing laws relating to food safety;
- strengthening infrastructural and managerial capacity in risk analysis;
- forging closer inter-ministerial collaboration, cooperation and coordination;
- involvement of all stakeholders in policy formulation of the food safety program; and
- strengthening the capacity of states and local governments to promote safe and hygienic practices by street food vendors and catering establishments.

The World Bank is preparing an Integrated Animal and Human Health Management project for Nigeria. One of the four proposed components aims to address food safety through (a) upgrading biosecurity and meat hygiene in live-bird markets, and (b) upgrading slaughter practices and meat handling hygiene in slaughter facilities and meat markets. Activities include upgrading live-bird markets, state and village-level slaughter facilities and slabs, and meat markets. Upgrading these links in the food safety chain will ensure that entire, integrated chains are developed, safeguarding meat quality from slaughter to consumer.

This study was commissioned by the GoN to summarize and generate evidence on the impact of food-borne disease associated with animal source foods.

1.2 Objectives of the study

The overall objective of this study was to assess the costs associated with consumption of poor quality meat in Nigeria. Sub-objectives included assessment of:

- major hazards associated with meat;
- prevalence of meat-borne hazards in livestock, meat and humans;
- KAP of meat value chain actors;
- health burden of meat-borne disease and other burdens;
- appropriate level of protection; and
- recommendation of possible approaches to improving meat safety in Nigeria.

1.3 Materials and methods

1.3.1 Approach

This introduction provides an overview and summary of materials and methods used in the study; further details are given in the relevant sections.

The over-arching methodology was risk analysis, which has been adopted by international and national organizations as the foundation for decision-making about food safety. Risk analysis has three components: risk assessment, risk management and risk communication. This study is concerned with assessment of risk and communication of risk to decision-makers. Risk assessment offers a science-based, structured, transparent method for answering the key concerns of policymakers and the public alike: *Is it safe? Is it a big and important risk? What efforts are appropriate to reduce the risk?* A risk-based perspective informed the literature review and KAP survey and quantitative microbial risk assessment (QMRA) was used to assess risks of two important microbial hazards namely toxigenic *Escherichia coli* and *Salmonella* spp.

Most food produced and consumed in Africa escapes adequate inspection. Food safety policies and regulations have often been adopted from developed countries and proven difficult to translate into practice (Grace et al. 2008). In order to improve food safety, it is important to understand the factors that influence choices made by value chain actors; construct messages that they find both easy-to-understand and motivating; and develop regulations that will likely influence behaviour. We used KAP surveys to better understand the behaviour and motivation of value chain actors.

Cost-of-illness studies measure the economic burden of a disease or diseases and hence the amount that could potentially be saved or gained if a disease were to be better controlled or eradicated. Cost of illness includes core costs resulting directly from the illness and other non-health costs. Within each category, there are direct and indirect costs. Direct costs are those for which payments are made, and indirect costs are those for which resources are lost. We used probabilistic modelling to assess direct and some indirect health-related costs.

1.3.2 Study components

The major components of the study were:

- Stakeholder consultation to understand their perspectives and get inputs into designing the studies
- Literature review to identify major hazards associated with meat, review evidence on presence and prevalence of these major hazards, and assess the human health impacts associated with hazards
- Assessment of knowledge, attitude and practices relating to meat safety and identification of risk factors and control points
- Risk assessment to estimate the risks to human health associated with meat-borne hazards and appropriate level of protection (ALOP)
- Cost-of-illness assessment to estimate the cost of illness in terms of work lost and health care

1.3.3 Sources of data and information

Five major sources of data and information were used as follows:

1. Expert consultations (workshop and key informant meetings)
2. Systematic literature review of published and grey literature
3. Re-analysis of previous ILRI studies on food-borne disease in Nigeria
4. Review of hospital records
5. Rapid assessment of meat value chains at producer, intermediary and consumer levels in four representative areas (Ibadan, Kaduna, Enugu and Abuja)

1.4 Structure of the report

The report is presented in eight chapters following the logical sequence of the major components of the study (as outlined in Section 1.3.2); with each subsequent chapter drawing from and building on previous chapters. After this introductory chapter (Chapter 1), Chapter 2 deals with the stakeholder consultation which considered the initial project design and offered directions including insights on data sources and the implementation of the associated field surveys, while Chapter 3 presents the results of the literature review.

In Chapter 4, evidence on presence and prevalence of two major hazards, *Salmonella* spp. and toxigenic *E. coli* is assembled from primary surveys of the beef value chain in Nigeria. Based on a previous ILRI study and further evidence collected from field surveys, Chapter 5 examines socioeconomic factors affecting beef safety using the KAP approach. Chapter 6 models the human health impacts associated with the hazards identified, risk pathways and assesses the ALOP while Chapter 7 combines all the results from the foregoing with hospital survey information to compute the costs of illness associated with food- and meat-borne disease in Nigeria. As each chapter could be considered a standalone in some sense, a final chapter (Chapter 8) is included to summarize the overall findings and conclusions.

CHAPTER 2

2. Stakeholder consultation

2.1 Participants

Officials of the Federal Department of Livestock, academics from four Nigerian universities teaching veterinary medicine, the Director of Research of the National Veterinary Research Institute, the Director General and Chief Executive Officer of the Nigerian Institute for Trypanosomiasis (and Onchocerciasis) Research, Chief Veterinary Officers from selected states, and representatives of the private sector were among those who met with ILRI scientists and consultants on 8 April 2010 at the International Institute of Tropical Agriculture, Ibadan to deliberate and address the outcome from the problem formulation for the study. Each participant received copies of the Terms of Reference of the study including a summary of the technical details to study in advance of the meeting. The main points of discussion were as follows:

- Identification of hazards to be investigated
- Scenario pathway through which the public in Nigeria would be put at risk
- Parameters needed to perform the quantitative risk assessment

2.2 Scope of study

The initial discussion focused on which food value chain to consider in the study and consensus was reached, after discussion with the ILRI staff present at the meeting, to focus the investigation on meat. Although information on the sources of food-borne disease is lacking in Nigeria, there was general consensus that animal-source foods (fish, eggs, meat and milk) are the most risky. And, as discussed later, this has been found to be the case for countries which keep detailed records on foods implicated in food-borne disease. Meat was selected because it is a major component of diets, and there was a more extensive literature on meat safety. Narrowing down further, it was agreed to focus on beef as this is consumed in all parts of Nigeria and has been implicated in several food safety outbreaks (ILRI 2009). Other food value chains also require investigation, but it was agreed that focusing on the beef chain would be an important first step, while the approaches and tools used could serve as models for investigating value chains of other types of food.

2.3 Identification of hazards

The group further agreed on a systematic approach by which the perceived hazards would be listed, stratified by their nature (bacterial, parasitic, viral and chemical), and selected for further investigation in the proposed study. The identified hazards were streamlined by elimination using three criteria:

1. Perception of importance among stakeholders
2. Availability of data on prevalence and impacts in animals and humans
3. Economic importance

Application of the criteria to each hazard was based on consensus among stakeholders. The categories and list of perceived hazards are shown in Table 1.

2.4 Key hazards

Among the pathogens listed, the following key hazards were suggested: *Salmonella typhimurium and S. enteritidis, E. coli* O157:H7, and *Mycobacterium bovis.* In addition, *Campylobacter* spp. was considered important but there was a concern that data at human level might not be available.

Table 1: Identification of hazards by stakeholders

Bacterial hazards: • *Salmonella typhimurium, S. enteritidis* • *Brucella* spp. • *Escherichia coli* serotype O157:H7 • *Shigella* spp. • *Listeria* spp. • *Campylobacter* spp. • *Mycobacterium bovis* • *Leptospira* spp. • *Actinomyces* spp. • *Bacillus* spp. • *Staphylococcus aureus* • *Clostridium* spp.	Parasitic hazards: • *Cysticercus* • *Echinococcus* • *Trichinella* spp. Chemical hazards: • Antibiotics and antihelminthics • Pesticides • Disinfectants Viral hazards: • Foot and mouth disease • Avian influenza • Swine flu

2.5 Food matrix and investigation approach

The discussion focussed next on the value chains. The group came up with the following stratification scheme based on their perception on meat consumption based on agro-ecological zones:

1. Humid: beef, chicken, pork
2. Sub-humid: beef, chicken, pork
3. Northern Guinea savannah: beef, chicken, mutton
4. Sudan savannah: beef, chicken, mutton

It is noteworthy that beef was considered important in all regions.

2.6 Scenario pathway

A conceptual pathway model was then developed for the purpose of focusing the data collection efforts. Figure 1 outlines the process through which humans would be put at risk to specific hazards from the consumption of a particular type of meat. Data are needed at each event on the respective pathogen occurrence (P), concentration (C), and practices that exacerbate or inhibit occurrence and concentration of the pathogen. In addition, data are needed on the risk of the identified hazards at the human level. Such data would include the incidence of the medical conditions caused by these hazards, the food matrix associated with them, and the population at risk.

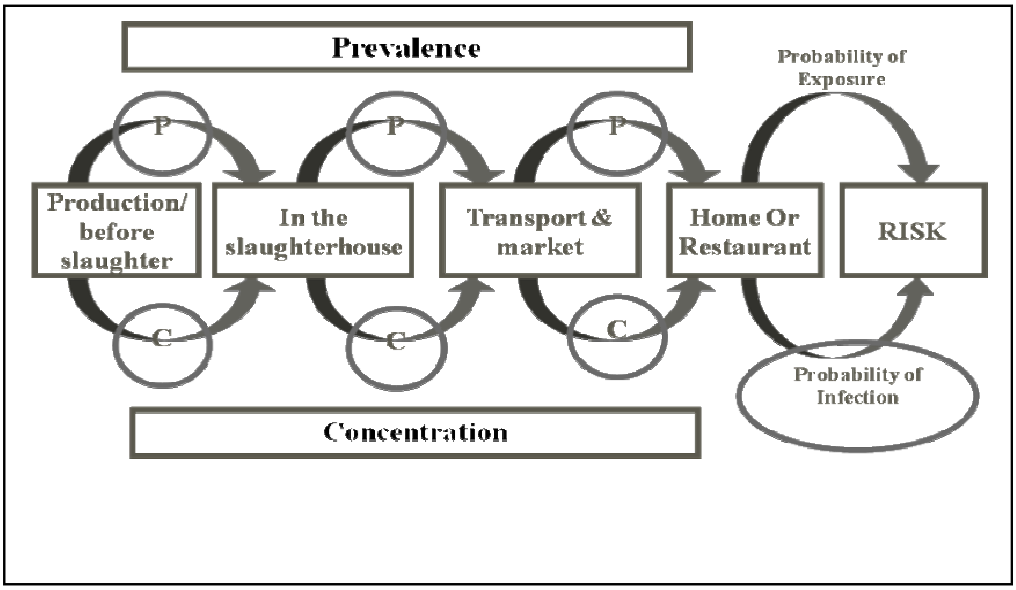

Figure 1: The farm-to-fork pathway for meat in Nigeria.

2.7 Information needed to perform the risk assessment and cost-of-illness assessment

Stakeholders identified the sources of information to be consulted, including literature (published and grey), hospital records and project documents. Given the paucity of information, it was considered necessary to conduct a rapid appraisal to generate additional information. The group agreed that this rapid appraisal would adapt KAP questionnaires and checklists that have been tested in similar ILRI studies. It was agreed that the survey would target four regions (Abuja, Enugu, Ibadan and Kaduna) and include slaughterhouses (butchers), meat sellers, meat shops, restaurants and consumers.

2.8 Summary of outcome of stakeholders workshop

The stakeholder engagement confirmed that experts and practitioners in veterinary public health as well as the private sector are concerned over food safety in Nigeria. Beef was seen as an important value chain in all parts of Nigeria. Participants identified 21 important hazards (biological and chemical) and considered *Salmonella* spp., toxigenic *E. coli* and *Mycobacterium bovis* to be key hazards. They also endorsed a risk-based approach to assessing, managing and communicating food-borne hazards.

CHAPTER 3

3. Risk profile: Literature review

This section presents an overview of the meat value chain with particular reference to beef and identifies major hazards associated with meat, especially those associated with microbiological (bacteria, protozoa, parasites etc.) contamination.

We first review the literature on the importance and aetiology (cause) of food-borne disease. Food-borne disease is one of the most important health problems in Nigeria; most cases are due to bacteria and zoonotic bacteria are among the most common causes. We next review the presence of hazards in food in Nigeria, finding that very high levels are present. Then we review evidence on presence of food-borne hazards along the meat value chain, finding many problems at the point of slaughter and sale. Finally, we consider specific food-borne diseases, summarizing evidence for their presence in animals and people.

3.1 Materials and methods

Terms of reference were drawn up outlining the databases to be consulted, and the search terms to be used to identify relevant abstracts for retrieval. A database was constructed where key information from studies was summarized. In addition, a search was done in the libraries of Faculties of Veterinary Medicine of the following Nigerian universities to abstract all postgraduate work on meat hygiene:

- Ahmadu Bello University, Zaria
- University of Ibadan, Ibadan
- University of Nigeria, Nsukka
- University of Maiduguri, Maiduguri
- University of Agriculture, Abeokuta
- Usman Dan Fodio University, Sokoto

Abstracts from postgraduate theses were then synthesized with results of search of peer-reviewed and grey literature along four sub-themes namely:

- food-borne diseases in people in Nigeria;
- presence of food-borne pathogens in food;
- animal processing plants in Nigeria; and
- food-borne and other zoonoses in animals.

3.2 Food-borne disease in humans

The WHO reports indicate that illness due to contaminated food is the most widespread health problem in the world and an important cause of reduced socio-economic productivity. Food-borne infection is endemic in Nigeria. The 1997 Local Government Health System profile for Nigeria on reported leading causes of deaths in different zones showed that diarrhoeal cases accounted for 25% of mortality followed by malaria (21.0%) and accidents (9.8%) (FAO/WHO 2002).

In Nigeria, as in most developing nations, there is no organized system for monitoring outbreaks of food-borne infections in humans (WHO 2007). Food-borne diseases in Nigeria appear to occur predominantly as isolated sporadic cases rather than taking the form of outbreaks and many, if not most, cases of food-borne infections are unrecognized, un-investigated and undocumented. Moreover, many patients do not seek help from hospitals but may rather engage in self-medication or use medicinal herbs. It is, therefore, difficult to determine the actual incidence of food-borne infections. However, diarrhoea is a good indicator of food-borne disease and better data exist for the prevalence and impact of diarrhoea in Nigeria.

Worldwide, diarrhoea is the second biggest killer of children under five years of age, accounting for 1.3 million deaths a year. Almost half of all the deaths of children under the age of five occurred in just five countries, of which Nigeria is one. The concentration of child deaths in a small set of countries is striking (Taylor et al. 2010). This result is partly related to the large populations of children younger than five years in these countries, but also suggests that epidemiological, environmental and/or socio-economic conditions may underly the high burden of diarrhoea in Nigeria.

The GBD study provides a comprehensive and comparable assessment of mortality and loss of health due to diseases, injuries and risk factors for all regions of the world (WHO 2008). The overall burden of disease is assessed using the DALY, a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health. The burden of diarrhoeal illness in Nigeria is 6,487,000 DALY and is further discussed in Chapter 7.

3.3 Aetiology of food-borne disease

In developing countries, typically 50-60% of diarrhoea cases are bacterial in origin. In Nigeria, the proportion may be higher at 65-80% (Ifeyeni et al. 2010). Most of the bacterial causes of diarrhoea are zoonotic, that is, transmissible between animals and humans.

The most important bacterial zoonoses are: toxigenic *E. coli* infection, campylobacteriosis, cryptosporidiosis, *Staphylococcus aureus* infection, salmonellosis, listeriosis, toxoplasmosis, and *Bacillus cereus* infection.

Important non-zoonotic bacterial causes of diarrhoea include typhoid and cholera. Some pathogens (such as *S. aureus*) have both a zoonotic and an anthroponotic transmission cycle. Others such as *B. cereus* may be environmental contaminants as well as zoonoses. This complexity makes it difficult to estimate the relative importance of infected animals, contaminated environments and infected people as sources of infection. In Nigeria, as in other developing countries, even if food-borne zoonotic pathogens are detected in humans they are often not traced back to the likely animal source.

In some countries, viral causes of diarrhoea predominate but these appear to be less important than bacterial diseases in Nigeria. Worldwide, rotavirus is the most important viral cause of diarrhoea in children and is non-zoonotic. Other viruses implicated in diarrhoea include astrovirus, calicivirus and adenovirus.

Parasitic infections are common in Nigeria but are less often implicated in diarrhoea. The most important parasitic zoonosis is caused by the protozoa *Cryptosporidium parvum* (which can cause diarrhoea). There is some controversy on the zoonotic status of *Giardia lamblia*, another protozoan parasite. Worldwide, *Entamoeba histolytica*, the cause of amoebic dysentery, is another important protozoan cause of diarrhoea (and zoonoses of non-human primates). However, it appears to be less important in Nigeria (Fadeyi et al. 2010). In Nigeria, the prevalence of human intestinal helminthiasis is high but these are usually acquired from the soil and not food. Echinococcosis and cysticercosis are important zoonotic parasitoses.

Only a few studies have attempted to identify the relative importance of different pathogens responsible for diarrhoea in Nigeria (Table 2). These suggest toxigenic *E. coli* is the most important cause of diarrhoea, followed by rotavirus. Other important causes include *Salmonella* spp*., Campylobacter* spp*., Cryptosporidium parvum* and *Staphylococcus aureus*.

Table 2: Studies of diarrhoea reported in Nigeria

	Method of lab. test	Prevalence/ Incidence
	Standard bacterial culture, enzyme-linked immunosorbent assay (ELISA) for rotavirus	Diar. *E. coli* 43% *Klebisella* 9% *Staph. aureus* 4% *Salmonella typhi* 2% *Pseudomonas* 3%
Acute diarrhoea in adults (Okeke et al. 2003)	Microscopy for parasites, culture , deoxyribonucleic acid (DNA) hybridization & serotyping for enteric pathogens	Diar. *E. coli* 36% *Entamoeba histolytica* 35%
Acute diarrhoea in children (Ogbu et al. 2008)	Standard parasitology, bacteriology and ELISA for rota virus	Rotavirus 24% Diar. *E. coli* 15% *Salmonella* 11% *Klebsiella* 11% **Shigella* 5% *Campylobacter* 3% *Y. enterocolitica* 3% *G. lamblia* 3%
Acute diarrhoea (Akinyemi et al. 1998)	Standard bacterial isolation, biochemical characterization and serotyping procedures	Diar. *E. coli* 46% **Shigella* 21% *Salmonella* 17% *Klebsiella* 9% ^*Aeromonas* 4% ^*Plesiomonas* 3%
Childhood diarrhoea (Ogunsanya et al. 1994)	Standard culture and biochemical testing of isolates, Serotyping and cytotoxicity assay in Vero and HEp-2 cell lines	Rotavirus 22% Diar. *E. coli* 39% *Salmonella* 3% **Shigella* 5% *Y. enterocolitica* 1% ^*A. hydrophila* 1% *E. histolytica* 0.5% *G. lamblia* 0.5% *T. hominis* 0.5% *T. trichura* 0.9%

Red= zoonosis ^ aquatic zoonoses *zoonosis of non-human primates

A larger number of studies have looked at specific pathogens or hazards. We summarise the findings for toxigenic *E. coli* and *Salmonella* spp. as these were considered the two priority meat-borne hazards by stakeholders.

Toxigenic *Escherichia coli* (TEC) strains are important food-borne pathogens responsible for gastroenteritis with manifestations of crampy abdominal pains, bloody diarrhoea and kidney failure especially in children (Paton and Paton 1998). Cattle are important reservoirs of TEC and contaminated meat is a major vehicle for its transmission from animals to humans (Paton and Paton 1998). The incidence of TEC organisms in human cases of diarrhoea in Nigeria is said to be on the increase (Smith et al. 2009). Ogunsanya et al. (1994) found TEC more prevalent in diarrhoeic children (5.1%) than in the control non-diarrhoeic patients (3%). Olorunshola et al. (2000) investigated the prevalence of *E.coli* O157:H7 in 100 patients with diarrhoea by stool culture in Lagos, Nigeria. Six (6%) of the 100 samples examined were positive for TEC O157:H7. Five of the six patients were children below five years of age and one was a teenager. Local fast-food restaurants commonly referred to as “*bukkas*” were regarded as likely sources of infection. In southeastern Nigeria, seven TEC isolates belonging to serotypes O26, O111, O138 and O157 were isolated from 520 diarrhoeic faecal samples from patients with acute diarrhoeal disease in Enugu and Onitsha (Nweze 2009). In Akwa Ibom State of Nigeria, bloody diarrhoea accounted for 31% of all cases of diarrhoea in humans (Akinjogunla et al. 2009). TEC strains were more prevalent in females (68.4%) than in males (30.6%). Incidence of TEC was high in people within age group 1 – 15 years old (95%), 16 -30 years old (80%) and 46 – 60 years old (70%) but comparatively low in people within age group 31 – 45 (55%) and 61 years old and above (45%) (Akinjogunla et al. 2009). Smith et al. (2009) reported the prevalence of TEC O157 in human stool samples to be 31.6%. The prevalence in female in different age groups ranged from 0% in women aged 40-49 years to 19% in those aged 0-9 years. In males, the prevalence ranged from 0.0% in those aged 30- 49 years to 11.9% in those aged 0-9 years (Smith et al. 2009). A significantly higher prevalence of TEC O157 was observed in Lagos (35.0%) with greater rate of meat consumption and more eateries than in Zaria (23.7%) which had a lower rate of meat consumption and fewer eateries (Smith et al. 2009).

Salmonella: In many sub-Saharan African countries, community-acquired bacteraemia is a major cause of high morbidity and death among children especially those from resource-poor settings (Kariuki et al. 2006). Zoonotic non-typhoidal *Salmonella*e (NTS) account for a steadily increasing proportion of these infections and represent about 20–50% of cases. Most individuals infected with NTS experience mild gastrointestinal illness involving diarrhoea, chills, abdominal cramps, fever, head and body aches, nausea and vomiting. Infections are contracted through food poisoning and are usually self-limiting (Kariuki et al. 2006). In most cases, outbreaks of NTS infection are caused by *Salmonella enterica* serotype *typhimurium* (*S. typhimurium*) and *Salmonella enterica* serotype *enteritidis* (*S. enteritidis*) (Kariuki et al. 2006). A variety of foods have been implicated as vehicles transmitting salmonellosis to humans among which are meat and other animal products. Contamination can occur at multiple steps along the food chain (Kariuki et al. 2006).

Ojeniyi et al. (1986) reported an outbreak of *Salmonella* food-poisoning in Ibadan, Nigeria in which 20 people died. The outbreak was attributed to the consumption of improperly preserved sandwiches contaminated with *Salmonella typhimurium* phage type U282. Olowe et al. (2007) investigated the presence of *Salmonella typhimurium* in faecal samples of diarrhoeic patients in Oshogbo and reported a prevalence of 8.3%. Children aged 1 – 5 years accounted for 69.6% of all positive cases while age group 5 – 12 and adults accounted for 13.4% and 17.0%, respectively. Akinyemi et al. (2007) investigated the involvement of *Salmonella* spp. in cases of pyrexia and diarrhoea in Lagos, Nigeria. Of the 235 blood samples screened from patients with pyrexia, 42 *Salmonella* isolates were identified of which 19 (45.2%) were *Salmonella typhi*, 9 (21.4%) *S. enteritidis* and seven (16.7%) each of *S. paratyphi* and *S. arizonae*. Thirty-three of the 206 stool samples from patients with diarrhooea were confirmed positive for *Salmonella* isolates. Of the *Salmonella* isolates, 18 (51.4%) were *S. enteritidis,* 11 (31.4%) *S. arizonae*, 4 (11.4%) *S. paratyphi* and 2 (5.7%) *S. typhi* (Akinyemi et al. 2007). Ezeaku (1994) reported an overall detection rate of 1.6% of *Salmonella* spp. in both diarrhoeic and non-diarrhoeic faeces from humans in Nsukka, Nigeria. The prevalence in non-diarrhoeic samples (5.2%) was higher than in diarrhoeic samples (0.7%). In Akure, 14 isolates of *Salmonella enteritidis* were obtained from 100 faecal samples comprising 60 from patients and 40 from apparently healthy pupils (Adegunloye 2006). Disseminated infections with *Salmonella typhimurium*, *S. enteritidis*, *S. arizona*, *S. dublin* and other NTS serotypes were recognized early in the human immunodeficiency virus (HIV) epidemic (Smith et al. 1985). Six (3.0%) NTS isolates comprising four *Salmonella typhimurium* and two *Salmonella enteritidis* were recovered from 201 blood samples from HIV-positive patients while three *Salmonella typhimurium* (6.2%) were isolated from 48 stool samples (Adeleye et al. 2008).

3.4 Presence of food-borne pathogens in food

Assessing the presence and level of hazards in food is an important part of risk assessment and we summarize the findings of the literature review for Nigeria in Appendix 1. The conclusion of the review is that there are very high levels of biological and other hazards in foods sold in Nigeria and that meat is particularly risky.

For example, Ukut et al. (2010) reported a high level of contamination of fresh meat from two major markets in Calabar, Nigeria. A total of 36 different bacterial isolates belonging to eight genera were detected. A study on beef found *Salmonella* serovars present at 2-8% (Orji et al. 2005), while a more recent study found 11% of beef samples were contaminated with *Salmonella* spp. (Okono et al. 2010). As summarized in the appendix, poultry, fish, dairy products, soups and prepared foods are also frequently highly contaminated.

As a generality, those studies that look for hazards in food in Africa find them (Grace et al. 2008). However, it is often difficult to interpret and compare the studies as in many cases presence of pathogens is reported rather than concentration; and where concentration is given this is not related to national or international standards.

Moreover, while contaminated food is always a hazard, the risk to human health depends on the risk-enhancing and risk-reducing processes and practices along the 'point of sale' to 'point of consumption' risk pathway. For example, in parts of East Africa raw milk is highly contaminated with *Brucella* pathogens but because the practice of boiling milk is almost universal, the risk to consumers is low (Grace et al. 2008).

In the past, food regulation and inspection were mainly based on the level of pathogens in food. It is increasingly realised that this is a blunt approach and that assessing the risk to human health is much more constructive and useful. An important concept from risk analysis is that there is no such thing as 'zero risk' and because risk reduction has costs there is an 'appropriate level of protection' which society is willing to support. For example, when the nutrition of many poor consumers is dependent on cheap food and the livelihoods of many poor producers are dependent on marketing animals, it may be unrealistic to demand highly costly standards of food safety.

3.5 Slaughter and processing

The abattoir environment and slaughtering processes play vital roles in determining the wholesomeness and safety of meat. Unhygienic practices in abattoirs and during post-process handling are associated with potential health risk to consumers due to the presence of pathogens in meat and environmental contamination (Abdullahi et al. 2006). Abattoir operations generate large quantities of waste which constitutes a major source of environmental pollution. Improper management of water is responsible for pollution of water bodies with an increased risk of water-borne disease in humans. Working in abattoirs can also result in occupational disease and injury.

3.5.1 Inadequate infrastructure and bad hygienic practices

Many slaughterhouses in Nigeria are characterized by lack of potable water, proper waste disposal facilities, and sanitary inspectors (Okoli et al. 2006). Essential infrastructure and equipment are generally lacking. There is inadequate maintenance and surfaces and equipment are damaged and dirty. One study found 15-27% prevalence of *Salmonella* spp. on slaughtering tables, washing basins, butchering knives and workers' hands (Amaechi and Ezeronye 2006).

There is typically no separation between clean and dirty areas and no practice of systems such as Hazard Analysis Critical Control Point (HACCP) which can reduce hazards. Animals are often slaughtered and eviscerated on the floor because of the absence of mechanical or manual hoists. This is a major source of contamination (Adeyemo et al. 2009). According to the report of Adeyemo (2002), meat safety and environmental sanitation measures at Bodija (Ibadan) abattoir are grossly inadequate thereby giving room for contamination and exposure of humans to pathogens. Animals are slaughtered and processed amidst heaps of waste materials such as bones and rumen contents accumulated from previous operations (Okoli et al. 2006).

Veterinary inspection is often inadequate. At Bodija (Ibadan) abattoir, ante-mortem examination of animals to be slaughtered is not conducted. Animals are led straight to the slaughter slab after off-loading from the truck. Post-mortem examination is inadequate, perfunctory, limited to a very few number of carcasses, and often restricted to the offal and some lymph nodes.

In most cases, water for meat processing is obtained from the same source to which animal wastes have been discharged. Awoseyi (2000) isolated *Escherichia coli* (55%), *Klebsiella* spp. (20%), *Pseudomonas aeruginosa* (7.5%) and *Proteus* spp*.* (7.5%) from well water used for processing of carcasses at Bodija (Ibadan) Municipal abattoir.

The abattoir attracts wild and domestic carnivores, rodents, flies and other insects that serve as vectors of diseases transmission to humans. Meat transport and storage facilities are inadequate and unhygienic.

A study conducted on a comparative assessment of the Lagos State old and new abattoir sections (with better slaughter facilities) using a score-card designed by the South African Directorate of Veterinary Services showed the new abattoir section which is mechanized with modern facilities for meat processing, preservation and transportation had significantly better hygiene and management practices (Akano 2007).

3.5.2 Lack of trained personnel

In Nigeria, most butchers are poor and have not received occupational training; there is no compensation if meat is condemned and butchers may strongly and even violently resist condemnation of diseased and unwholesome meat (Okoli et al. 2006). It has been observed that abattoir workers engaged in unhygienic practices which directly put consumers of meat at risk (Cadmus et al. 2008). For example, in the study in Ibadan, it was reported that butchers would put fresh blood on old meat to make the meat appear fresh.

3.5.3 Proximity of meat market to slaughterhouse

Most meat is sold in outdoor markets close to slaughterhouses. Meat-sellers are often inadequately and poorly dressed (Okoli et al. 2006). The humid tropical environment encourages the breeding of flies which swarm and perch on meat displayed for sale, form a major nuisance at these markets and aid in the spread of disease agents of significant public health importance (Okoli et al. 2006).

3.5.4 Hazards in cattle at time of slaughter

Cadmus et al. (2008) reported that 1.5% of cattle slaughtered at Oko-Oba abattoir, Lagos carried one or more diseases of public health importance. *Salmonella* spp. is one of the leading causes of food-borne gastroenteritis. Olayemi et al. (1979) isolated *Salmonella* from 4.0% of total specimens examined [gall bladder (6.9%), rectal swab (3.2%) and small intestine (1.3%)] at the Sabon Gari abattoir in Zaria. Ojo (2007) reported contamination of meat at Bodija (Ibadan) municipal abattoir and meat markets by TEC O157. The organism was found more in the offal than in muscle. Processing and consumption of offal were indicated to be risk factors for infection with *E. coli* O157 (Ojo 2007).

3.5.5 Environmental pollution

Abattoirs and slaughterhouses are major sources of water and air pollution worldwide. Inadequate disposal technologies and high cost of waste management are responsible for the build-up of waste with adverse impact on the environment (Adeyemi and Adeyemo 2007).

Water pollution

Many abattoirs in Nigeria discharge their effluent directly into streams or land which drains into surface water and leached into underground water (Adesemoye et al. 2006). In Rivers State, Nigeria, most abattoirs and slaughter slabs discharge the entire blood and gastrointestinal contents of slaughtered animals into nearby rivers (Aniebo et al. 2009). Important physico-chemical parameters of water quality such as pH, conductivity, total dissolved oxygen, temperature, total suspended solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, ammonia, heavy metals and nitrate are far above the recommended values (Sangodoyin and Agbawhe 1992; Ojo 2006; Osibanjo and Adie 2007; Omole and Longe 2008). Water is also contaminated by bacterial pathogens such as *Clostridium perfringens, Bacillus* spp., *Pseudomonas* spp., *Micrococcus* spp., *Vibrio* spp., *Lactobacillus* spp. and fungi including *Aspergillus* spp., *Mucor* spp., *Saccharomyces* spp., *Penicillium* spp., and *Fusarium* spp. (Adesemoye et al. 2006).

Studies have shown that wells within abattoir vicinity were more contaminated by enteric bacterial than those outside the abattoir vicinity (Akoleowo 2002; Olokede 2005; Ojo 2006). Bacterial contaminants found in water collected from wells located around abattoirs were similar to those found in effluents generated from abattoir activities (Akoleowo 2002; Olokede 2005). These microorganisms include *Klebsiella* spp., *Pseudomonas* spp., *Proteus* spp., *Enterobacter* spp., *Escherichia coli,* as well as streptococci and staphylococci (Akoleowo 2002; Olokede 2005).

Solid waste pollution

In Bodija (Ibadan) municipal abattoir, the main waste disposal practice is dumping at a site which has piled up to form a refuse hill (Adeyemi and Adeyemo 2007). This system is unsustainable, environmentally unfriendly and makes the meat processed and offered for public consumption unwholesome (Adeyemi and Adeyemo 2007; Ukut et al. 2010).

Nwanta et al. (2010) studied the environment and public health implications of unhygienic sanitary condition at the abattoir and its environs as a consequence of poor waste disposal and management in Nsukka, Nigeria. A total of 194 kg of solid (rumen/stomach) wastes was generated daily without any clearly defined system of disposal and management. Microbiological testing showed that *E. coli, Bacillus* sp. and *Staphylococcus* sp. were most frequently isolated, followed by *Streptococcus* sp., *Salmonella* sp. and *Campylobacter* sp*.*

Urban pollution
Abattoir activities and management have direct and indirect impacts on the environment and the health of people living within the vicinity of the abattoir. Nearby residents consider the abattoir a nuisance, objecting to build-up of waste which include dung, bone and blood and pollution of surface and underground water. According to Bello and Oyedemi (2009), 66 different organisms belonging to seven genera of public health importance were detected in wells that supply water for domestic use in the abattoir neighbourhood. Flies and insects vectors of diseases such as mosquitoes were numerous in the neighbourhood. Burning of bones and hooves produced smoke which constituted air pollution. Bad odour from the abattoir led to impairment of air quality, limited outdoor recreation by children, prevented opening of windows facing the abattoir, affected breathing and caused respiratory ailments. The movement of cattle on the streets within residential areas caused traffic build-up. There was elevated level of headache, excessive coughing, shortness of breath, heartburn, diarrhoea/dysentery, general body weakness, fever and typhoid fever among residents in the abattoir vicinity (Bello and Oyedemi 2009).

3.5.6 Animal welfare

Observations made at animal control posts and subsequently at various slaughter points in Imo State, Nigeria showed that the welfare of animals destined for trade was not considered an important factor during their transportation (Okoli et al. 2006). Carcasses of cattle that died of suffocation during transit can sometimes be seen in lorries (Okoli et al. 2006). A large proportion of animals brought for slaughter at Nigerian abattoirs undergo stress due to rough handling during transportation and at slaughter (Okoli et al. 2006; Sanusi et al. 2007; Adeyemo et al. 2009).

3.6 Specific food associated diseases

There are around 200 food-associated diseases but a much smaller number is responsible for substantive sickness and death (Perry and Grace 2009). While disease may be the result of biological or chemical hazards, the great majority of the health burden is due to biological hazards and this review will focus on these.

Biological hazards

- Neglected zoonoses: tuberculosis, brucellosis, leptospirosis, anthrax, Rift Valley fever
- Food-borne disease: campylobacteriosis, cryptosporidiosis, cystic echinococcosis

Chemical hazards

- Intoxications: pesticides
- Antibiotic resistance

3.6.1 Tuberculosis

Importance: Tuberculosis (TB) is a chronic contagious debilitating disease cause by infection with certain species of acid-fast bacteria belonging to the genus *Mycobacterium.* In most cases, the lungs are affected (pulmonary TB); but extra-pulmonary disease is also possible. Tuberculosis is one of the most important infectious diseases in the world and is the leading cause of death due to a single infectious agent among adults (Cosivi et al. 2008). Nigeria has the world's fourth largest tuberculosis burden with more than 460,000 estimated new cases in 2007 (USAID 2010). In Nigeria, a prevalence of 9.2% has been reported with a case fatality rate of 12% (Salami et al. 2002; Salami et al. 2003).

Aetiology: The great majority of cases are probably due to the non-zoonotic bacterium *M. tuberculosis* but an unknown proportion is zoonotic tuberculosis due to *Mycobacterium bovis* of cattle origin. Tuberculosis in humans due to *M. bovis* is both clinically and pathologically indistinguishable from cases caused by *M. tuberculosis* (Wedlock et al. 2002) and is often under-diagnosed. However, *M. bovis* is more often associated with extra-pulmonary tuberculosis.

Transmission: Infected cattle shed *M. bovis* in sputum and in faeces (as a result of swallowing sputum) so direct contact with infected cattle is hazardous. Occasionally mammary glands are infected and raw milk or dairy products are important sources of infection. The pathogen is rarely present in muscle meat, but organs may be infected and if food is eaten raw this is another possible transmission route.

Prevalence in Nigeria in people: Studies dating from the 1970s and 1980s report the proportion of TB due to *M. bovis* was 10% in northern states and 4% in Lagos (Mawak et al. 2006). More recently, Cadmus et al. (2006) reported 5% in Ibadan and Mawak et al. (2006) found an incidence of 15% in the Jos Plateau. A study by Abubakar et al. (2005) found 20% of herders and 26% of cattle were culture positive for *Mycobacterium* sp. which was also cultured from milk samples from lactating cows and unpasteurized milk sold for human consumption; this is suggestive of zoonotic TB. Adesokan (2008) also reported the isolation of *M. bovis, M. tuberculosis* and other unclassified *Mycobacterium* species from livestock in cattle traders and livestock workers at Akinyele cattle market and Bodija Municipal Abattoir, Ibadan. The age groups most affected were between 20 – 59 years.

Prevalence in Nigeria in cattle: In a survey of bovine tuberculosis in the derived guinea savanna and Sahel savanna zones, Atsanda (2006) reported an overall prevalence of 10.2% in cattle older than 2 years. Ayanwale (1984) reporting on prevalence in Lagos, Oyo and Ogun States in southern Nigeria between 1977 and 1984 found a prevalence 13% and 18% respectively. In Ondo State, Akingbade (2002) reported a prevalence of 1.6% between 1991 and 2002; this was higher than the 0.6% reported in 1984 in the same area. *Mycobacteria* pathogens have also been isolated in fresh milk (*nono*) (Shalin 1989).

Infection with *M. bovis* has also been confirmed in cattle slaughtered in abattoirs in Nigeria (Cadmus et al. 2004; Cadmus et al. 2008). Infected cattle can transmit *M. bovis* to other species of food animals reared together. Cadmus et al. (2009) detected *M. bovis* and *M. tuberculosis* in goats suggesting transmission of bovine and human tuberculosis from the primary hosts to goats.

3.6.2 Brucellosis

Importance: Brucellosis or undulant fever is a chronic disease characterized by headache, recurrent or continuous fever, sweating, joint pain, joint swelling, general body malaise or backache. Worldwide, brucellosis remains a major disease in humans and domesticated animals (Corbel 1997). In cattle it causes abortions, reproductive problems and lowered productivity and is a major impediment to trade. Prevention of human brucellosis depends on the control of the disease in animals (Corbel 1997).

Aetiology: Four species of *Brucella* can cause disease in humans: *Brucella melitensis, B. abortus, B. suis and B. canis. Brucella abortus* is the predominant species in cattle in Nigeria (Corbel 1997). According to Ocholi et al. (2004), all 25 isolates of *Brucella* spp. from aborted foetuses, hygroma fluids, milk and vaginal swabs obtained from aborting cattle, sheep, goats, pigs, and horses in Nigeria belonged to one species, *Brucella abortus* biovar 1. *Brucella melitensis* as well as *B. sius* have also been reported but at a lower prevalence (Corbel 1997).

Transmission: Contact transmission may occur when broken skin contacts freshly killed meat, or when mucous membranes, such as lips, nose or conjunctiva of the eye, are contaminated with aerosols or droplets of animal tissue fluids. Infection by ingestion may occur by drinking raw milk, or eating undercooked meat and dairy products (cheese) from infected animals. In a slaughterhouse, nail biting and eating or smoking with hands contaminated by animal fluids are the main sources of infection by ingestion. Airborne transmission may occur when aerosols containing *Brucella* organisms are inhaled. Higher antibody titres are found among occupationally exposed people, including cattle herdsmen, abattoir workers and veterinarians, than the general population (Alausa and Awoseyi 1976; Alausa 1977).

Prevalence in Nigeria in people: Over 55% of humans examined in different parts of Western Nigeria have positive *Brucella abortus* antibodies in their sera (Alausa and Awoseyi 1976) and Cadmus et al. (2006) also reported an infectious rate of 63.3% among butchers. However, it should be pointed out that infection does not necessarily result in clinical disease. Among prisoners in Sokoto, Nigeria the prevalence was 7% (Junaidu et al. 2008). Among patients with acute febrile illness, the sero-prevalence of *Brucella* infection was 7.6% in Makurdi Nigeria. Most of the infections (77.2%) were caused by *Brucella abortus* while the rest were *by Brucella mellitensis*. According to the authors, other hospital studies show sero-prevalences varying from 6-28%.

The incidence and level of human infection are significantly higher among the northern population than those living in the west (Alausa 1977). The differences are related to many factors, including the number of cattle per head of population, the rate of active infection in the cattle herd, the system of animal husbandry and imported bovine infection from neighbouring countries (Alausa 1977).

Abattoir workers, butchers, livestock and livestock product handlers are more affected ($P<0.05$) than other occupational groups (Ofukwu et al. 2008). In another study by Cadmus et al. (2006), brucellosis was found to be endemic among slaughtered cattle at the abattoir making it a source of occupational hazard to abattoir workers. Using Rose Bengal Test, 5.8% of cattle, 0.86% of goat and 63.3% of butchers were positive for *Brucella* infection. Most of the butchers screened complained of symptoms consistent with those of brucellosis which often are similar to those of malaria and therefore may be misdiagnosed. High incidence of brucellosis among butchers was suggested to be associated with poor state of meat inspection services and unhealthy practices by the butchers. Non-wearing of protective clothing and constant contact with infected materials are some of the identified risk factors responsible for high incidence of brucella infection among butchers.

Prevalence in Nigeria in cattle: Numerous studies have shown that brucellosis is endemic in Nigerian cattle at prevalences varying from 0.2 to 80% (Cadmus et al. 2006; Esuruoso 1974; Falade 2002; Okoh 1980; Chukwu 1987; Ajogi et al. 1998; Ishola et al. 2001). Onunkwo et al. (2003) reported a seasonal variation of the disease with 3% incidence in the rainy season as against 1% in the dry season. Most of these studies are based on serological diagnosis (such as Rose Bengal test, Plate agglutinating test and ELISA).

3.6.3 Leptospirosis

Importance: Leptospirosis is a contagious disease of animals and humans caused by the spirochaete *Leptospira.* In humans, leptospirosis can cause headaches, fever, chills, sweats and myalgia. Other symptoms may include lethargy, aching joints and long periods of sickness. Some highly pathogenic serovars may cause pulmonary haemorrhaging and death. While mild type leptospirosis is probably the most common form of infection, the disease can sometimes be acute. Leptospirosis is of increasing importance as an occupational disease as intensive farming practices become more widely adopted. Veterinarians, farmers, abattoir workers and meat inspectors are at particularly increased risk of infection from contact with contaminated urine. Leptospires can survive long periods in water, soil and mud. The spread of pathogenic leptospires can contaminate the environment and pose increased public health risks.

Aetiology: There are around 20 species of leptospires. The primary hosts are wild mammals (mainly rodents) although farm animals can act as reservoir hosts for some strains transmissible to humans.

Transmission: In many cases, infection occurs through mucosal contact with water or soil contaminated with the urine of infected animals. Consumption of improperly cooked kidney may thus constitute a risk of leptospiral transmission from carrier animals to humans.

Prevalence in Nigeria in people: In Plateau State, Nigeria, antibodies to leptospiral organisms were detected in 18% human volunteers sampled (Ezeh et al. 1991). Abattoir workers were particularly at risk with a prevalence of 30%. Serological examination of sera from human volunteers in Enugu and environs in eastern Nigeria showed that leptospiral antibody titres of 1:100 and above were present in 89 (13.5%) of total 661 sera samples (Onyemelukwe 1993). Coal miners were most at risk with a prevalence rate of 41 (46%), followed by the butchers/abattoir workers 26 (29.2%), farmers 18 (20.2%) and hospital laboratory personnel 4 (4.5%) (Onyemelukwe 1993).

Prevalence in Nigeria in cattle: Diallo and Dennis (1982) isolated leptospiral strains from 6.4% of bovine kidneys of cattle in Zaria, Nigeria. Agunloye (2002) evaluated the prevalence of leptospiral antibodies in sheep and goats by the microscopic agglutination test (MAT) using a total of seven leptospiral serovars. Of 575 animals tested, 17.7% were positive to leptospira by the MAT. The prevalence in sheep and goats was 23.5% and 13.1%, respectively. The highest reacting leptospira in both species was *L. pomona* with a rate of 25.9%. This was followed by *L. icterohaemorhagiae* (17.9%) and *L. autumnalis* (17.0%), respectively.

3.6.4 Other food associated neglected zoooses

Cystic echinococcosis

Cystic echinococcosis is a condition of livestock and humans that arises from eating infective eggs of the tapeworm *Echinococcus granulosus*. Dogs are the definitive hosts for this parasite, with livestock acting as intermediate hosts and humans as aberrant intermediate hosts. The outcome of infection in livestock and humans is cyst development in the liver, lungs or other organ system. Sheep and goats are the most common intermediate hosts but cattle strains also occur.

Numerous studies have been conducted in Nigeria to assess prevalence in bovine carcases; estimates range from 4-26%. Studies based on abattoir records show prevalences of less than 1% indicating inadequate inspection for this readily detectable disease.

Rift Valley fever (RVF)

RVF is mainly spread by mosquitos but infection can also occur by contacting fresh tissues or body fluids from an infected animal. There are many reports of abattoir workers becoming infected with RVF after contact with infected tissues. Home slaughter was also a risk factor in the recent outbreak in East Africa. No outbreaks have occurred in urban consumer populations. RVF is widespread in both livestock and people in Nigeria; most infections are sub-clinical. Sero-surveys have reported prevalences of 10% in cattle and 15% in people.

Q fever

Q fever is a zoonotic disease caused by *Coxiella burnetii*. Cattle, sheep and goats are the primary reservoirs of *C. burnetii*. Organisms are excreted in milk, urine and faeces of infected animals. Most importantly, during birth the organisms are shed in high numbers within the amniotic fluids and the placenta. The organisms are resistant to heat, drying and many common disinfectants. These features enable the bacteria to survive for long periods in the environment. Infection of humans usually occurs by inhalation of these organisms from air that contains air-borne barnyard dust contaminated by dried placental material, birth fluids and excreta of infected herd animals. Humans are often very susceptible to the disease and very few organisms may be required to cause infection. A sero-survey in Nigeria reported 11% prevalence in cattle (Addo and Schnurenberger 1977).

Anthrax

Anthrax is endemic in sub-Saharan Africa. It is highly lethal to ruminants but in humans the most typical manifestation is skin lesions (malignant pustule). However, if spores are inhaled death may result. All parts of the carcass of an anthrax victim may be infective. An earlier study found 5% of carcass swabs from cattle and 10-20% of blood samples from slaughterhouse workers were positive and 6-30% of these workers also had malignant pustules (Okolo 1985).

Campylobacteriosis

Campylobacteriosis is a leading cause of gastroenteritis in humans and animals all over the world. *Campylobacter* spp. is widely distributed among animal populations (especially poultry) and human infection can occur following transmission from animal reservoirs through consumption of contaminated food substances. *Campylobacter enteritis* is endemic in Nigeria as in most other developing countries of the world (Adegbola et al. 1990). Prevalence of *Campylobacter enteritis* ranges from 0.5% to 19.2% in different parts of Nigeria (Coker et al. 1994; Samuel et al. 2002; Adekunle et al. 2009). A correlation was observed among the common biotypes and serogroups of *Campylobacter* isolates from human and animal origins in Nigeria suggesting a possible animal-to-human route of infection (Adegbola et al. 1990). *Campylobacter coli* was established as a cause of diarrhoea in children in Nigeria (Adekunle et al. 2009). Cattle have been identified as a likely source of *Campylobacter* infection in humans (Elegbe 1983).

3.7 Gender and food safety

Food is a gendered commodity and in Nigeria, men and women typically have very different roles in livestock production and processing with implications for food safety. Both men and women are more likely to rear smaller animals like goats and chickens, while men focus more upon larger animals like cattle and sheep. Women have some authority on decision-making for selling, slaughtering, consuming or control over income, especially over animals they rear. There are also notable differences between the north and south (Olowoye et al. 2006).

A study in Ibadan looked at the role of men and women. Slaughtering cattle and dressing the carcass is considered an exclusively male occupation. Selling of meat and offal is done by both men and women, with men predominating in meat retail. Women are solely responsible for fetching of water. Women also have a predominant role in the cooking and selling of street food and a major role in preparation of food within the household. These different roles and responsibilities have implications for creation and management of risk (Grace et al. 2008).

3.8 Conclusion on food-borne diseases in people in Nigeria

Our review suggests that the general public is at high risk of contracting food-borne pathogens through the consumption of contaminated animal products, and people working closely with animals are at even greater risk of exposure. However, because the number of consumers of meat is much greater than the number of people working closely with animals and their products, the greatest burden of health is borne by consumers.

Prevention of many food-borne zoonotic infections in humans can best be achieved by reducing the infection rates in animal reservoirs. Epidemiological surveillance and periodic monitoring provide good understanding of the dynamics of food-borne pathogens in animal populations and help in the assessment of the factors that contribute to the distribution and persistence of the pathogens in animals as well as their transmission to humans.

However, it appears that the slaughterhouse is a critical control point at which massive contamination occurs and diseased animals are not effectively identified. Adherence to hygienic principles during food processing, storage, marketing and preparation as part of the measures to promote good health and prevent the transmission of pathogens from animals to humans cannot be over-emphasized. Training of abattoir workers should be accompanied by provision of adequate and functional facilities that will limit meat contamination during processing, storage and transportation.

Because of the enormity of the problem and the scarcity of resources, risk-based approaches are strongly recommended. These help prioritize interventions so the most important hazards are tackled first. Risk-targeting allows identification of operations and practices that create most risk.

Education and public awareness programs are important measures in sensitizing the general public and people at risk and the greatest improvements of meat hygiene have been deman- led, following on from public outrage over inadequate facilities. These are essential strategies to forestall outbreaks of food-borne infection and limit the spread of infection should outbreak occur.

For this sub-theme an alternative tabular format has also been used to present some of the key findings organized in terms of the name of the disease, method of identifying the sick, any risk factors identified, method of laboratory test, and the prevalence or incidence of the disease (Appendix 1).

CHAPTER 4

4. Survey of key pathogens in beef

This section draws from literature and assembles evidence from a survey of the beef value chain on presence and prevalence of two major hazards, *Salmonella* spp. and TEC. The results show that only 20% of meat samples had acceptable quality, that is, absence of hazards.

4.1 Materials and methods

4.1.1 Mapping the beef supply chain

Expert opinion was used to map the supply chain for beef passing from abattoirs to consumers. We estimated that the majority of meat is sold at the meat markets adjacent to the slaughterhouse and most beef is consumed in the home as shown in Figure 2.

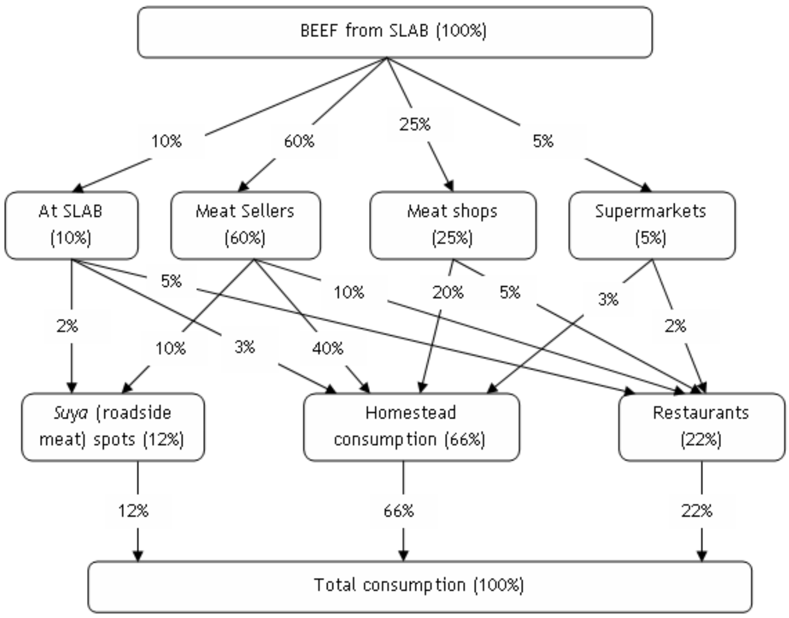

Figure 2: Provisional beef supply chain in Nigeria.

A rapid assessment of meat value chain was conducted at major abattoirs at Ibadan, Kaduna, Enugu and Abuja using structured questionnaire (according to the protocols in Appendix 2) and microbiological analysis done to determine hazards and cost of illness. A questionnaire was administered to a total of 400 respondents including slaughterhouse workers, butchers and consumers. Two hundred meat samples were collected for analysis, 100 each from Enugu and Abuja (Ibadan and Kaduna having been covered in a previous ILRI study) from abattoirs, meat sellers, meat shops, restaurants and consumers.

4.1.2 Study sites and population of interest

The two locations selected purposively for meat samples were Enugu and Abuja. Two abattoirs (Ogbete and 82 Division) were visited in Enugu State. 82 Division is located along Abakpa-Nike road while Ogbete is along Ogbete market road. In both abattoirs, live cattle are purchased from all the northern states and transported to Garki cattle market which serves as the source of cattle for the two abattoirs. An average of 20 cattle are slaughtered in 82 Division, while in Ogbete 30 are slaughtered daily. The abattoir in Ogbete is enclosed with a covered roof, while that of 82 Division is an open space. The floor of the abattoirs is made of concrete and cattle dung is usually deposited near the slaughterhouse. The water used is clean and a veterinary inspection team is also present to monitor activities in the slaughterhouse. We estimated 220 meat sellers were present in Ogbete market and around 100 in 82 Division. Systematic sampling was used to select 15 and 10 meat sellers respectively from the two abattoirs.

In Kaduna, Kawo abattoir is located along U'Dusa-Kawo road, Kawo in Kaduna State. Cattle are usually brought from neighbouring states (Katsina, Bauchi and Kaduna). The abattoir is an open space with a concrete floor. On average, about 20 cattle are slaughtered daily. The sources of water are borehole and tap. Cattle dung is deposited very close to the abattoir, with the drainage blocked. The abattoir is located about 200 metres away from the meat market. About 150 meat sellers were estimated to be present in Kawo market. Systematic sampling procedure was employed to select 25 meat sellers sampled in the market.

4.1.3 Collection of samples

A total of 200 meat samples weighing 50 grams each were collected from meat sellers in Enugu and Abuja, Nigeria (Tables 3 and 4). In Enugu, 31 fresh beef and 6 intestine samples were collected from 82 Division's abattoir in the morning between 0800 and 1100 hours. In the evening between 1600 and 1800 hours, 55 fresh beef and 6 intestine samples were collected from Ogbete market. Two ready-to-eat meat samples including one sample of barbecued meat (*suya*) from a vendor in the street of Independence layout and one sample of fried meat from a hawker within the 82 Division abattoir were also collected. In Abuja, 21 fresh beef and 16 intestine samples were collected from Karu abattoir between 0800 and 0900 hours.

Table 3: Selection of meat samples

Source of meat	Abuja	Enugu	Total
Karu abattoir	37	0	35
Karu market	25	0	25
Meat shop	2	0	2
Nyanyan market	25	0	25
Barrack abattoir	0	38	38
Ogbete market	0	61	61
Street	11	1	1
Total	100	100	200

Table 4: Meat sample collection at Abuja and Enugu

Sample type	Enugu	Abuja	Total sample by type
Fresh beef	86	58	144
Intestine	11	31	42
Barbecued meat(*suya*)	2	8	10
Fried beef	1	3	4
Total	100	100	200

Fourteen fresh beef and 11 intestine samples were also collected from Karu market between 0930 and 1100 hours. Between 1530 and 1730 hours, 21 fresh beef and 4 intestine samples were collected from Nyanyan market. Two fresh beef samples were collected from two meat shops within Garki area of Abuja. In addition, ready-to-eat meat including eight barbecued meat and three fried meat samples were collected from street meat vendors in the Garki area.

Sampling was done aseptically. Only one sample was collected from an individual meat seller. Each seller was asked to directly put the meat sample into a sterile sample container. The samples were properly labelled and preserved in a cooler with ice packs during transportation to the laboratory for microbiological analysis.

4.1.4 Isolation and enumeration of *Escherichia coli* and *Salmonella* spp. from meat samples

Isolation of *E. coli* O157

Ten grams of each meat sample were weighed and homogenized in 90 ml of sterile distilled water. One millilitre of the homogenate was inoculated into sterile tryptic soy broth (TSB) (Oxoid, Basingstoke, UK) for pre-enrichment. The TSB culture was incubated at 37°C for four hours. From the TSB culture, 1 ml was inoculated into 9 ml of modified TSB (mTSB, Oxoid, Basingstoke, UK) supplemented with novobiocin (0.01mg/ml) for selective enrichment. The mTSB culture was incubated at 37°C for 18 hours. With 1 ml of the mTSB culture, a tenfold one-in-ten serial dilution was made in sterile distilled water. One millilitre from dilution 10^{-7} was transferred into a sterile disposable Petri dish. Twenty millilitres of molten BCIG-sorbitol MacConkey agar (Oxoid, Basingstoke, UK) (prepared according to the manufacturer's instructions) supplemented with cefixime ($5x10^{-5}$/ml) and potassium tellurite (0.0025/ml) was poured into the Petri dish containing the diluted broth culture. The Petri dish was swirled for mixing, the agar left to solidify and incubated at 37°C for 18 hours. After incubation, straw coloured colonies on the plate presumptively identified as those of *E. coli* O157 were counted using a Coulter colony counter. Five of the identified colonies were tested biochemically using a biochemical test kit for oxidase-negative Gram-negative bacteria (Microbact GNB 24E®, Oxoid, Basingstoke, UK) for confirmation of *E. coli*. Isolates that showed characteristics consistent with those of *E. coli* were identified serologically by latex agglutination test using dryspot *E. coli* O157 latex test kit (DR0120M, Oxoid, Basingstoke, UK).

Isolation of *Salmonella* spp. from meat

Salmonella organisms are very fragile organisms. To diminish the risk of obtaining false negative results, non-selective pre-enrichment of meat samples was carried out. Also, a combination of two selective enrichments and plating on two selective media was performed as follows:

Day 1: Non-selective enrichment: Ten grams of each meat sample were weighed out using a weighing balance. The samples were transferred into a sterile mortar and homogenized in sterile distilled water at a ratio of 10 g of meat in 90 ml of sterile distilled water. One millilitre of homogenate was then aseptically transferred into 9 ml of prepared Buffered Peptone Water in sterile universal bottles. The bottles were agitated to thoroughly mix the contents. The mixtures were then incubated at 37°C overnight (16-20 hours).

Day 2: Selective enrichment: One millilitre of the pre-enrichment broth was aseptically transferred with a pipette into aseptically prepared 10 ml tetrathionate broth. The solution was thereafter incubated at 37.0°C ± 0.5°C overnight (18-24 hours).

Day 3: Selective agar plates (Pour plate): 10 test tubes were arranged on a test tube rack, each containing 9 ml of sterile distilled water for tenfold serial dilution of the tetrathionate broth. One millilitre of enrichment tetrathionate broth was taken with a sterile pipette and dispensed into the first test tube on the rack. This made up the volume of the content of the test tube to 10 ml (i.e. a 1 in 10 dilution). The solution was mixed thoroughly but gently by shaking the test tube. One millilitre of the solution in the first test tube was also taken with a pipette and transferred into the second test tube. The solution was thoroughly mixed and 1 ml taken from it and transferred into the third test tube. The process (serial dilution) continued for 1 in 1000; 1 in 10,000; 1 in 100,000 and so on, to the tenth test tube. The 1 ml solution taken from the tenth test tube was discarded into a disinfectant solution. 0.1 ml each from the sixth test tube of the serial dilution (i.e 10^{-6}) was then transferred into sterile petri dishes. Prepared molten *Salmonella* Chromogenic agar at 45-50°C was poured into the inoculated petri dishes and mixed. The petri dishes were allowed to solidify and then incubated at 37.0°C ± 0.5°C for 48 hours.

Day 4: Sub-cultivation of Salmonella suspect colonies: Suspected colonies were identified. *Salmonella* spp. appeared as magenta coloured colonies on *Salmonella* Chromogenic agar. Suspect colonies were enumerated using a colony counter. Representatives of the suspected colonies were then picked and subcultured on Xylose Lysine Desoxycholate (XLD) agar plates. The XLD plates were incubated at 37°C for 24 hours.

Typical *Salmonella* colonies produce a slightly transparent zone of reddish colour and black centre; a pink-red zone was seen in the media surrounding the colonies in most cases. *Salmonella* growth on XLD was marked with + in the record sheets.

Day 5-7: Biochemical confirmation: Single colonies from the surface of the XLD plates were picked and streaked on MacConkey agar plates. The plates were incubated for 18 hours at 37°C and then pure cultures inoculated into two separate tubes of media [Triple Sugar Iron (TSI) agar-smeared slope and stabbed butt and Urea Broth (UB) base (with added urea solution)]. The TSI and UB tubes were incubated at 35°C. The UB tube was examined after 5 hours and 18 hours. Tubes that showed red or pink colouration were discarded (this maybe due to urea hydrolysis by *Proteus* or other organisms). Where there was no urea hydrolysis, the TSI agar tubes were examined after 18 hours and 48 hours. Most typical *Salmonella* spp. produced acid (yellow) and gas in the butt and no change or alkaline (red) in the slant.

4.1.5 Analysis

Statistical analysis was used to compare different categories, using cluster weighted Chi square test (Donner and Klar 2000) to take into account clustering of samples within markets in the two locations (Abuja and Enugu). All calculations were performed with Stata®.

4.2 Results and discussion

Laboratory analysis revealed high levels of contamination with toxigenic *E. coli* O157 and *Salmonella* spp. International guidelines are that *Salmonella* should be absent from 10 g of meat and zero tolerance for *E. coli* O157; given our analysis methodology, we conclude that any detection of *E. coli* O157 or *Salmonella* is unacceptable. (This is a conservative assumption as the sample analyZed represented 0.1 gram of meat collected). By these criteria, only 20% of samples were acceptable. This finding is compatible with other results from Nigeria cited in the literature review.

We also investigated the risk factors for presence of pathogens; Table 5 shows some comparisons. Abuja tended to have more acceptable samples than Enugu but this difference was not significant. *E. coli* O157 counts were significantly higher in samples collected in the morning but *Salmonella* counts were higher in the evening. Cooked meat was twice as likely to be free of pathogens compared to raw meat, and this was significant at $p<0.1$ despite the low power of the test. Cooking is an important risk mitigation strategy, and it was concerning to find that 60% of cooked meat samples were of unacceptable quality. This suggests that cooking is inadequate or (more likely) meat is being contaminated after cooking. Only two samples were taken from meat shops but these were of better quality; street-sold beef was also of better quality probably because it was cooked.

Interestingly, there was a slight negative correlation (-0.09: 95% confidence interval -0.22-0.05) between contamination with *E. coli* O157 and *Salmonella* spp. suggesting that the source or means of contamination are different. There were also differences in trends of the two pathogens across food matrices and time, with *Salmonella* spp. highest at the abattoir and *E. coli* O157 at point of sale in markets.

While the great majority of samples were unacceptable, the majority of contamination was clustered in a minority of samples (Figure 3). We considered samples with more than 100 colony-forming units (cfu) per gram to be high. Just 38 out of 200 respondents had high levels of *E. coli* O157 and these 19% were responsible for 81% of the *E. coli* contamination. In the case of *Salmonella*, 10% of respondents had high levels and these 20 people were responsible for 85% of the total contamination.

Table 5: Contamination of meat samples with toxigenic *E. coli* and *Salmonella* spp.

	E. coli O157 present (%)	*Salmonella* present (%)	Acceptable (%)	n
Abuja	60	33**	24	100
Enugu	65	49**	16	100
Morning	73***	32**	20	103
Evening	52***	50**	20	97
Barbecue (*suya*)	56	11	33	9
Fried meat	0	50	50	4
Fresh beef	63	43	50	144
Intestine	67	20	20	33
Cooked meat	38*	23	38*	13
Raw meat	64*	42	19*	187
Abattoir	47***	53**	21	75
Market	76***	35**	16	111
Meat shop	50***	50**	50	2
Street	42***	16**	42	12

*significant at p<0.1; **significant at p<0.05; ***significant at p<0.01

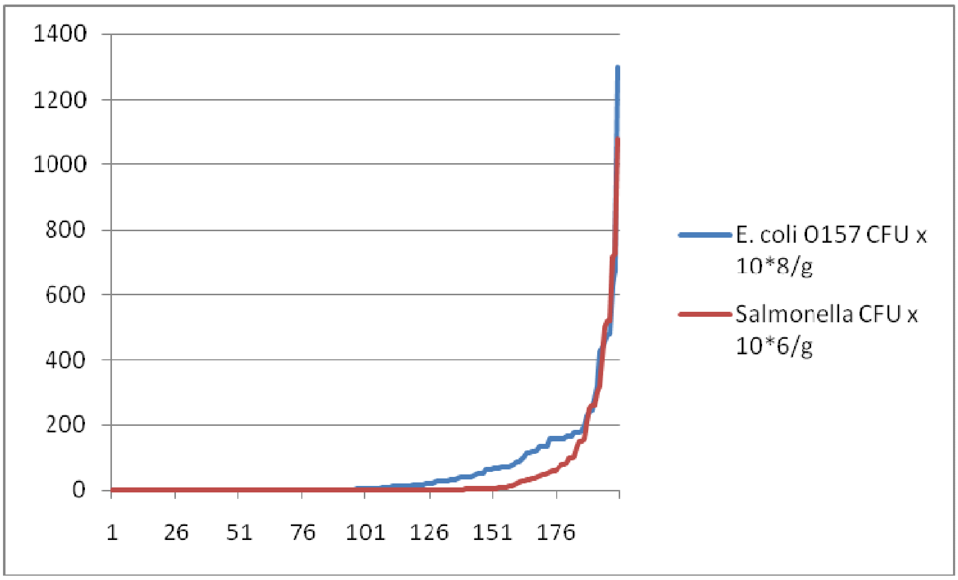

Figure 3: Bacterial counts for meat and meat products sampled in Abuja and Enugu.

Looking more closely at these 'negative deviants' we find some strongly predictive risk factors (Table 6). In the case of *E. coli* O157, being in Enugu and in one market increases risk significantly while morning samples and abbatoir samples are less likely to be contaminated. For *Salmonella*, Enugu is also high-risk, and one abbatoir is significantly more likely to be contaminated. Morning samples and abattoir samples are more likely to be highly contaminated.

Table 6: Risk factors for meat being highly contaminated by toxigenic *E. coli* and *Salmonella*

Hazard	Risk factor	Risk	P
E. coli O157	Ogbetti Market	8.55	0.000
	Enugu	8.50	0.000
	Morning sample	0.21	0.000
	Abattoir sample	0.38	0.007
	Karu market	0.00	0.010
	Nyanan market	0.00	0.010
	Karu abattoir	0.38	0.061
Salmonella	Barrack abattoir	14.21	0.000
	Enugu	12.00	0.002
	Abattoir sample	5.56	0.002
	Morning sample	3.14	0.058
	Karu abattoir	0.00	0.076

One of the most important insights offered by risk-based management is that a small proportion of the actors are responsible for a large proportion of risk. With risk-based management, data and expertise are marshalled to pinpoint where along the production, distribution and handling chains there is the greatest potential for contamination and other problems. This allows appropriate amounts of resources and attention to be directed those high-risk areas and increases the chances of catching problems before they turn into widespread outbreaks.

4.3 Conclusion and policy implications

This study found the majority of meat sampled contained unacceptable levels of one or both of the important pathogens surveyed (toxigenic *E. coli* and *Salmonella* spp.). It suggested that the dynamics of the two pathogens are different and further investigation would be needed to understand this and identify critical control points. Meat at the abattoir was highly contaminated and this is obviously a critical point for preventing contamination down the chain. Cooking is considered an important risk mitigating strategy, but although it halved the risk of contamination, levels of pathogens were still unacceptably high (60%). An important finding was that a relatively small proportion of actors generated the majority of risk. This makes a risk-targeted strategy attractive where, by identifying the chains and actors where there is greatest potential for contamination, scarce resources can be allocated to where they will have most impact.

CHAPTER 5

5. Socio-economic aspects of beef safety

This chapter consists of two case studies: one was drawn from a recently completed project by ILRI on meat-associated disease in Ibadan and the other from the rapid assessment carried out for the present study.

5.1 Case study 1: Determinants of meat quality in Bodija market, Ibadan and relation between meat microbiological quality and food safety outcomes

5.1.1 Introduction

Many studies have documented a high level of hazards in meat sold in wet-markets in Nigeria. However, there is much less information on the knowledge, attitudes and practices (KAP) around meat safety; the gender and social determinants of meat safety; or the relation between hazards in meat and health outcomes in consumers of meat. This case study attempts to address these gaps.

5.1.2 Materials and methods

Study site: The study took place in Bodija market, the main market centre in Ibadan for livestock slaughter, processing and marketing. Ibadan is the capital of Oyo state in southern Nigeria. Data were collected between August 2008 and December 2009. The study population was processors and retailers of beef in Bodija market. These are self-organized into occupational groups (butchers' associations), which were the unit of observation for the participatory and qualitative studies. We identified 16 associations in the market and then randomly selected 201 meat processors/retailers from the list of members. In order to obtain more information on women workers, we subsequently randomly selected an additional 61 women. This brought the total sample size to 262.

Data analysis: Qualitative methods consisted of focus group discussions held with four women's groups and four men's groups and six in-depth interviews with two sets of key informants: leaders of processing and marketing groups (4 men, 2 women) and government officials (1 man, 4 women). Interview guides were prepared. Participatory Appraisal tools used in the qualitative studies included community mapping to show spatial features; Venn diagrams to illustrate social organization patterns; and Problem Tree Analysis to allow groups to describe their perspectives regarding the causes and consequences of conditions.

Quantitative methods consisted of KAP questionnaires combined with checklists administered to 262 meat processors (n=201 men and 61 women). Knowledge was assessed through 18 questions about food safety; attitude was assessed through a 30-item Likert scale; and practices through 12 questions about self-reported behaviour plus direct observation. Respondents were also asked about meat consumption and illness in the previous two weeks.

A cross-sectional survey was carried out to assess meat bacteriological quality and presence of certain food-borne zoonoses (n=200 meat samples). Standard bacteriological methods were used to assess total aerobic counts, enterobacteriaceae counts and coliform counts. In addition we investigated the presence of five important zoonoses (*Escherichia coli, Salmonella* spp*., Listeria monocytogenes, Staphylococcus aureus* and *Yersinia* spp.) and eight bacteria associated with environmental contamination also associated with diarrhoea.

Statistical analysis: Comparisons between continuous variables used the cluster-adjusted t-test and between categorical variables the cluster-adjusted chi-square test. Intra-cluster correlations were used to compare how similar members of a group were to each other as compared to non-members. Univariate analysis was used to investigate the relation between putative risk factors and self-reported gastrointestinal illness in the previous two weeks. Based on the univariate analysis and a causal diagram, we developed a logistic regression model to explore the relation between socio-economic factors and gastrointestinal illness. We used case-wise deletion in the case of incomplete data and robust standard errors with clustering on association. All statistical calculations were with STATA 10®.

5.1.3 Results

Characterization of meat processing and selling in Bodija market

Cattle, small ruminants and pigs are slaughtered, processed and sold at Bodija market. This study focused on cattle. Around 250-300 cattle are slaughtered daily; more are slaughtered on weekends and fewer during Muslim holidays. Most butchers slaughter only one animal a day (participants estimate 75-90% of butchers fall in this category); butchers sell to retailers who have small kiosks in a different part of the market and sell directly to consumers (Figure 2). More rarely, a household buys an entire carcass for a ceremony: this only happens on weekends. Retailers are also mostly small-scale, typically buying a quarter of a carcass. A few have specialized by supplying boneless beef to hotels and fast food establishments or to institutions such as the University College Hospital, Ibadan. Most butchers consider themselves poor: they don't have money to buy an animal for slaughtering and obtain it on credit.

Cattle are held in pens then moved to the slaughter slab. They are tied down at the slab and killed by cutting the throat. The dead cattle are then dragged on the ground to the abattoir area. This is a shed with a concrete floor and open sides. Processing, that is skinning, removal of the intestines and quartering, is done on the floor. Portions of the carcass are then carried to the adjacent butchers' stalls where they are sold. All parts of the animal have potential uses. Muscle meat and offal are sold for food. Bones are used to make bone meal for animal consumption as well as in the production of serving plates. The skin is used to make leather for bags, shoes and boxes or eaten. Horn is processed into buttons and decorations and can also be used for incantations. Hooves are used in the manufacture of buttons, while the teeth are soaked in water and used for treating people who have problems with their own teeth. The bile is swallowed raw by people in the belief it will strengthen them. Urine is used in treating convulsions in children. Blood is processed into blood meal used as animal feed. Gut contents and faeces are used for fertilizer. However, for the last four by-products (urine, bile, faeces and gut contents) supply exceeds demand and the greater part is piled as waste or allowed to run into gutters.

The abattoir is under municipal management and officers collect tax and tariffs on each cow amounting US$ 1 per animal. The role of environmental sanitary officers is to inspect slaughter slabs and the general environment and ensure the area is clean. However, the filthy conditions of the market witness the challenges they face in carrying out their work. The veterinary department is supposed to check animals before slaughtering and inspect meat after slaughter, but many animals escape inspection and even when problems are found veterinarians find it difficult to ensure condemned meat is discarded. Most butchers kill only one animal a day, and if this is condemned by veterinarians as unfit for human consumption they lose their entire days earnings. Hence, they strongly resist attempts to condemn meat.

Socio-demographic and institutional characterization of processing and selling meat

Meat processing and retailing was the main livelihood strategy with around two-thirds of respondents reporting it as their only source of income. Both men and women are involved in beef processing and retailing, but among flesh processors (butchers), men predominate. Most processors/retailers had received had at least some primary education (men more than women). These data are summarized in Table 7.

Table 7: Socio-demographic characteristics of men and women butchers

	Women	Men	
Age	39 years	34 years	0.014
Muslim religion	83.9%	90.6%	ns
Yoruba ethnicity	98.4	96.6%	ns
Single	19.0	11.1	ns
No formal education	38.3%	10.1%	0.000
Secondary or above	6.8%	8.1%	ns
Other sources of income	34.9	33.5	Ns
Involved in trade	28.6	16.5	0.04

The qualitative study allowed a broad characterization how collective action and gender influenced work. The butchers' associations include the slaughterers who kill and section the animal but also cattle owners, marketers of live animals, those who bring the cattle to the slaughter slab, leg sellers, skin sellers, head sellers, offal sellers and meat sellers. Although self-organized, the associations are structured with executive members, regular meetings, registered names and linkages to other associations as well as to 'umbrella' organizations. Many of the associations have existed for over 25 years. Membership varies from around 20 to above 60. There are male only, female only and mixed associations. Most of the activities of processing and sale can be carried out by men or women. However, slaughtering of cattle is an exclusively male role and fetching water an exclusively female activity.

The butchers' associations provide opportunities for apprenticeship and financial and social support, and represent members in interactions with officials and other associations. They have rules and regulations but these are essentially aimed at maintaining harmony among members rather than standard-setting e.g. *"Members must not steal from each other and members must not take each other's wife, except after divorce."*

Group membership is important for processors and retailers with 87% of men and 98% of women reporting regular attendance of meetings. Around one-fifth (22% men, 18% women) were committee members. Respondents belonged to other groups as well as butchers' associations. Women belonged to an average of 1.6 savings groups, significantly more than men. However, male members of savings groups contributed significantly more money per week than women (US$ 19.2 versus US$ 11.2: p=0.005).

Determinants of meat quality

Most meat samples showed unacceptably high levels of aerobic bacteria, enterobacteriaceae and/or coliforms (98% of samples). Zoonotic pathogens were present in 67% of samples and environmental contaminants in 46%.

Because meat quality was measured at the group level, but demographic characteristics and KAP at individual level, it was difficult to disentangle the relationship. While most butchers had positive attitudes towards meat safety, knowledge and practice scores were lower. Of the socio-demographic considered, gender was the strongest predictor of poor meat quality. Being of Yoruba ethnicity, single and with no formal education decreased the odds of poor meat quality but this is probably due to confounding with gender.

Knowledge and practice had weak positive correlation and attitude had a weak negative correlation with practice, suggesting a gap between what people say and what they do. Women had significantly more good practices than men (Table 8), despite there being no significant difference in knowledge and attitude.

Table 8: Comparing knowledge, attitude and practice of beef hygiene between men and women butchers

	Women	Men	Maximum score	p
Likert attitude scale	27.4	27.3	30	0.94
Knowledge scale	6.0	5.7	18	0.175
Practice scale	9.2	8.1	12	0.03

Statistical analysis suggested that group membership influenced meat quality. Endemic diseases in animals typically have an intra-cluster coefficient (ICC) of less than 0.1 (highly contagious epidemic diseases can have ICC of 0.3-0.4) (Otte and Gumm 1997). Given that food-borne pathogens and contaminants are not highly contagious between animals, the moderate to high ICC suggests that group members had greater similarity to members of the same group than to members of other groups in terms of quality (Table 2). This evidence of intra-group similarity allowed us to divide groups into 'better quality' and 'worse quality' based on differences in average bacterial counts. We considered the five groups with highest total aerobic count, enterobacteriaceae and coliforms to be 'bottom-half' quality and the five with lowest to be 'top-half' quality. Moreover, although all had overall poor quality, two were considerably worse than others (considered 'worst quality') and two were considerably better (considered 'best quality').

A significantly higher percentage of men than women belonged to a group with bottom-half quality (73% versus 53% respectively [p=0.028]). The effect was even stronger for belonging to groups with worst bacterial quality; they had 92% male and 8% female membership compared to 73% male and 27% female in other groups (p=0.007). Consistent with this, groups with the best bacterial quality were 59% male and 41% female versus 85% male and 15% female in non-belongers (p=0.001).

There was no significant difference between men and women with regards to knowledge of food safety and attitude towards food safety. However, women had significantly (p=0.03) better practice of food safety.

Self-reported illness among beef handlers
Ill health was very common among the meat handlers surveyed: 88% reported illness in the previous two weeks. Seventeen different problems were reported: the most common symptom was fever (79%) followed by backache (69%) and gastrointestinal symptoms (47%). Of these, 30% reported diarrhoea and the remainder constipation and/or vomiting. The majority of those reporting illness (89%) took medicine, suggesting most illnesses were non-trivial. Overall there was no significant difference in reported illness between women and men (89% and 87% respectively: p=0.749). However, men were significantly more likely to report backache (p=0.008) and neck pain (p=0.018) and women significantly more likely to report anorexia (p=0.021) and vomiting (0.058: marginally significant).

We investigated meat consumption as a risk factor for self-reported gastrointestinal illness. Meat consumption was high: 97% of people had eaten meat in the previous two weeks. Overall, 52% of people consumed their own products while 42% of people bought meat. The remainder either did not consume in the previous two weeks or received meat as a gift. Women were more likely to buy meat than men (30% versus 18%) and less likely to eat their own produce (14% versus 33%): these differences were significant at p=0.019 and p=0.000, respectively. Beef, offal and chicken were the meat most consumed. Women were significantly more likely to consume offal (p=0.004). They were also less likely to consume beef and chicken, although this was significant only at p=0.1.

The logistic model constructed to investigate the relation between risk factors and self-reported gastrointestinal illness showed eating beef was the strongest and most significant predictor of illness (increasing the odds of diarrhoea nine-fold (p<0.01). Belonging to a group with poor quality of meat; eating chicken; consuming one's own products; and eating offal were also strong and significant predictors of disease. Being male was protective; however, this effect was not significant when other confounding factors were taken into account.

People who belonged to groups with bottom-half quality meat were significantly more likely to have had signs of gastrointestinal illness in the previous two weeks and to have sought treatment (see Table 4). These groups had 23% additional illness compared to the groups with better quality meat.

The qualitative study showed the helplessness and total resignation of meat retailers to illness. Focus group participants considered they worked in an unhealthy environment but when asked what could be done to reduce the threat to their health, they responded that, "*Concerning diseases and illnesses, there is nothing we can do.*" The qualitative study also revealed another risky practice: although meat is usually well-cooked before consumption, retailers were sometimes observed to cut a small piece of raw meat and eat it, in order to convince the customer of the safety of their product.

5.1.4 Discussion
Our study confirms the results of many previous ones that conditions in Nigerian abattoirs and meat markets are very poor (Adeymo 2002; Cadmus et al. 2008). Food-borne infection is endemic in Nigeria. The 1997 Local Government Health System profile for Nigeria on leading causes of deaths in different zones showed diarrhoeal cases accounted for 25% followed by malaria (21%) and accidents (10%) (FAO/WHO 2002).

The level of self-reported disease from meat retailers in this study is very high. Studies from developing countries have estimated episodes of diarrhoea in adults at 0.5 to 2 per year (Walker and Black 2010). In our study, meat retailers had a rate of 7.9 episodes a year. The extremely unhygienic work conditions and the practice of eating unsold (and even raw) products may contribute to this high rate. This leads to the interesting conclusion that meat retailers may be a sentinel community for detecting food safety problems.

The importance of animal food consumption as a risk factor for diarrhoea is not surprising. In this study of beef retailers, consumption of beef was more strongly associated with illness than consumption of other meat, but again this may reflect the practice of eating unsold meat. Consumption of offal was also associated with illness, which may be due to more rapid spoilage or difficulty in cleaning. Women consumed more of the low-value offal than men who consumed more high-value muscle meat. Differential access to more expensive food is common and has been implicated in lower nutritional status of women (WHO 2008). To our knowledge, this is the first time differential access to food has been linked to higher exposure to food-borne disease.

Our study found that women were involved in all aspects of beef processing and sale apart from slaughter of animals. An earlier study in Ibadan found a similar substantial involvement by women. However, a parallel study in Kaduna in northern Nigeria found much lower involvement of women (Olawoye 2006). Women meat retailers were quite similar to their male counterparts; their lower education and higher involvement in savings groups was predictable.

Although women often have a key role in food processing, preparation and sale (Canet and N'diaye 1996), few previous studies have looked at how gender influences food safety among meat retailers. The finding that women had significantly better hygienic practice and groups with higher proportions of women had better quality meat was interesting.

People belonging to the same butchers' association had similar qualities of meat. The study also showed the importance of butchers' associations in establishing norms and in interacting with officials and other associations. This suggests that associations may be a conduit for improving food safety through increasing access to information, by helping good practices take root and in lobbying for the infrastructure essential for hygienic meat processing and sale.

Previous interventions have typically focused on municipal authorities and government officials. This study suggests that involvement of butchers' associations may be a useful complementary strategy in improving food safety. It was interesting that there were relatively few differences between men and women in their involvement with groups. Women's higher involvement in savings groups has been previously documented (Chowa 2006). African women are typically under-represented in government, parastatals and private companies (Losindilo et al. 2010). It was interesting that in these informal, self-organized associations the proportion of women in leadership posts was no different from that of men.

An important finding was the clear link established between food safety practices, food safety microbiological outcomes and level of self-reported gastrointestinal disease.

5.2 Case study 2: Knowledge, attitude and practice (KAP) of beef value chain actors in four regions of Nigeria

5.2.1 Materials and methods

A questionnaire was administered to a total of 400 respondents based on a systematic sampling proportional to the population served by abattoirs in each city as follows (Ibadan 200, Kaduna 100, Enugu 50 and Abuja 50).

Ibadan: The abattoir visited in Ibadan was Bodija market (see more in Sections 5.1.2 and 5.1.3). Systematic sampling procedure was used to obtain a total of 25 meat sellers. Three households were also interviewed per meat seller making a total of 75 households. Details of the sampling procedure are presented in Appendix 2.

Enugu: Two abattoirs (Ogbete and 82 Division) visited in Enugu State have been described in Section 4.1.2 of this report. We estimated there were 220 meat sellers at Ogbete market and around 100 in 82 Division.

Systematic sampling procedure was adopted with the selection of every fifteenth meat seller in Ogbete and every tenth in 82 Division giving 15 and 10, respectively, in both markets.

Kaduna: Kawo abattoir in Kaduna State with about 150 meat-sellers has been described in Section 4.1.2 of this report. Systematic sampling procedure was employed with the selection of every sixth meat seller to make a total of 25 meat sellers sampled in the market. Three households were also interviewed for each of the meat-sellers selected, making a total of 75 households.

Abuja: Karo abattoir is located along Old Chief Palace road, Karo in Abuja. The total number of meat sellers in Karo market was estimated to be around 125. Systematic selection of every fifth meat seller, however, gave a total of 25 required samples of meat sellers in Karo market. Also, three households per meat seller were interviewed giving a total of 75 households.

5.2.2 Results and discussion

Meat consumption

Beef was the most widely consumed meat by consumers with a weekly average consumption of 3 kg per household and 0.7 kg per capita (Table 9). This is considerably higher than the national per capita suggesting that urban customers at the sampled beef markets have high consumption levels. Household size in our survey was also somewhat higher than the national average (5 persons).

Table 9: Household consumption of different foodstuffs (kg)

	Beef	Other meat	Fish	Dairy	Vegetables	HH consumers	Beef/capita per week
Abuja	3.5	1.9	2.4	0.0	2.2	4.6	1.1
Enugu	2.7	1.5	1.8	.	1.5	5.6	0.5
Ibadan	3.2	1.4	1.5	1.0	1.9	5.0	0.7
Kaduna	2.7	0.8	1.5	1.8	1.7	7.2	0.4
Total	3.0	1.4	1.8	0.9	1.8	5.6	0.7

KAP at consumer level

Time of purchase and interval between purchase and cooking

Most consumers bought meat in the morning when temperatures were still low (Table 10). Interestingly, this pattern was reversed in Ibadan where the majority of people bought meat in the afternoon. This suggests a difference in timing of the main meal of the day (mid-day for most regions but evening for Ibadan). The very short time between buying and cooking meat (average 2.67 hours) is a powerful risk mitigation measure. Only 7.3% of consumers left meat for more than five hours before cooking and only 2.5% left meat overnight.

Table 10: Time of beef purchase and interval between purchase and cooking

	Abuja	Enugu	Ibadan	Kaduna	Total
Buy beef in morning	0.65	0.69	0.11	0.48	0.52
Cook in morning	0.21	0.32	0.01	0.49	0.24
Cook in afternoon	0.75	0.68	0.97	0.51	0.76
Cook next day	0.04	0.00	0.01	0.00	0.00
Time: buying to cooking (hrs)	3.09	2.53	3.09	1.36	2.67

Beef storage

Around three-quarters of all respondents reported storing meat in a fridge; this relatively high proportion strengthens our hypothesis (based on high household consumption of beef) that the respondents surveyed were relatively well-off. Fridge ownership was highest in Abuja (88.00%) followed by Ibadan (74.67%) with other regions equally (69.33%); the difference was significant (p=0.024). Respondents with fridges tended to keep meat longer than those without (2.8 hours versus 2.2 hours) but this was not significant when clustering was taken into account.

Beef preparation

Boiling was the most popular method for processing beef, being used by all 300 households (Table 11). The average boiling time was 32 minutes and the maximum 90 minutes; this is adequate to destroy most pathogens in meat. Frying emerged as the most risky practice; 39% of respondents used this method. Of those who did, 6% cooked for 6 minutes or less which is probably insufficient to inactivate pathogens.

Table 11: Type of beef cooking and average, minimum and maximum time for cooking

Place	Process	Use method proportion	Mean cook time (mins)	Minimum cook time	Maximum cook time
	Boil	1.00	32.27	10	90
Abuja	Fry	0.09	20.00	10	30
	Roast	-	-	-	-
	Boil	1.00	43.13	15	90
Enugu	Fry	0.41	15.06	7	60
	Roast	0.01	20.00	20	20
	Boil	1.00	22.40	10	65
Ibadan	Fry	0.48	24.72	5	35
	Roast	0.17	21.15	10	40
	Boil	1.00	43.17	10	65
Kaduna	Fry	0.57	10.81	5	15
	Roast	-	-	-	-
	Boil	1.00	35.24	10	90
	Fry	0.39	16.77	5	60
Total	Roast	0.05	21.07	10	40

Risky practices

There was a striking regional difference with risky practices only reported from Ibadan and Kaduna (Table 12). (Of course, this may represent normative bias because if people are aware a practice is risky they may choose not to report it.) Of particular concern was the high level of consumption of raw beef in Kaduna, as this may expose people to a variety of pathogens. Throwing away leftover food or feeding it directly to animals may facilitate the transmission of pathogens between humans and animals.

Table 12: Risky behaviours around meat handling by consumers

	Abuja	Enugu	Ibadan	Kaduna	Total
Eat cold leftovers	0.00	0.00	0.00	0.41	0.10
Eat leftovers reheated	1.00	1.00	0.87	1.00	0.97
Give leftovers to animals	0.00	0.00	0.13	0.12	0.06
Throw away leftovers	0.00	0.00	0.17	0.07	0.06
Eat raw beef	0.00	0.00	0.00	0.15	0.04

Beliefs around beef and beef safety

There were interesting and significant differences between regions with respect to their beliefs around beef safety. While most respondents believed that beef could cause illness (78%) only 19% reported experiencing illness after consuming beef (Table 13). There were significant differences between regions (p=0.011 and p<0.001, respectively). People are poor judges of what food was responsible for illness (Box 1).

Table 13: Consumer beliefs about the role of beef in causing illness

	Abuja	Enugu	Ibadan	Kaduna	Total
Believe beef can cause illness	80	65.33	86.67	81.33	78.33
Experienced illness after eating beef	41.33	1.33	4.05	28	18.73

Most people (96%) incorrectly believed that thorough cooking of food would render meat safe. (Though adequate cooking is a powerful risk mitigating practice, it does not inactivate all hazards: see Box 1). Another 11 respondents mentioned washing meat well and one respondent mentioned exposing meat to the sun as practices that reduce risk. Both of these are effective risk reduction practices.

Only 28% of customers considered buying from a trusted source a way of ensuring beef safety. Regional differences were highly significant ($p<0.01$); interestingly in Abuja where respondents were less likely to buy from a trusted source, they were also less likely to agree with the statement that they would complain if meat was of poor quality (Table 14).

Table 14: Strategies reported by consumers to increase beef safety

	Cook well	Buy from a trusted source	Complain if meat was of poor quality
Abuja	1.00	0.00	0.04
Enugu	0.96	0.17	0.79
Ibadan	0.97	0.53	0.43
Kaduna	0.91	0.43	0.53
Total	0.96	0.28	0.45

Most people (88%) wrongly believed that one could tell if beef is safe to eat by its appearance (Table 15). There were significant differences across regions ($p<0.01$)

Table 15: Consumer beliefs that unsafe beef can be detected by its appearance

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Abuja	1.33	92	1.33	5.33	0
Enugu	68	24	0	5.33	2.67
Ibadan	29.33	64	2.67	2.67	1.33
Kaduna	28	45.33	4	13.33	6.67
Total	31.67	56.33	2	6.67	2.67

Box 1: Common myths around food safety

Myth 1: Foodborne illness is caused by the last thing you ate
Fact: Usually diarrhoea from a contaminated food does not start until at least 4-6 hours after having eaten that food and can last for as long as three days after consumption. So if you experience diarrhoea in less than four hours of eating it is most unlikely to be that meal which made you sick as a result of "food poisoning". You need to consider the previous meal or even food you ate the day before.

Myth 2: The food which you throw up when vomiting is responsible for the illness
Fact: The food material present when you vomit is not always an indication of the food responsible for your illness. The food responsible for your illness may have been consumed a day or so before the symptoms appeared.

Myth 3: Food that makes you sick must smell or taste bad
Fact: It is a common misconception that in order to get sick from food it must look, taste or smell bad or be "off". In fact, most food poisoning bacteria do not cause foods to appear bad. The reverse situation is also true: there are some types of bacteria that will spoil food but will not make you sick if you accidentally eat it.

Myth 4: Cooking food well makes it safe
Fact: While cooking food well will kill many important pathogens, it will not deactivate all hazards. Some toxins and other hazards (e.g. antibiotic residues) survive cooking. Moreover, it is very easy for cooked food to be cross-contaminated.

Consumers are concerned with quality and safety
Most consumers (81%) have concerns about the quality and safety of meat (Table 16). Interestingly, all consumers in Abuja, Enugu and Kaduna were concerned but only 23% of those in Ibadan (p<0.01). This may reflect the effect of the presence of an ILRI project during the previous five years in Ibadan meat market and abattoir, which seems to have both improved safety of beef and confidence of consumers and beef sellers. The main concerns are the generic 'meat is of poor quality' followed by the dirtiness of the environment in which meat is sold. Other concerns (not included in the table) include flies; use of dirty water; meat source and sale of meat from female animals. Interestingly, price was only mentioned as a concern by a minority. Similarly, 81% of customers disagreed strongly or very strongly with the statement *"Customers care more about price than about quality".*

Table 16: Consumer concerns over different aspects of beef quality

Place	Concerns about meat	Quality	Dirty environment	Freshness	Dirty seller/table	Price
Abuja	1.00	0.43	0.55	0.03	0.07	0.07
Enugu	1.00	0.28	0.36	0.13	0.11	0.00
Ibadan	0.23	0.18	0.01	0.00	0.00	0.07
Kaduna	1.00	0.74	0.25	0.00	0.00	0.14
Total	0.81	0.41	0.29	0.04	0.04	0.07

Self-reported diarrhoea
In all, 27% of respondents reported a health problem in the previous two weeks and 8.6% reported having diarrhoea in the same period (Table 17). This was significantly lower in Ibadan (p=0.056).

Table 17: Consumers reporting health problems in the previous two weeks

	Health problem	Diarrhoea	Fever	Other
Abuja	0.24	0.13	0.09	0.01
Enugu	0.29	0.09	0.24	0.00
Ibadan	0.15	0.01	0.11	0.03
Kaduna	0.41	0.11	0.29	0.01
Total	0.27	0.09	0.18	0.01

Univariate analysis of the relation between the 44 risk factors and reporting diarrhoea in the previous two weeks did not reveal many significant predictors (Table 18). Those who were concerned over quality had a much lower chance of reporting illness and those who thought that price was more important than quality were much more likey to be sick.

Table 18: Risk factors that significantly influence the likelihood of reporting diarrhoea

	Odds ratio	P
Are concerned about quality	0.00	0.010
Eat leftovers cold	0.00	0.070
Ibadan	0.11	0.009
Buy in morning	2.66	0.028
Think price more important than quality	2.87	0.045
Have been sick previously	4.46	0.000

In similar studies of traditionally marketed food, we have observed that where food bought is of relatively good microbiological quality, consumer practices (e.g. washing, cooking method, hygiene, storage) have a large effect on the likeliness of reporting illness. This is because consumer behaviour is the critical factor in allowing or preventing contamination. Conversely, where consumer practice has little influence on illness, this suggests that meat is already highly contaminated at purchase and hence subsequent consumer action is less effective in reducing risk. The findings from Nigeria are consistent with the second hypothesis.

KAP of beef sellers

Characteristics of beef sellers

Beef-sellers were all male except in Ibadan where 4% where female. They had an average of 15.3 years working as a meat retailer, suggesting a stable population and that training meat-sellers is likely to be a good investment. Nearly half (48%) of started to sell beef between 0600 hours and 0700 hours and finished between 1700 hours and 1800 hours. Compared to other wet-market meat retailers, this is a long working day and will be risk enhancing. Apart from Ibadan, beef-sellers sold relatively small amounts of beef daily (Table 19).

Table 19: Descriptive characteristics of beef vendors

	Abuja	Enugu	Ibadan	Kaduna	Total
Male (proportion)	1.00	1.00	0.96	1.00	0.99
Work experience (year)	13.6	14.4	15.8	17.5	15.3
Quantity beef sold daily (kg)	28.6	91.6	279.5	47.4	779.5
Quantity unsold (kg)	9.1	1.0	2.7	4.7	4.3
Regular customers	11.7	13.2	8.8	14.9	12.2
Occasional customers	12.4	12.2	11.1	11.5	11.8

Hygiene

Ninety-six percent of the meat sellers were reported to have perfectly clean hands. However, a lower proportion (83%) was reported to have perfectly clean clothes. Ninety-one percent of the meat sellers were reported to have perfectly clean equipment whereas only 86% were reported to have perfectly clean surfaces. Given photographic evidence of poor hygiene and the low frequency of cleaning, this may reflect low standards on the part of the enumerators.

All meat sellers reported cleaning the surfaces on which meat was placed. Most (80.4%) cleaned the surfaces once a day whereas 11.8%, 6.9% and 1% cleaned the surfaces 2-5 times a day, lees than once a day and more than 5 times a day, respectively (data not shown). People working with meat should clean equipment and surfaces before, during and after handling; cleaning once a day is quite inadequate for good hygiene. The meat sellers used an average of 35.2 litres of water (range 26-44 litres) per day for cleaning (Table 20).

Table 20: Daily quantity of water used to clean utensils

Study site	Quantity of water (litres) used to clean utensils per day		
	mean	s.d.	n
Abuja	33.8	15.7	25
Enugu	26.3	6.1	27
Ibadan	43.9	52.7	21
Kaduna	39	21.2	25
All	35.22	28.26	98

Majority of meat sellers sourced their water from water tankers (41.2%) and taps (36.3%) (Table 21). However, meat sellers from Kaduna and Enugu were likely to source water from water tankers and taps, respectively. In addition, a substantial proportion of meat sellers from Abuja and Ibadan were likely to source water from boreholes relative to other study sites. Water quality is crucial to satisfactory cleaning and the lack of clean, potable tap water represents a major constraint to maintaining hygiene.

Table 21: Sources of water for the meat shops

Study site	Tap water (% of All n)	Tanker (% of All n)	Water tanker (% of All n)	Borehole (% of All n)	Well (% of All n)	Others (% of All n)	All n
Abuja	32.0	0.0	24.0	32.0	4.0	8.0	25
Enugu	55.6	14.0	18.5	0.0	11.1	0.0	27
Ibadan	28.0	0.0	52.0	20.0	0.0	0.0	25
Kaduna	28.0	0.0	72.0	0.0	0.0	0.0	25
All	36.3	3.9	41.2	12.8	3.9	2.0	102

Approximately 80% of the interviewed meat sellers reported using a cleaning agent (Table 22). Majority (77%), however, used a detergent compared to either a bar soap (5%) or a bleaching agent (1%) (Table 22). Adequate cleaning is not possible without a soap and detergent, and cleaning without disinfection will not reduce pathogen loads. Of the agents mentioned, only bleach is a disinfectant.

Table 22: Use of cleaning agents

	Use cleaning agent		Use bar soap		Use bleach		Detergent		Other agent	
Study site	n	% yes	n	% yes	n	% yes	n	% yes	n	% yes
Abuja	25	80	25	0	25	0	25	72	25	0
Enugu	27	89	26	4	26	0	26	88	26	4
Ibadan	25	76	25	4	25	4	25	72	25	16
Kaduna	25	76	25	12	25	0	25	76	25	0
All	102	80	101	5	101	1	101	77	101	5

Cooking methods

The meat-sellers' cooking methods were very similar to those of the consumers in the same regions. However, meat sellers were more likely to fry or roast beef (Table 23). Also, whereas 6% of consumers cooked meat for a dangerously short time, only 3.5% of meat sellers did so.

Table 23: Meat-sellers' methods of processing meat they eat themselves

Place	Process	Proportion	Mean cook time (min)	Minimum cook time (min)	Maximum cook time (min)
	Boil	0.96	25.3	15	40
	Fry	0.20	12.6	5	25
Abuja	Roast	0.04	30.0	30	30
	Boil	1.00	42.4	20	60
	Fry	0.67	18.6	10	60
Enugu	Roast	0.11	18.3	5	30
	Boil	1.00	27.4	15	45
	Fry	0.84	24.5	15	40
Ibadan	Roast	0.40	22.0	10	30
	Boil	1.00	36.1	10	60
	Fry	0.57	15.9	5	30
Kaduna	Roast	0.00	na	na	na
	Boil	0.99	33.0	10	60
	Fry	0.57	19.6	5	60
Total	Roast	0.14	21.8	5	30

One risky practice, which was reported by a worryingly high 11% of beef-sellers was consuming raw beef. Qualitative studies in Ibadan suggested that butchers did this as a way of convincing customers that the beef being marketed was safe to eat.

Self-reported illness

An overall average of 40% of the interviewed meat-sellers reported a health problem during the previous two weeks with the overall difference with those who did not have a health problem across all study sites borderline insignificant (p=0.07) (Table 24). This proportion was relatively higher in Kaduna (75%) relative to other study sites. For these health problems, 22%, 58% and 11% of all respondents, respectively, reported diarrhoeic symptoms, fever and other problems. None of the respondents (n=8) from Enugu reported having diarrhoea. The difference between respondents who reported and who did not report diarrhoea and other symptoms was statistically significant (p<0.0001). However, the difference between respondents who reported and who did not report fever was not significant (p<0.23).

The higher prevalence of reported diarrhoea in meat-sellers than consumers suggests that the former are a high-risk group because of poor working conditions and risky practices such as tasting raw meat and eating unsold products.

Table 24: Meat sellers reporting diarrhoea and other health problems in the preceding two weeks

	Any health problem		Diarrhoea		Fever		Other health problems	
Location	n	% yes	n	% yes	n	% yes	n	% yes
Abuja	22	55	20	35	20	60	20	5
Enugu	27	26	8	0	8	88	8	13
Ibadan	25	12	2	50	4	50	4	0
Kaduna	24	75	4	16	25	48	25	16
All	98	41	13	22.8	57	58	57	11

Overall, 68% of the respondents reported that it was possible to get sick from consuming beef from each study site, with the difference who reported in the negative being significant ($p<0.0003$). The difference between respondents who sought treatment for diarrhoea and those who did not was not significant ($p=1.000$).

Beliefs around consumer behaviour and beef safety
A majority (56%) of beef-sellers strongly or very strongly agreed with the statement that *'customers care about price more than quality'*. This is interesting given that 81% of customers strongly or very strongly disagreed with this statement. There were significant regional differences with beef-sellers in Ibadan most likely to agree strongly and those in Enugu most likely to disagree strongly.

The great majority (95%) of butchers agreed or agreed strongly that *'you can tell beef is safe to eat by looking at it'* and almost as many (92%) agreed or agreed strongly that *'customers will complain if there is a problem with beef'*.

5.2.3 Conclusions

Case study 1
In Nigeria, butchers' associations have an important role in the meat value chain. Members have some education and, for most, meat processing is their primary occupation. Slaughter, processing and sale of beef take place under unhygienic conditions and meat sold by association members is of unacceptable quality. However, some groups have consistently better quality meat and this is positively correlated with the proportion of women members. Given the two-week period previous to the interview as recall time, 85% of meat sellers reported illness and 47% reported gastrointestinal illness. Eating beef; eating chicken; eating offal; consuming one's own products; and belonging to a group with poor quality of meat were all strong and significant predictors of self-reported gastrointestinal illness.

The study shows the importance of butchers' associations and suggests they may be good entry points for interventions to improve food safety. It also finds that even under the difficult conditions of Bodija market, some groups can achieve better food safety and better health outcomes. This study shows a clear relation between meat of poor microbiological quality and higher incidence of gastrointestinal disease (23% more illness in groups with poor quality meat).

Self-organized groups play an important role in slaughtering, process and sale of meat in Bodija market, Ibadan, Nigeria. Slaughtering cattle is only carried out by men but women are involved in all other aspects of processing and sale although men dominate most activities. There is little difference in women's socio-economic characteristics and group involvement compared to men; however, they do have better hygienic practice and better hygienic outcomes in terms of meat safety. Environmental conditions are very poor and meat quality low; however, some groups do obtain/have better quality meat and these also report less illness.

Case study 2
Risky practices were reported by a minority of consumers but have potentially large impacts on health (eating cold left-overs; frying for less than seven minutes; giving left-overs to animals; eating raw meat). False beliefs were common, for example, 88% of people believed that one can tell unsafe beef by its appearance and 96% that cooking beef makes it safe. Most customers (81%) are concerned about the meat they buy (especially hygiene and quality) and 81% disagreed with the statement that customers cared more about low price than quality. Consumers who have concerns about safety report much less illness, and those who believe price is more important than quality have much more. This study showed marked and significant differences between regions implying food safety interventions should be targeted for regions.

Risky practices of beef sellers include: selling meat over a long period; retaining meat for sale the following day; tasting raw meat; inadequate washing of surfaces; and negligible use of disinfectants. Beef-sellers report more diarrhoea than customers, suggesting they are an at-risk group but also providing an incentive for changing behaviour. There are belief asymmetries with most beef sellers agreeing that *'price is more important* *than quality to consumers'* but most consumers disagreeing and 92% of beef-sellers believing customers will complain if there are problems with beef but only 45% of customers agreeing.

CHAPTER 6

6. Risk assessment

This section assesses human health impacts associated with the hazards identified, models risk pathways and assesses effects of processes e.g. temperature, time, cross-contamination along the pathway on decreasing or increasing risk. An assessment of the appropriate level of protection (ALOP) is also presented.

6.1 Objectives

1. Estimate the risk of illness associated with the consumption of beef contaminated with *E. coli* O157:H7 and identify factors that are likely to modify this risk.
2. Estimate the risk of illness associated with the consumption of beef contaminated with *Salmonella* and identify factors that are likely to modify this risk.

6.2 Materials and methods

A quantitative risk assessment approach was adopted to address the stated objectives. The approach was based on the model been suggested by the Food and Agricultural Organization of the United Nations (FAO) through its Codex Alimentarius Commission. The hazards of interest in this study were *E. coli* O157:H7 and infectious strains of *Salmonella*. The hazard characterization is discussed in a different report. The focus in this report is on the exposure assessment and the risk characterization steps. Parameters used in the analysis were obtained from two sources: our own data and the literature.

6.3 Conceptual framework

The conceptual framework for the approach consists of a traditional scenario delineating the pathway by which these two food-borne pathogens are likely to move from the sources to the susceptible host. The scenario is shown in Figure 4.

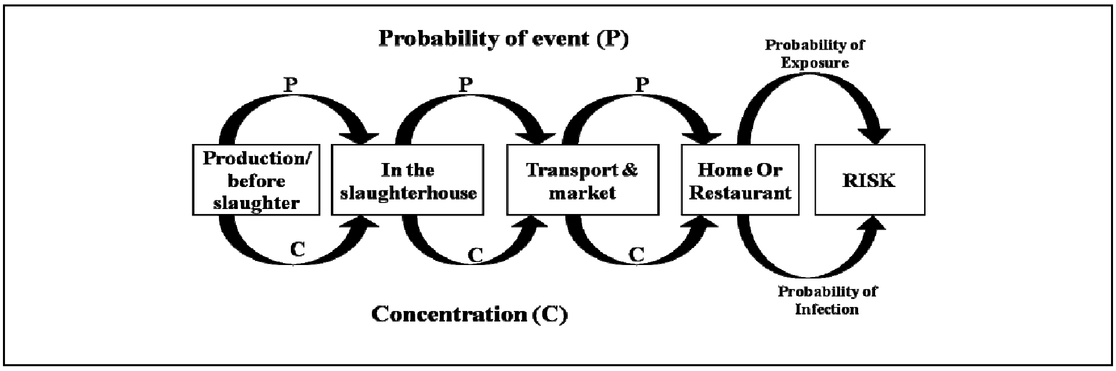

Figure 4: Hypothesised scenario pathway by which the target population would be at risk from pathogens.

We hypothesized that events would take place before humans would be at risk of the pathogens, as follows:

- The animal will be presented to the slaughter slabs with certain bacterial (initiating event) infection probability that equals to the prevalence of shedding (P_s). Animals infected with a particular pathogen would shed the organism at a concentration of C_s colony-forming units per gram (cfu/g).

- At the second event, the animal would go through several processing steps inside the slaughter slab and different beef cuts would be produced. These cuts would be contaminated with a particular pathogen at a proportion of P_p. The concentration of a respective pathogen in those meat cuts would increase by the ratio of increase between the shedding rate prior to slaughter (P_s) and detection rate post-processing (P_p).

- The meat cuts would be transported to the market (third event). The meat would go through several stages of handling before being sold to a restaurant/food-stand or a household. At the market, the meat would be contaminated with a respective pathogen and that contamination rate would equal to the detection rate (P_m). The concentration of the particular pathogen in the meat at the market would change at the ratio of the change in the detection rate between the slaughter-slab and the market.

- From the market, the meat cut would go either to the restaurant or to the household (fourth event). The meat would be roasted and this cooking process is likely to reduce the bacterial load on the meat. The contamination rate on the roasted beef (P_r) would equal to the detection rate of the pathogen on samples collected from this type of food. The reduction ratio would be equal to the ratio between the detection of the pathogen in the meat at the market and on the roasted beef (P_m:P_r).

- Consumers would be exposed to the pathogen through the consumption of contaminated roast beef. The probability of illness would be a function of the amount of beef consumed (D) or the individual exposed to the pathogen and the susceptibility of the host (r). This probability of illness is computed through the risk characterization process which captures the likelihood of the presence and concentration of the respective pathogen as well as the susceptibility of the host.

6.4 Exposure assessment for E. coli O157:H7 and Salmonella spp.

Prevalence of *E. coli* and *Salmonella* in cattle faeces (P_s)

There were no data provided on the prevalence of shedding of pathogens in slaughtered cattle in Nigeria. However data from around the world suggested a shedding rate between 5 and 9 % for *E. coli*; a report by Smith et al. (2009) indicated a prevalence of 15% for all *Salmonella* spp. We decided to use an estimate of 7% and 12% respectively in a stochastic distribution (Beta-binomial) which allows us to incorporate the prior absence of data (Table 25).

Concentration of *E. coli* and *Salmonella* per gram

Data are lacking on the concentration of shedding of *pathogens* in faeces. However, most of the acceptable detection techniques, i.e. immune-magnetic separation and polymerase chain reaction techniques have a limit of detection of 5 cfu. Since this pathogen is detected by either of these techniques, we assumed that that the minimum concentration that could be in the faeces is the limit of detection. We modelled this uncertainty using the Log-normal Distribution with mean of 5 cfu and standard deviation of 5 cfu (Table 25).

Prevalence of *E. coli* and *Salmonella* in meat samples after processing

We initially hoped to capture the dynamics of contamination of meat within the slaughter slabs. However, obtaining relevant data was a challenge. We used data from the survey that was carried out in this project to capture the potential variability in the contamination of meat after evisceration of the carcass and modelled this variability using the Beta Distribution (Table 25).

Changes in the concentration of *E. coli* and *Salmonella* after processing

Data on the concentration of *pathogens* on the carcass after processing were not available. We assumed that the changes in the concentration would be proportional to the change in the detection rate. The final concentration on the processed meat was then obtained by adjusting the concentration in faeces by a factor that was equal to the ratio of detection rate between meat and faeces ($F_{s\text{-}f}$) (Table 25).

Detection of *E. coli* O157:H7 and *Salmonella* at the market

Data on the occurrence of *pathogens* (P_m) in samples collected at the meat market were obtained from the survey. The survey reported that *E. coli* were detected in 73% of the samples and *Salmonella* in 36%. We assumed that the distribution follows the Beta-Binomial with the parameters being equal to the number of positive samples and the total number of samples that were examined (Table 25).

Change in bacterial load between the slaughter slab and the market
Many factors play a role in the number of cfu/g during transportation of the meat from the slaughter slab to the market. These factors include handling methods, storage temperature and time to market. Data on the number of organisms per gram of meat in samples collected from the market and the factors that play role were lacking. As a proxy, we assumed that the increase in the number of cfu is directly correlated with the increase in the detection rate. A change factor in the number of cfu was computed as the ratio between the detection rate at the market and the slaughter slab after evisceration (P_m/P_s). To compute the expected number of cfu/g the concentration of the pathogen g^{-1} was multiplied by this factor ($F_{s\text{-}m}$) (Table 25).

Detection of *E. coli* in roasted meat at the restaurant
Estimates of the bacterial load on the roast beef were obtained from the study by Dahiru et al. (2008) which was conducted in Kano city, Nigeria. They were able to detect *E. coli* in 38 out 150 roast beef samples. Since we did not have similar data in our survey we opted to use the estimate from the study by Dahiru et al. (2008) and model the uncertainty in the estimate (P_r) using the Beta-Binomial distribution (Table 25). We assumed that the similar detection rate would be at the household level. We also assumed that the sanitary practices at the restaurant and the households were similar; therefore, the contamination level is the same.

Changes in bacterial load between the market and the restaurant
Many factors could play role in influencing the bacterial load on meat between the market and the restaurant or the household. The change factor (F_r) was estimated as the ratio between the detection rate at the market and the rate after preparing the meat by roasting (P_r/P_m) (Table 25). In the situation where data are lacking, we assume that this change factor is the best proxy.

Table 25: The variables and parameters, and their distributions used in the analysis

Variable	Parameter	Distribution	Source
Prevalence of EC in faeces (Ps)	0.07	Beta(7 +1, 100 – 7 + 1)	(Omisakin et al. 2003)
Prevalence of Salm in faeces	0.12		(Smith et al. 2009)
Concentration in beef (Pc)	5[a]	Lognormal(5, 5)	(Omisakin et al. 2003)
Final concentration in faeces (cfu/g)	Ps x Cs		
Prevalence of EC on carcass (Pc) after evisceration	0.45	Beta(24 +1, 53– 24 + 1)	Survey
Prevalence of Salm on carcass (Pc) after evisceration	0.57	Beta(30 +1, 53– 30 + 1)	Survey
Change factor—meat cut and faeces (Fs-f)	(Pc/Ps)		
Detection of EC at the market (Pm)	0.73	Beta(67 +1, 92– 67 + 1)	Survey
Detection of EC at the market (Pm)	0.36	Beta(33 +1, 92– 33 + 1)	Survey
Change factor—market and meat cut (Fm-s)	(Pm/Ps)		
Detection of Pathogens at the restaurant (Pr)	0.25	Beta(38 +1, 150– 38 + 1)	(Dahiru et al. 2008)
Amount of meat consumed			
Restaurant g/day/10	571	Pert(114, 571, 4286)	
Household g/day/10	429	Pert(71, 429, 2571)	Survey
Probability of illness (EC)			
Female (Pdf)	0.26	Beta(48 +1, 186– 48 + 1)	Survey
Male (Pdm)	0.30	Beta(34 +1, 114– 34 + 1)	
Probability of illness (Salm)			
Female (Pdf)	0.11	Beta(11 +1, 100– 11 + 1)	Survey
Male (Pdm)	0.30	Beta(34 +1, 114– 34 + 1)	
Dose-response model			
Susceptibility for female rFi	0.0027	Exponential-single hit	Survey
Susceptibility for male rMi	0.0049		
Dose-response model			
Susceptibility for female rFi	0.0011	Exponential-single hit	Survey
Susceptibility for male rMi	0.0017		

a: Conservative estimate because the study was carried out in a different country

Amount of meat consumed at the restaurant and at household

The distribution of the serving size of beef was estimated from the survey per household and at the restaurant. We assumed that the household consists of on the average six members and the party at the restaurant also consists of six members. Because the estimates obtained from the survey were kg/week per household, the final estimate of serving per person per day in grams was computed (Table 25). The data were provided for both females and males. The consumption of beef in grams per day per member enabled us to capture the variability among members using the Pert Distribution because the data did not appear to be normally distributed and we had the parameters to fit the Pert Distribution (Table 25).

6.5 Dose response model

Model

Several dose-response models for *E. coli* O157:H7 exist in the literature. We chose to use the commonly used single-hit model, where the probability of illness is the function of the average number of viable infectious units in the serving of food ingested (D) and the susceptibility factor (r). The model is described as follows:

$$P_i = 1 - (1 - r)^{D}$$

Where

P_i : probability of infection

r : Host-organism interaction, probability of infection from a single cell (susceptibility)

D : The ingested dose of *E. coli* or *Salmonella*

In this single-hit model, the assumption is made that each organism in the ingested dose has a distinct probability of surviving all defence barriers in the host and reaching a target site to establish colonization. The value ***r*** captures the interaction between the infectious organism and the host. In our study, we estimated *r* from the probability of illness that was provided through the survey and the dose as computed from the data.

Probability of illness

Estimates for the probability of illness were obtained from the survey conducted as part of this project. Data on the number of patients that were diagnosed with diarrhoea attributed to *pathogens* were provided by gender. To capture the potential variability in the population, we modelled that data using the Beta-Binomial Distribution by gender (Table 25).

Estimate of susceptibility (r)

In order to estimate the value of **r** from the data collected in the survey, we used the probability of illness in the report for each gender. In the computation of ***r,*** we took into account the variability of the service size per individual per day (Table 25). Since we had the probability of infection/illness from the survey and the dose, we solved for $\mathbf{r}_i$ for each gender (Table 25).

6.6 Risk characterization

In the risk characterization step, we integrated the data on exposure together with dose-response relationship to compute and estimate the risk of illness in each scenario stratified by gender. The numbers of cfu/g in each dose were estimated through the exposure assessment step.

Model simulations and scenario analyses

A simulation of inputs in the model was performed using the @Risk® software (Palisade Software, Newfield, NY, USA) and the simulation was performed using Latin Hypercube sampling. The rationale for using the Latin Hypercube sampling was that this method uses stratified sampling capturing the spectrum of variability among variables. Such a method offers coverage of the variability and produces a more reliable estimate of the relevant variable/factor. Inputs in the model are described in Table 25. The model resulted in a number of output distributions which were used to predict the daily risk of illness following the consumption of *E. coli*

O157:H7 or *Salmonella* contaminated beef samples. Several scenarios were evaluated using the same approach. The scenarios that are considered in this analysis are: (1) the risk of illness for a healthy female due to exposure at either a food-stand/restaurant or at the household; (2) the risk of illness for an immunocompromised female due to exposure at either a food-stand/restaurant or at the household; (3) the risk of illness for a healthy male due to exposure at either a food-stand/restaurant or at the household; (4) the risk of illness for an immunocompromised male due to exposure at either a food-stand/restaurant or at the household.

Sensitivity analysis
Sensitivity analysis was performed to identify the impact of several inputs on the outcomes using the *"if-scenario"* approach. The rationale was to assess the impact of the uncertainty of some of the parameters in the risk of illness from *pathogens* due to the consumption of contaminated beef. This was accomplished by rank order correlation analysis because it makes no assumptions about the relationship of the composite of the distributions used. In some instances, it is illustrated by the use of tornado charts, where the longer bars have the greatest impact on the model's output.

6.7 Results and discussions

The amount of *E. coli* and *Salmonella* that a consumer in Nigeria is exposed to in a serving per day was computed as a function of the original number of cfu/g in the faeces of animal presented at the slaughter slabs and the subsequent effects of handling during transportation to market/retail stands and cooking. Estimates for the probability of sickness under two scenarios where the bacterial load in the faeces was 5 and 3 cfu/g are shown in Table 26. The impact of the change in the initial load on the probability of illness is shown in Figures 5 and 6. As one would expect, the concentration of the cfu/g drops along the events in the pathway under the scenario where the initial bacterial load in the faeces is at the lower level of 3 cfu/g.

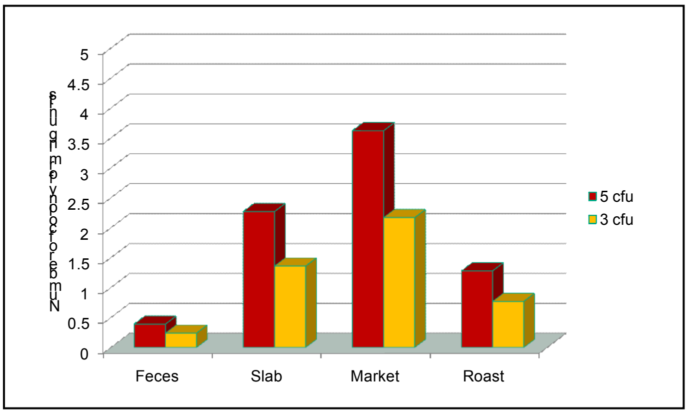

Figure 5: The impact of the initial bacterial load on the concentration of *E. coli* in subsequent events.

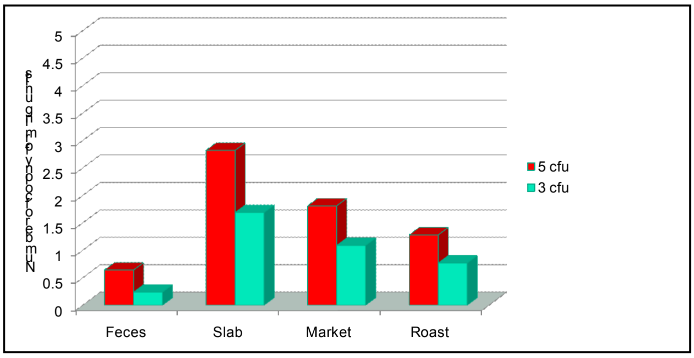

Figure 6: The impact of the initial bacterial load on the concentration of *Salmonella* in subsequent events.

Using the assumptions described above, the probability of illness for females and males who are healthy or immunocompromised was estimated from the model. Estimates were obtained using the Latin Hypercube sampling with initial seed chosen randomly.

Risk of illness for females

The mean risk (probability) of illness from eating beef contaminated with *E. coli* O157:H7 or *Salmonella* for a healthy female eating roast beef at a restaurant was 0.28 and 0.09, respectively, with a relatively large variability. Although the mean risk of illness was relatively high, one should note that the distribution of the probability of illness was skewed. Five percent of the healthy female population would have a probability of illness from *E. coli* that was higher than 66% and only 1 % of the same population would have a probability of illness equal to or higher than 62% from the consumption of beef were contaminated with *Salmonella*. The mean probability was high because of the few extremely higher risk values, as apparent in the long tail in the relative frequency distribution shown in Figure 7. It appears that the risk of illness for a female at household was lower than the risk of eating at the restaurant, perhaps due to better hygiene in the household. Also, one of the factors that were significantly associated with the risk of illness was the efficiency of reduction in the bacterial load attributed to food preparation (roasting). We assume that household cooks are aware of the risks of eating contaminated beef and hence, roasting is more efficient. Another speculative explanation is that meat in the restaurant would be stored in relatively poor conditions that support the growth of bacteria and the concentration would increase. We did not have enough data on the length and temperature of storage to perform the analysis in support of this speculation.

Our analysis showed that the risk of illness for immunocompromised females is significantly higher in comparison to healthy females; three times higher (0.86/0.38) in the case of *E. coli* and seven times higher (0.61/0.09) in the case of *Salmonella*. There was no difference in the risk illness between eating at the restaurant and at the house for immunocompromised women. In our simulation, we assumed that the immunocompromised individuals were 10 times more susceptible than the healthy individuals.

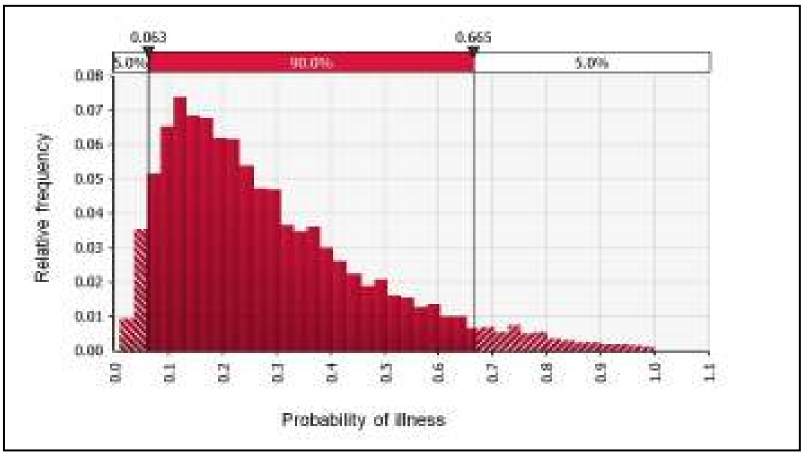

Figure 7: Relative frequency of the probability of illness among females who are exposed at the restaurant.

Figure 8 shows the relative frequency distribution of the probability of illness among the female immunocompromised population which is skewed to the right. Ninety percent of the population will have a probability of illness greater than 48% and the median risk was 93%. The majority of the patients who are afflicted with an immunocompromised condition are at a very high risk of experiencing illness from the consumption of beef that is contaminated with *E. coli*. There is no surprise here because this finding, in addition to being expected, is consistent with the findings in the literature. However, as seen in Figure 8, a small proportion, less than 5%, would have a risk of illness of less than 0.48. One speculative explanation for the reason in the difference in the risk is the role of education among this minority of individuals who are health conscious.

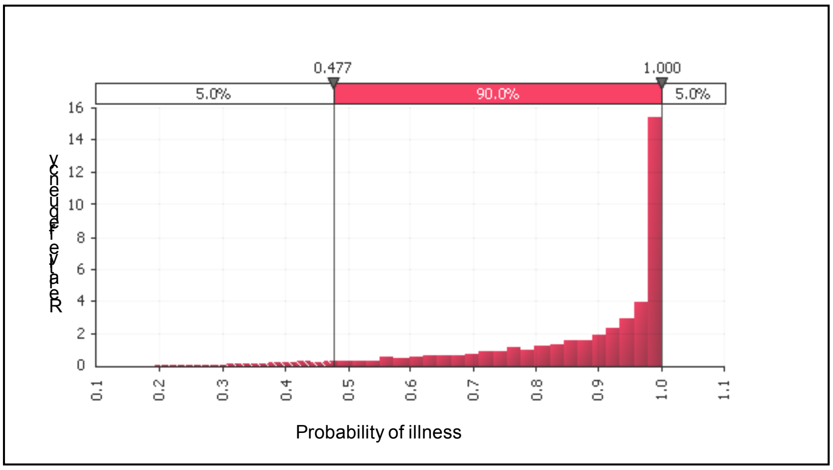

Figure 8: Relative frequency of the probability of illness among immunocompromised females exposed at the restaurant.

Table 26: The probability of illness from the consumption of beef contaminated with *E. coli* O157:H7 under different scenarios

	Probability of illness per day (S.D.) 5 cfu		Probability of illness per day (S.D.) 3 cfu		Probability of illness per day (S.D.) less beef	
	Healthy	IC	Healthy	IC	Healthy	IC
Risk of illness for female at the restaurant	0.28 (0.19)	0.86 (0.17)	0.19 (0.14)	0.75 (0.22)	0.007 (.009)	0.07 (0.08)
Probability of illness for female at the household	0.24 (023)	0.86 (0.17)	0.17 (0.19)	0.62 (0.3)	0.005 (.006)	0.05 (0.05)
Risk of illness for male at the restaurant	0.44 (0.30)	0.89 (0.19)	0.33 (0.27)	0.82 (0.24)	0.013 (.017)	0.12 (0.12)
Risk of illness for male at the household	0.32 (0.20)	0.89 (0.16)	0.22 (016)	0.79 (0.21)	0.009 (.010)	0.09 (0.9)
Increase efficiency of roasting by 10-time—r reduction in cfu/g						
Risk of illness for female at the restaurant	0.14 (0.12)	0.64 (0.24)	0.09 (0.08)	0.50 (0.24)	0.001 (.002)	0.07 (0.08)
Risk of illness for female at the household	0.13 (0.15)	0.53 (0.31)	0.08 (0.11)	0.42 (0.29)	0.001 (.001)	0.07 (0.08)
Risk of illness for male at the restaurant	0.26 (0.24)	0.75 (0.27	0.18 (0.19)	0.64 (0.30)	0.003 (.004)	0.12 (0.12)
Risk of illness for male at the household	0.16 (0.13)	0.69 (0.24)	0.10 (0.09)	0.55 (0.25)	0.002 (.003)	0.09 (0.9)

IC: immunocompromised; SD: standard deviation

Table 27: The probability of illness from the consumption of beef contaminated with *Salmonella* under different scenarios

	Probability of illness per day (range & median) 5 cfu		Probability of illness per day (range & median) 3 cfu		Probability of illness per day (range & median) less beef	
	Healthy	IC	Healthy	IC	Healthy	IC
Risk of illness for female at the restaurant	0.09 ($1.1x10^{-3}$ – 0.99)	0.61 (0.01- 1.0)	0.04 ($3x10^{-4}$ – 0.92)	0.43 ($3x10^{-3}$ – 1.0)	$1.8x10^{-3}$ ($1.5x10^{-5}$ – $9.3x10^{-2}$)	$1.8x10^{-2}$ ($1.5x10^{-4}$ – $1.5x10^{-1}$)
Probability of illness for female at the household	0.06 ($6.7x10^{-4}$ – 0.97)	0.47 (0.01 – 1.0)	0.04 ($4x10^{-4}$ – 0.73)	0.31 ($4x10^{-3}$ – 1.0)	$1.2x10^{-3}$ ($2x10^{-5}$ – $4.4x10^{-1}$)	$1.2x10^{-2}$ ($2x10^{-3}$ – $3.6x10^{-1}$)
Risk of illness for male at the restaurant	0.13 ($1.5x10^{-3}$ – 1.0)	0.76 (0.02 – 1.0)	0.08 ($5x10^{-4}$ – 0.98)	0.58 ($5x10^{-3}$ – 1.0)	$2.7x10^{-3}$ ($2.3x10^{-5}$ – $1.3x10^{-1}$)	$2.7x10^{-2}$ ($2.3x10^{-4}$ – $7.5x10^{-1}$)
Risk of illness for male at the household	0.09 ($1x10^{-3}$ – 1.0)	0.62 (0.01 – 1.0)	0.06 ($6x10^{-4}$ – 0.87)	0.43 ($6x10^{-3}$ – 1.0)	$1.8x10^{-3}$ ($3.1x10^{-5}$ – $6.6x10^{-2}$)	$1.8x10^{-2}$ ($3.1x10^{-4}$ – $5x10^{-1}$)
Increase efficiency of roasting by 10-time—r reduction in cfu-1g						
Risk of illness for female at the restaurant	0.010 ($1.5x10^{-4}$- 0.34)	0.1 ($1.5x10^{-3}$- 0.98)	0.006 ($5.5x10^{-5}$- 0.31)	0.06 ($5.6x10^{-4}$- 0.98)	$2x10^{-4}$ ($1.6x10^{-6}$ – $8.9x10^{-3}$)	$2x10^{-3}$ ($1.6x10^{-5}$ – $8.6x10^{-2}$)
Risk of illness for female at the household	0.007 ($7x10^{-5}$- 0.29)	0.07 ($7x10^{-4}$- 0.97)	0.004 ($3.9x10^{-5}$- 0.21)	0.04 ($3.8x10^{-4}$- 0.90)	$1x10^{-4}$ ($1.3x10^{-6}$ – $1.0x10^{-2}$)	$1.3x10^{-3}$ ($1.3x10^{-5}$ – $9.8x10^{-2}$)
Risk of illness for male at the restaurant	0.016 ($2x10^{-4}$ - 0.50)	0.15 ($2.2x10^{-3}$ - 1.0)	0.001 ($8.6x10^{-5}$- 0.44)	0.09 ($8.6x10^{-4}$- 0.99)	$3.1x10^{-4}$ ($2.5x10^{-6}$ – $1.4x10^{-3}$)	$3.1x10^{-3}$ ($25x10^{-5}$ – $1.3x10^{-1}$)
Risk of illness for male at the household	0.011 ($1x10^{-4}$- 0.41)	0.17 ($1.1x10^{-3}$- 0.99)	0.006 ($5.9x10^{-5}$- 0.30)	0.06 ($5.9x10^{-4}$- 0.97)	$2.0x10^{-4}$ ($2.0x10^{-6}$ – $1.6x10^{-2}$)	$2.0x10^{-3}$ ($2.0x10^{-5}$ – $1.5x10^{-1}$)

IC: immunocompromised

Risk of illness for males

It appears that males have higher risk of illness in comparison to females (Table 26 and 27). However, the pattern of risk was similar to what we observed among females where the risk of illness for males eating outside the house was higher in comparison to those eating at home (0.44 vs. 0.32 and 0.13 vs. 0.09 for *E. coli* and *Salmonella*, respectively). The distribution of the probability of illness for men eating at restaurants was also slightly skewed to the left with the median value of 0.38 and 0.13, respectively. On the other hand, the distribution of the probability of illness for healthy males eating at home assumed a similar risk as for females and was more skewed to the left. The median probability of illness was 0.27 and 0.09 for *E. coli* and *Salmonella*, respectively (Figure 9). There was a low proportion of individuals, less than 5%, who were likely to have a high risk (probability of illness greater than 73%) of illness from the consumption of contaminated roast beef at home.

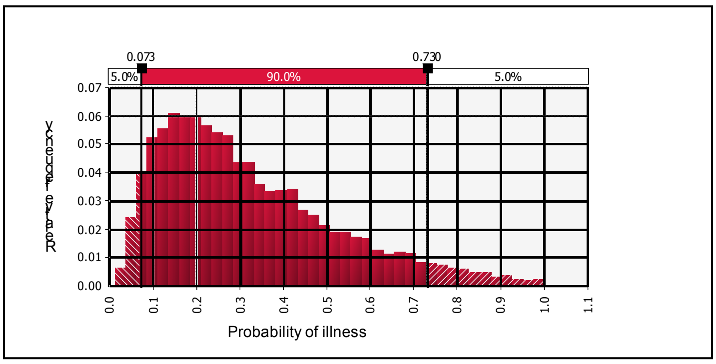

Figure 9: Relative frequency of the probability of illness among males who are exposed at the home for *E. coli*.

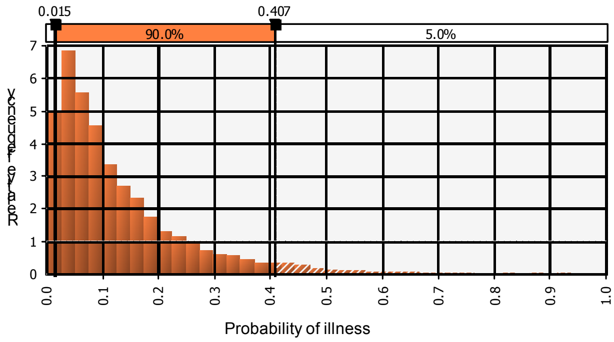

Figure 10: Relative frequency of the probability of illness among males who are exposed at the home for *Salmonella.*

The risk of illness for immunocompromised males eating at restaurants in our analysis was significantly higher than for healthy males (Tables 26 and 27). The risk for the former was twice the risk for healthy ones (0.89/0.44 and 0.76/0.13, respectively). The data were skewed to the right and the median risk was 0.99 and 0.76, respectively. Similar risk was observed for immunocompromised males who eat contaminated beef at home; the mean probability of risk was 0.89 and 0.62, respectively. The distribution of this probability was also skewed to the right. Compared to the healthy male exposed at the household, the immunocompromised male had approximately three times the risk of illness (0.89/0.32 = 2.8) from *E. coli* and seven times the risk of illness (0.61/0.09 = 6.8) from *Salmonella*.

Sensitivity analysis

We performed sensitivity/impact analysis for one of the uncertain parameters, the amount of beef consumed per capita in Nigeria. As indicated earlier, the estimate used in the analysis was obtained from the survey. However, other data indicated that the average amount of beef consumed per capita in Nigeria is between 3 and 6.4 kg/year. We converted these consumption data to amount consumed per day instead of per week. The risk of illness dropped significantly from 0.28 to 0.007 for healthy females eating at the restaurant/food stands for *E. coli* (Table 26) and from 0.09 to 0.0018 for *Salmonella* (Table 27). A similar drop in risk was obtained for other sub-groups in the population including the immunocompromised individual. Accordingly, the risk differed depending on which consumption data were used. It is possible that the consumption data in the survey were obtained from urban population while the data in the literature consisted of estimates for both urban and rural populations.

Three variables/factors showed consistent correlation with the probability of illness from the consumption of contaminated beef with *E. coli*: the initial concentration in the faeces before the animal was processed, the rate of presence of the pathogen in roast beef (efficiency of roasting), and the susceptibility of the host. Table 28 shows the correlation and regression coefficients for the relationship between each of these three factors and the probability of illness for healthy females. This pattern is consistent for immunocompromised female, healthy male, and immune compromised male at both restaurant and at the household.

Two variables/factors showed consistent correlation with the probability of illness from the consumption of contaminated beef with *Salmonella* under different scenarios: the contamination rate at the slaughter slabs and the efficiency of roasting. Table 28 shows the correlation and regression coefficients for the relationship between each of these two factors and the probability of illness for healthy males and females under different scenarios (eating at the restaurant/food-stand and household). This pattern was consistent for immunocompromised females, healthy males and immunocompromised males eating at restaurants and at the household.

The initial count of bacteria in the faeces had the highest correlation with the risk of illness at either the restaurant or at the household. We assessed the impact of overestimating of the initial bacterial count in the faeces by reducing the count to 3 cfu/g. The results are shown in Table 26. Using an initial count of 5 cfu/g instead of 3 cfu/g, the risk of illness from consuming beef contaminated with *E. coli* O157:H7 would have been inflated on average by approximately 30%. This analysis indicates one possible critical control point to reduce the incidence of the disease burden in the population which is controlling the likelihood of shedding the pathogen in faeces by introducing intervention strategies at the production site. One factor to consider before implementing such an intervention is the cost of the strategy. For example, in some parts of the world vaccination against *E. coli* O157:H7 has been implemented to reduce the incidence of shedding of this pathogen. We are not sure that would be a strategy of choice in the Nigerian situation, irrespective of the economic assessment [free market (benefit cost ratio) or cost-effectiveness].

Table 28: The impact of the parameters used in the model on the estimate of the risk of illness as a result of consuming beef potentially contaminated with *E. coli* or *Salmonella*

Parameter	Restaurant		Household	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
Female				
E. coli in faeces	0.97	0.9	0.64	0.53
Susceptibility	0.16	0.16	0.11	0.11
Efficiency of roasting	-0.15	-0.15	-0.11	-0.10
Male				
E. coli in faeces	0.63	0.54	0.96	0.83
Susceptibility	0.12	0.12	0.18	0.19
Efficiency of roasting	-0.09	-0.09	-0.16	-0.15
Female				
Salmonella in meat at slaughter slab	0.75	0.74	0.77	0.74
Efficiency of roasting	-0.13	-0.12	-0.12	-0.12
Male				
Salmonella in meat at slaughter slab	0.75	0.73	0.76	0.76
Efficiency of roasting	-0.13	-0.12	-0.13	-0.12

The susceptibility of the host was one of the factors that influenced the probability of illness from consuming beef contaminated with *E. coli* O157. We computed the susceptibility values (r_i) from the probability of *E. coli* in diarrhoeic patients for either gender as provided in the survey. As the regression coefficient indicates, the estimated probability of illness for healthy females in the analysis is likely to increase by 15% due to a unit change in the likelihood of isolating *E. coli* from diarrhoeic patients. Similar interpretations could be made for other sub-populations at risk using the respective regression coefficient (immunocompromised females and males). We realize that the estimate in the survey is likely to overestimate the true incidence because it focuses on diarrhoeic patients only and not all patients that were admitted to the hospital. This point notwithstanding, the analysis has provided another critical point of intervention to reduce the risk of illness from consuming contaminated beef, which is to reduce the incidence of diarrhoea in the population in general. A strategy like increasing awareness about the risk of illness coupled with education on improved sanitary and hygiene practice would decrease the risk of illness.

In the case of *Salmonella*, our analysis demonstrated that there is a significantly high correlation between the risk of illness and the degree of contamination at the slaughter slab (Table 28). As the regression coefficient indicates, the estimated probability of illness for healthy females eating at restaurants in the analysis is likely to increase by 74% due to a unit change in the likelihood of isolating one cfu/g of *Salmonella* at the slaughter slabs. This is a critical insight in the analysis which sheds light in the importance of the improvement of sanitary practices at these slaughter slabs. It appears that education and improvement of the facilities is likely to have a major impact on reducing the incidence of illness from this food-borne pathogen. The impact of this intervention was significant at both restaurants and households for both genders (Table 28). We recognize that the estimate of the amount of beef consumed in the survey is likely to overestimate the actual consumption data; still the impact of reducing the contamination at the slaughter slabs, either by improving the facilities or through sanitary practice education program, would significantly impact the probability of illness. A strategy like increasing awareness about the risk of illness coupled with education on improved sanitary and hygiene practices would likely decrease the risk of illness.

The efficacy of roasting was another factor in our analysis that appeared to influence the probability of illness from consumption of contaminated beef (Table 28). For example, reducing the bacterial count in roast beef by one log, through increasing the temperature or the time of cooking, is likely to reduce the risk of illness for healthy females by 15% (the regression coefficient is 0.15, Table 28). The pattern of reduction is consistent for all subcategories of the population. These results provide another option of a critical control point of intervention to reduce the risk of illness from consumption of contaminated beef. Such an intervention appears to be easy to implement through education on cooking, by increasing either the temperature or the time of cooking, or a combination of the two without compromising taste.

Conclusions

Despite the uncertainties associated with the prediction of the risk of illness due to the consumption of beef contaminated with *E. coli* O157 or *Salmonella*, as a result of uncertainties in some of the parameters, the model provides a scientific basis for the awareness about the importance of the risk. In addition, the model provides the foundation for risk managers and public health professionals to better understand the prevention strategies against illnesses associated with the consumption of contaminated beef.

6.8 The policy challenge: Acceptable/appropriate level of protection (ALOP)

Policy seeks to establish a balance between ensuring the safety of the food supply while maintaining the viability of the industries and communities engaged in that supply. In the developing-country context, food security is also a policy objective, and Nigeria specifically faces unmet demand for beef.

Approaches to food safety

In an attempt to achieve this balance, countries have developed approaches to standardize the methods by which food safety could be assessed and policies and recommendations could be made. The microbial risk assessment approach has been accepted as a method to assess the safety of food in relation to a particular hazard (CAC 2004). This has served developed countries well and helped both producers and policymakers design management strategies that ensure the safety of the food produced and control the associated potential public health hazard. The availability of resources, good data and a framework for collaboration between industry and policymakers have all played a positive role in instituting good management practices and policies. However, elements that contributed to the institution of safe food production practices and policies in the western hemisphere are largely lacking in developing countries.

These challenges to the developing countries have been made more complex by their aspirations toward participation in international trade, and the complexity of the global food production system. It is possible to imagine a scenario where raw food material is produced at one site, in a developing country, and processed at another, in a developed country. International food trade volume has been estimated at US $300-400 billion, the majority of which is from developed to developing countries (FAO 2002). Harmonization of standards for food safety across countries would facilitate this trade. The World Trade Organization (WTO) has promoted the concept of equivalence (whereby compliance is required for food safety outcomes, rather than procedures) introduced in the WTO Agreement on Sanitary and Phytosanitary (SPS) Measures (WTO 1995; 2000).

At the national level, acceptable level of protection (ALOP) and food safety objectives (FSO) are two concepts that have gained a lot of momentum among policymakers in the developed countries in the recent years. The concepts lend themselves to both development objectives and science-based policy. The WTO's SPS agreement uses the concept of ALOP and encourages nations to develop their own standards within the guidelines published by international agencies such as the Codex Alimentarius Commission of the FAO/WHO, for Food Safety. Consumer scares and disease outbreaks have heightened awareness, contributing to revision and strengthening of food safety systems for both international trade and domestic markets. For example, ILRI studies (Jabbar et al. 2010) have shown that developing-country consumers are well aware of safety risks in animal-source foods and further, that they modify their consumption and expenditures accordingly.

ALOP as defined in the WTO/SPS agreement is "the level of protection deemed appropriate by the member country establishing a sanitary or phytosanitary measure to protect human and animal or plant life or health within a territory".

FSO assists in translating the concept of ALOP into standards for food producers, for practical implementation. For example, this might be the maximum concentration of a microbial hazard in a food that would be considered tolerable for consumer protection at the time of consumption. The FSO could be interpreted as the maximum frequency and/or concentration of a hazard in a particular food matrix at the time of consumption which contributes to ALOP. By virtue of this interpretation the FSO became a subjective measure that the community or society is willing to tolerate or accept. In economic terms, this interpretation would translate to the costs that a society is willing to bear to achieve a specific degree of control and encompasses social, economic, ethical, medical and legal costs.

Food safety as policy

Other interpretations and suggestions regarding the utility of FSO have also been advanced (Havlaar et al. 2004), addressing health as a private and public good. The obvious measure that public health officials use to assess FSO is the incidence of the disease due to a particular hazard. This incidence is a function of all the factors listed earlier in this report. In calculation or establishment of the FSO in a developing country, a difficulty is encountered in integrating the standpoints of both private and public health. However, the obvious level that all countries could operate with, and that reflects the operational level of the contributory factors, is the endemic level of the disease. As resources become more available to the officials, these resources could be allocated optimally to modifiable factors which influence the endemic level of the disease. Stringer (2005) summarizes discussion on the implications of the FSO for microbiological food safety.

In the current study, we have used the risk assessment approach to examine the utility of these concepts in developing countries under traditional food production and marketing systems. One of the common practices in developing countries for the majority of food matrices is the cooking of the food before consumption. For such hazards the FSO is likely to be negligible or approaching zero. In the two scenarios developed in the current study, we demonstrated that increase in the cooking temperature significantly altered the risk of illness from exposure to contaminated beef. The only additional risk associated with such an intervention is the potential for cross contamination after cooking, either in the cooking area or after preparation and before consumption. In such scenarios of cross contamination, the FSO should incorporate hygiene and sanitary measures at the consumer and food serving levels in the function of the endemic level of diseases.

In developed countries, the FSO has been translated to the producer in terms of the performance objective. Historically, these producers have used the microbiological criteria as an internal measure for quality assurance, largely in acceptance or rejection of food lots. Several sampling techniques have been developed to aid in the decision of acceptance or rejection. Microbiological criteria have helped producers to develop good hygiene practices (GHP), good manufacturing/management practices (GMP), and hazard analysis of critical control points (HACCP) plans.

These concepts have potential applications in Nigerian conditions. As we observed, a reduction in the initial bacterial load from 5 to 3 cfu per gram in the faeces of animals at the slaughter slab would reduce the likelihood of illness from exposure to *E. coli* O157:H7 by more than 50%. If education and incentives are provided to producers then we would expect an impact (measurable in microbiological terms) in the shedding of this food-borne pathogen in beef cattle.

The mechanism of performance objectives

Satisfaction of performance objectives undoubtedly adds to producers' costs, and several arguments traditionally surround their application. First, where surveillance is available, compliance is likely both to satisfy requirements (for example, an appropriate level of protection) and to do so at a level of cost that is the lowest possible across the industry. Notably, firms for which compliance costs exceed the benefits available at prevailing prices will be forced to exit the industry. Second and conversely, where surveillance is too expensive or subject to subversion (e.g. in corrupt environments), firms will be able to derive a cost advantage from non-compliance: industry exit is then more likely amongst complying than non-complying firms. The extent to which the first or second arguments prevail will rely partly on consumer sovereignty; where products are traceable to particular shops or processing plants then some degree of consumer surveillance can be brought to bear. Certification systems and retailers' trust by consumers represent basic versions of this effect in less developed markets. However, these are unlikely to reflect fully the performance objectives, and lack basic recourse to the risk analysis of the type presented above.

Goal setting
A further challenge is the establishment of a reliable database upon which to set and pursue objective public health goals. Temptations include surrender to special-interest groups and retreat to the safety of the familiar through adoption of precautionary principles.

The most logical alternative is to carry out a risk assessment for a particular hazard in a particular food matrix, and compensate for lack of (or uncertainty in) data through simulations. Such simulations can incorporate expert opinions and partial data; in many developing countries there are conveniently available studies that provide information for risk assessment. Such an approach would provide insight into the likely consequences of proposed recommendations.

6.9 Summary and conclusion

We carried out a study to assess the potential risk of illness from the consumption of beef contaminated with *Escherichia coli* O157:H7 and *Salmonella* spp. in a subpopulation in Nigeria. In the study we used the quantitative risk assessment (QRA) methodology that allowed us to collate and analyze data from different sources to estimate the risk associated with the consumption of contaminated beef. In addition to estimating the risk, the QRA helped in identifying stages in the production system from farm to table that are likely to play a role in mitigating or exacerbating the risk of illness associated with the consumption of beef that is contaminated with these two pathogens. Knowledge gained on these critical stages through the QRA will help in focusing resources to devise cost-effective intervention strategies to mitigate the associated risk of the food-borne pathogens.

We used primary data from a survey conducted on the target population and complemented the data with information from literature, applying a stochastic approach. Parameters from the collated data were applied to model the human risk associated with these food-borne pathogens in beef. In the model we predicted the human exposure and combined the exposure with the dose-response model to estimate the probability of illness. The effect of uncertainty and variability of the different parameters used in the model on the predicted risk of illness was evaluated using Monte Carlo simulation.

The probability of illness for a healthy female from the consumption, at a restaurant, of beef contaminated with *E. coli* O157:H7 ranges from 7×10^{-3} to 28×10^{-2} depending on the amount of beef consumed. However, the risk of illness is lower for a healthy female eating contaminated beef at home (5×10^{-3} to 24×10^{-2}). The estimates of illness are three times higher for immunocompromised females exposed either at the restaurant or at home. We also evaluated the risk for healthy males being exposed to contaminated beef at restaurants and their risk was higher than for females under a similar scenario (13×10^{-3} to 44×10^{-2}). A similar trend of reduced risk was observed for men exposed to contaminated beef at home (9×10^{-3} to 32×10^{-2}). The risk of illness due to this pathogen could be significantly reduced for either gender under different scenarios by increasing the efficacy of roasting of beef before consumption.

The probability of illness for a healthy female from the consumption, at a restaurant, of beef contaminated with *Salmonella* spp. was much lower than the risk associated with *E. coli*-contaminated beef; the risk ranged from 1.8×10^{-3} to 9×10^{-2} depending on the amount of beef consumed. However, the risk of illness for a healthy female eating contaminated beef at home is lower (1.2×10^{-3} to 6×10^{-2}). The estimates of illness are three times higher for immunocompromised females exposed to contaminated beef either at the restaurant or at home. We also evaluated the risk for healthy males being exposed to contaminated beef at restaurants and their risk was higher than for females under a similar scenario (2.7×10^{-3} to 13×10^{-2}). A similar trend of reduced risk was observed for men exposed to contaminated beef at home (1.8×10^{-3} to 9×10^{-2}). The risk of illness due to this pathogen could be significantly reduced for either gender under different scenarios by increasing the efficacy of roasting of beef before consumption.

We caution the readers that the findings in this study are preliminary and are based on data that were collated from a single survey and from the literature. We attempted to capture the uncertainty of the parameters used in the model through the stochastic approach. The accuracy of the estimates depends largely on the validity of the survey and the reliability of parameters in the literature. However, the study has provided preliminary data on the potential risk associated with the consumption of beef contaminated with these food-borne pathogens. Before we invest resources on the cost-effective strategies to mitigate the risk of illness there should be more confidence in the parameters used in the model. In other words, additional studies are needed to validate the parameters used in this study and hence improve the estimates of the probability of illness.

CHAPTER 7

7. Cost of food-borne and beef-borne illness in Nigeria

7.1 Introduction

Diarrhoea is one of the top three killer infectious diseases in most poor countries, killing an estimated 1.4 million children a year (Black et al. 2010). In developed countries where relatively good information exists, we have reasonable evidence that:

- Food-borne disease is a common cause of diarrhoea, being responsible for 33-90% of cases (Unnevehr and Hirschhorn 2000; Flint et al. 2006)
- The great majority of cases (over 90%) are caused by bacteria and viruses not chemicals, although the latter are often of more concern to the public (Kafetstein et al. 1997)
- Zoonotic pathogens are among the most important causes of food-borne disease (Thorns 2000; Schlunt et al. 2004),
- Animal-source food is the most risky food (Adak et al. 2005; Lynch et al. 2006).

Food-borne disease does not just result in diarrhoea and vomiting. The bacterial pathogens responsible for acute gastrointestinal disease can also cause chronic effects (including abortion, arthritis, developmental defects, paralysis, septicaemia and seizures) which are of similar impact to acute diarrhoea (Lindsay 1997). Other food-borne diseases do not cause gastrointestinal illness. For example, toxins may cause neurological deficits, cancer or malnutrition; parasitic diseases may cause cysts in body organs; and antibiotic resistance may lead to treatment failures in human patients.

In developing countries, much less is known about the pathogens that cause diarrhoea*,* the prevalence of food-borne disease, the presence and prevalence of other food-borne diseases*,* high-risk foods, or the cost of illness (Kaferstein 2003). The first two questions are being addressed by a WHO Working Group and better attribution data should be available from 2011 (Kuchenmuller 2009).

7.2 Material and methods

7.2.1 Conceptual framework: the multiple burdens of food-borne disease

Food-borne disease has multiple burdens. The most obvious is sickness and death and this is well captured by the GBD metric of DALY which reflects years lost from death or disability. However, the GBD gives the burden associated with diarrhoea, not all of which is associated with food. Also, it does not give the non-diarrhoeal burden of food-borne disease. Finally, the GBD is based on national reporting which is plagued by problems of inaccuracy and under-reporting.

Food-borne disease costs dollars as well as DALYs. People who are sick incur costs for treatment and also lost productivity because of ill health. Where treatment is obtained from public providers, the health facilities that treat them incur additional costs. Food-borne disease also results in costs to the livestock sector and veterinary public health as well as more intangible costs to ecosystems. Figure 11 attempts to summarize these costs. This study looks only at two aspects: DALYs and cost of illness to the individual and household.

	Actors	Cost of illness	Cost of prevention	Intangible and opportunity costs
Private	Individual and household	Treatment costs (e.g. medication; care taking) Loss of household production	Risk mitigation such as boiling water, filters	Disutility of ill health for individual (DALY) Disutility of ill health for friends family etc.
	Livestock sector	Cost of treatment, herd slaughter, product recall Mortality, morbidity, lower production Loss of export	Costs of increased biosecurity, vaccination, practices and procedures to control disease along the value chain	Cost of future emerging disease Loss of animal genetic resources Loss of opportunities occasioned by spending on disease prevention and cure
Public	Health (human and animal)	Treatment costs (hospital provision etc.) Outbreak costs, movement restrictions, culling, vaccination	Risk mitigation such as water fluoridation, vaccination Disease surveillance Research	
	Ecosystem	Spill-over into wildlife Loss of ecosystem services	Biosecurity, avoiding wildlife and vectors Disease surveillance Research	
Dark box=market prices available and commonly included in economic assessments of disease White box= market prices less available and commonly ignored in economic assessments of disease Black box= included in health metrics (DALYs) Grey box = market prices not available but costs can be estimated through other methods				

(Adapted from Grace et al. in press)

Figure 11: The multiple burdens of food-borne disease on human, animal and ecosystem health.

7.2.2 Data collection

There were three major inputs to this study:

- A systematic review of the literature on diarrhoea and food-borne disease in the Nigerian population as well as presence of hazards in food and livestock.
- A value chain study of actors involved in the slaughter, retail, restaurant sale and consumption of beef in four regions of Nigeria. This comprised a questionnaire on knowledge and attitudes relating to beef safety as well as costs of illness; a questionnaire and observation check-list on practices; and a microbiological study of beef quality (detailed protocols in Appendix 2).
- A retrospective study of admissions to a major hospital in Ibadan, Nigeria with details of cases related to food safety (hospital study).

In developing a cost-of-illness estimate for meat- and beef-borne disease in Nigeria, we were faced with the challenge of inadequate data on the diseases associated with meat, their incidence, prevalence and associated costs. We, therefore, decided to focus on the most salient aspects of cost of illness (cost of hospital treatment and lost productivity and cost of individual disutility from ill health).

7.2.3 Justification for model assumptions

Reporting of diarrhoea

In the value chain study, 8.7% of beef consumers reported diarrhoea in the previous two weeks, the equivalent of two episodes per person per year. This is around twice the annual rates reported from developed countries for which we have reasonably good data (Table 29). Although we do not have accurate estimates for the incidence of diarrhoea in developing countries (especially adult diarrhoea), the prevalence is believed to be higher than in developed countries, because of the greater level of pre-disposing factors (poverty, poor hygiene, vulnerable population groups, tropical climate, inadequate control etc). For example, children in developing countries are believed to suffer on average three episodes each year (Kosek et al. 2003) and some studies have reported much higher rates [for example, 8.3 episodes per year for children in slums in Nairobi, Kenya (Magadi 2004)].

Table 29 : Annual incidence of diarrhoea in developed countries

Country	Cases of diarrhoea per year	Authors
United Kingdom	0.2 – 5.5	Wheeler et al. (1999); Flint et al. (2005)
Netherlands	0.3	Wit et al. (2001)
Ireland	0.4-6	Scallan et al. (2004)
USA	0.7 -1	Imhoff et al. (2004); Scallan et al. (2004)
Australia	0.8	Hall et al. (2005); Scallan et al. (2004)
Norway	1.2	Kuusi et al. (2003)
Canada	0.7-1.3	Majowicz et al. (2004)

We conservatively assumed that the survey result (2.25 episodes) was most likely, with a lower limit of 0.92 episodes and upper limit of 3.28 from the groups in the studies with least and highest prevalence.

Proportion of diarrhoea attributable to food-borne disease

There is little consensus on the importance of food-borne disease in the aetiology of diarrhoea with estimates ranging from 30 to 90% (Schlundt 2002; Flint et al. 2005). In some studies, foods of bovine origin have the highest case-fatality rates (Adak et al. 2005). In developed countries, there is often an age association with viral aetiology more important in infant diarrhoea. However, there is little evidence from developing countries on the proportion of diarrhoea attributable to food-borne disease in general or animal-source food in particular.

Our literature review found a few studies have attempted to identify the relative importance of pathogens responsible for diarrhoea in Nigeria (see literature review in Chapter 3). These suggest toxigenic *Escherichia coli* is the most important cause of diarrhoea, followed by rotavirus, *Salmonella* spp*.*, *Campylobacter* spp*.*, *Cryptosporidium parvum* and *Staphylococcus aureus*. With the exception of rotavirus, all of these are zoonoses (or partial zoonoses) which are most commonly transmitted via food. This suggests that food (especially animal-source food) plays an important role in diarrhoea in Nigeria.

Synthesizing the above information we assume 50% of the diarrhoea burden may be attributable to food-borne disease, with a lower limit of 33% and an upper limit of 90%.

Proportion of people consuming beef

We considered that households consuming beef daily to weekly would be at risk of beef-borne pathogens. A data-set for urban household food consumption and expenditure patterns during one week in households selected from Abuja, Kaduna and Kano – three major cities in Nigeria – found 77% of households consumed beef (Ezedinma et al. 2006). Obayelu et al. (2009) found 33.1% of households in north-central Nigeria regularly consumed beef (13.1% of rural households and 56.6% of urban households). A study from Abia state found 67% of households consumed beef daily (Igwe and Onyekwere 2007) while a 24-hour recall study in two communities in Edo state found 33% and 50%, respectively, consumed beef (Ngwu undated). It appears that although per capita consumption of beef is very low, small amounts of beef are consumed frequently. However, very small amouns of meat (grams) can have sufficient bacteria to cause infection.

Synthesizing the above information we assume 33.1% of households consume beef at least weekly with a lower limit of 20% and an upper limit of 77%.

Proportion of food-borne diarrhoea attributable to beef consumption

In developed countries, animal-source foods are most frequently implicated in diarrhoeal illness. For example, in the USA, between 1998 and 2002 most (69%) food-borne disease outbreaks with an identifiable vehicle were caused by animal-source foods. Poultry was the food most often implicated (25%) but beef, pork, shellfish and finfish were also important, each causing over 10% of the total (Lynch et al. 2006). In the United

Kingdom, a similar pattern is seen. In the four years from 1996 to 2000, most illness was attributed to eating poultry (30%), complex foods (27%) and red meat (17%).

According to the literature review (Chapter 3), the majority of the pathogens responsible for diarrhoea in Nigeria are zoonotic and cattle are important reservoirs for many (including toxigenic *E. coli; Salmonella* spp.*; Cryptosporidium parvum; Campylobacter* spp. and *Staphylococcus aureus*).

In our hospital study, of the cases examined 28.4% (33 cases out of 116) had a history of meat consumption shortly before the onset of symptoms. However, this may under-estimate the roles of meat in diarrhoea, (because not all patients were asked about consumption), or over-estimate such roles (because patients' attribution may be incorrect). In terms of meat consumption, beef is most commonly consumed in urban areas (Obayelu et al. 2009) and we would expect food safety problems to be greater in urban areas because of longer food chains and general unhealthy environment, which again would argue for beef being an important cause of food-borne disease.

A study by ILRI (Chapter 4) among beef processors and retailers in Ibadan showed that beef consumption was associated with a nine-fold increase in the odds of experiencing diarrhoeal illness. Consuming beef of poor microbiological quality resulted in an additional four-fold increase in the odds of diarrhoea. Beef is the most commonly consumed meat in Nigeria, increasing its potential contribution to the food-borne diarrhoea burden.

Synthesizing the above information we assume that, among people consuming beef, 20% of the food-borne disease burden may be attributable to beef (with a lower limit of 15% and an upper limit of 30%).

Health care utilization
In the value chain study, respondents were asked where they sought treatment and 31.3% of people reported visiting public health care facilities or hospitals.

- A study in the UK (where treatment is free) found that only 17% of people with diarrhoea visited a doctor (FSA 2001); the same proportion was reported in Norway (Kuusi et al. 2003) while in the Netherlands only 5% of people experiencing diarrhoea saw a doctor (Wit et al. 2001). Given income constraints, it may seem implausible that 30% of Nigerians seek treatment at a health facility. Moreover, this equates to 63.2% of the population seeking hospital/health facility care for diarrhoea per year which seems high.
- However, our results are compatible with other surveys from Nigeria. For example, a study on a university population found that 49% of respondents claimed to visit a public health facility when ill (Chukuezi and Anelechi 2009). In a study of market traders in Oyo, south-western Nigeria, 40% reported using public health facilities (Ige and Nwachukwu 2009) as did 45% of people randomly selected from a northern Nigerian town (Tanimola et al. 2009) and 64% of mothers of sick children (Oshikoyo et al. 2007). In a rural community in south-west Nigeria, 44% of respondents to the survey who were ill in the preceding six months visited a public health facility for treatment, while others relied on self-medication/self-treatment (Sule et al. 2008). On the other hand, in a rural area with poor health infrastructure in south-west Nigeria, only 0.5% reported consulting a physician for diarrhoea (Arikpo et al. 2010).
- The only study we found on population attendance of health facility reported 58.1% of the population attended the hospital in one year (all causes) (Fatiregun et al. 2007) while in our study, 63% of the population attended health care facilities (hospitals and others) in one year. It is possible, therefore, that the participants in our study use hospital/health facilities at higher rates or that they are over-reporting usage of hospitals (Chukuezi and Anelechi, 2009).
- Ibadan metropolis has a population of 2 million, 21 hospitals and around 100 health facilities. In our study, there were 44 cases a month of which 70.7% were hospitalized. In the absence of detailed attendance data, if we assume the other health centres treat similar numbers this corresponds to 63,731 hospital/health facility visits per year in Ibadan. Extrapolating from consumer reports of hospital attendance, would imply 138,000 persons go to hospital per year. Interestingly, respondents in Ibadan reported significantly lower diarrhoea and hospital/health facility attendance than other

regions. The implication is either the group of beef consumers have higher frequency of seeking hospital/heath centre treatment or are over-reporting attendance.

- Other studies indicate 56.6% of urban consumers and 33.1% of both urban and rural consumers eat beef (Obayelu et al. 2009). We can assume that the beef consumers are among the richer half of the urban population and hence may be more likely to seek hospital/health facility treatments. This may explain a higher attendance among our respondents.
- Several studies in Nigeria report a relatively long delay in seeking illness (10-60 days) with the reason being that respondents wait to see if the problem persists (Tanimola et al. 2009; Fatiregun and Ejekam 2010). Diarrhoea is often acute and it may be that when respondents report their health-seeking behaviour, they do not include minor and self-limiting episodes. This is also compatible with the surprisingly low level of diarrhoea reported overall.

In conclusion, the findings from the study on health care utilization seem reasonably compatible with the literature and we use 30.3% as the most likely for urban populations. For rural populations, we assume 10%. Weighting this by the proportion of urban population (48% of the population according to UN statistics) we assume a most likely overall attendance of 0.190 with an upper limit of 0.347 and a lower limit of 0.1.

The hospitalization rate (71%) seemed high. In the study from Norway cited above, only 24% of those attending a general practitioner were hospitalized (Kuusi et al. 2003). However, it is consistent with our hypothesis that only patients with relatively severe signs attend hospital.

In conclusion, the findings from the study on hospitalisation seem reasonable for urban Nigeria (48% of the population according to UN statistics) but may over-estimate hospitalisation in rural areas. We assume a best estimate of 0.71 with an upper limit of 0.8 and a lower limit of 0.1.

The most likely cost of treatment per episode of diarrhoea treated in the community and in the hospital was taken from the value chain actor survey and hospital survey (US$ 3 and US$ 13.6, respectively). These were compatible with the literature on costs of treatment in urban areas but may over-represent costs in rural areas.

The most likely number of days lost from sickness (1.2 days if not hospitalized and 5.6 days if hospitalized) were taken from our survey. The cost of days lost was the average daily wage in Nigeria (US$ 3.3). Estimates of the population were obtained from Human Development Indicators for 2009.

Assumptions for regional model

There was no significant regional difference in reports of diarrhoea (p=0.56, χ^2); a significantly lower proportion of people sought hospital treatment in Ibadan (p=0.014, logistic regression); there was a significantly higher cost of treatment in Abuja versus Enugu (0.034) and Ibadan (0.000 both Anova with Sidak post hoc comparison); Kaduna had significantly more days sick than Enugu (0.007) and Ibadan (0.004: Anova with Sidak post hoc comparison).

Because data were insufficient to parameterize distributions for the regions separately, we estimated costs for the regions through a simple mathematical calculation taking into account the proportions of different categories in the region.

Additional data were derived from the following sources:

- Population figures by sex for each of the 36 states was obtained from the 2006 population census in Nigeria
- Proportion of the total population by sex for each age class was obtained from the 1991 population census data
- Proportion of the population of immunocompromised group was obtained from Sentinnel surveillance of 2005

7.2.4 Modelling cost of illness

We used probabilistic modelling to estimate the cost of illness associated with diarrhoea and, more specifically, beef-borne disease taking into account variability and uncertainty. We used data from the literature review, value chain study and retrospective study of hospital clients to develop a probabilistic model. Where there was a large amount of uncertainty over parameters, we used pert distributions (representing lower estimate, best estimate and upper estimate). Another approach to modelling woud have been to assign likely distributions to the data and parameterize according to our data. However, statistical testing suggested that data from different regions followed different distributions and given the small sample sizes we felt there were too little data to confidently assign distributions and so used the survey results as point estimates suggesting a range. The parameters, equations, and data sources used are given in Table 30. We ran for 10,000 iterations using Latin hypercube sampling using @Risk®.

Table 30: Model parameters for assessing cost of illness of beef-borne disease in Nigeria

	Symbol	Source of data
Population Nigeria	a	Census (updated)
Proportion consuming beef	b	Assumptions
Episodes diarrhoea per person per year	c	Value chain study
Proportion using other care for diarrhoea	d	Hospital study
People using hospital/health facility care for diarrhoea	e	Hospital study
Proportion diarrhoeal illness associated with food	f	Assumptions
Proportion of diarrhoeal illness associated with beef consumption	g	Assumptions
Cost per episode diarrhoea in the community Naira	h	Value chain study
Cost per episode diarrhoea hospital/health facility care Naira	i	Hospital study
Naira to dollar	j	Current exchange
Total treatment cost of diarrhoea per year USD	z=a*c*e*i/j + a*c*d*h/j	Output
Total treatment cost of beef associated diarrhoea per year USD	y=z*b*f*g	Output
Patients attending hospital/health facilities who are hospitalized	k	Hospital study
Days in hospital per epidode diarrhoea	l	Hospital study
Days of labour lost for those not hospitalized per episode disarrhoea	m	Value chain and hospital study
Proportion in workforce	n	Human Development Indicators, 2009; CIA, 2010
Cost of days lost labour	o	
Cost of lost labour for diarrhoea per year USD	a*c*e*k*l*n*o + a*c* e*(1-k)*m*n*o +a*c*d*m*n*o = q	Output
Cost of lost labor for beef-associated diarrhoea per year USD	q*b*f*g=w	Output
Cost of treatment and lost labour for diarrhoea	z+q	Output
Cost of treatment and lost labour for beef -ssociated diarrhoea	y+w	Output

7.3 Results

7.3.1 Cost of illness associated with food-borne and beef-borne diarrhoea in Nigeria

The simulation suggested the following:

- 173 million episodes of diarrhoea in Nigeria attributable to food
- 35 million episodes of diarrhoea attributable to beef
- Costs of diarrhoea are US$ 3.6 billion (1.2-7.1 billion)
- Costs of food-borne diarrhoea are US$ 2.0 billion (0.6-4.6 billion)
- Costs of beef-borne diarrhoea from treatment and lost income are US$156 million (42-351 million)

These results are shown graphically in Table 31 and Figure 12 along with associated confidence intervals.

Table 31: Annual cases of diarrhoea, their direct treatment costs and medical costs combining treatment and lost labour

	Annual cases	Treatment costs (US $)	Treatment and lost labour costs (US $)
Diarrhoea episodes (95% confidence intervals)	346,842,276	3,129,078,383 (0.87-6.45 billion)	3,648,491,200 (1.24-7.10 billion)
Food-borne diarrhoea (95% confidence intervals)	173,421,138	1,685,192,686 (0.44-3.62 billion)	1,964,637,151 (0.62-4.06 billion)
Beef-associated diarrhoea (95% confidence intervals)	34,684,228	134,115,532 (30-314 million)	156,336,088 (42-351 million)

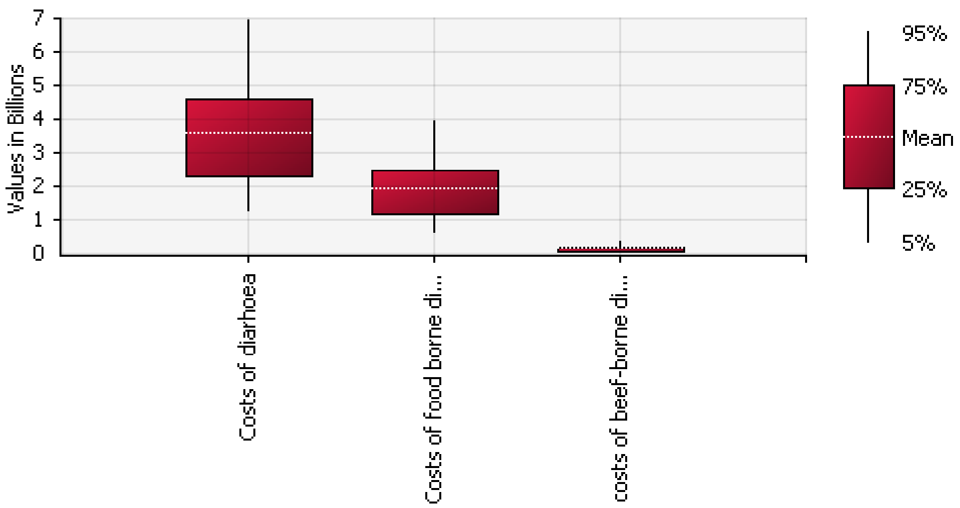

Figure 12: Costs (direct and indirect) associated with diarrhoea of all causes, food-borne diarrhoea and beef-borne diarrhoea in Nigeria.

The relatively wide confidence intervals reflect uncertainty and variability in the model parameters. We conducted a sensitivity analysis on the estimate for beef-borne diarrhoea (Table 32). The regression coefficient was highest for costs of medical treatment per episode of diarrhoea for those who did not seek treatment at a health facility or hospital. This suggested that (1) improving the accuracy (reducing uncertainty) of this estimate would have greatest benefits in allowing more precise estimates of costs and (2) there was wide variation in treatment costs depending on the course of the disease (high variability). The next most important factor was the number of episodes experienced per year.

Table 32: Sensitivity analysis on the estimate for beef-borne diarrhoea

	Regression Coeff. R^2=0.882
Cost per episode diarrhoea in the community	0.533
Episodes of diarrhoea per person per year	0.414
Proportion consuming beef at least weekly	0.406
Proportion of diarrhoea associated with food-borne disease	0.296
Cost per episode diarrhoea hospital/health facility care	0.294
Proportion of food-borne illness associated with beef consumption	0.202
Proportion using hospital care for diarrhoea	0.158
Proportion using community care for diarrhoea	0.046
Days in hospital	0.058
Cost of days lost labour	0.037
Population in workforce	0.016
Days of labour lost community treatment	0.021
Proportion patients attending hospitals/health facilities who are hospitalized	0.020

Estimates and disaggregated data for the regions are given in Tables 33 and 34.

Table 33: Estimates for cost of diarrhoeal illness in Nigeria (US $)

	National	Abuja	Kaduna	Ibadan	Enugu
Elderly (F)	58,985,937	10,842,644	20,807,720	14,890,786	12,575,577
Adult (F)	896,795,038	164,846,577	316,350,999	226,392,655	191,193,291
Children (F)	784,217,159	144,152,798	276,638,330	197,972,778	167,192,116
Immunocompromised (F)	39,734,707	7,303,932	11,520,776	7,264,912	10,116,027
Elderly (M)	71,798,270	13,197,775	25,427,470	17,896,097	15,410,330
Adult (M)	918,944,777	168,918,085	325,445,733	229,051,823	197,236,541
Children (M)	836,184,939	153,705,383	296,136,206	208,423,497	179,473,489
Immunocompromised (M)	41,830,375	7,689,153	12,171,655	7,567,691	10,678,358
Total female	1,779,732,840	327,145,951	625,317,824	446,521,130	381,077,011
Total male	1,868,758,360	343,510,395	659,181,064	462,939,108	402,798,718
Total	3,648,491,200	670,656,347	1,284,498,887	909,460,238	783,875,728

Table 34: Estimates for cost of diarrhoeal illness attributable to beef consumption in Nigeria (US $)

	National	Abuja	Kaduna	Ibadan	Enugu
Elderly (F)	2,527,519	464,602	891,601	638,063	538,857
Adult (F)	38,427,235	7,063,596	13,555,488	9,700,816	8,192,540
Children (F)	33,603,327	6,176,878	11,853,819	8,483,038	7,164,102
Immunocompromised (F)	1,702,613	312,970	493,660	311,298	433,467
Elderly (M)	3,076,521	565,518	1,089,555	766,839	660,325
Adult (M)	39,376,340	7,238,058	13,945,193	9,814,760	8,451,491
Children (M)	35,830,121	6,586,202	12,689,294	8,930,846	7,690,352
Immunocompromised (M)	1,792,411	329,476	521,550	324,272	457,562
Total female	76,260,694	14,018,046	26,794,567	19,133,215	16,328,966
Total male	80,075,394	14,719,255	28,245,591	19,836,717	17,259,731
Total	156,336,088	28,737,301	55,040,158	38,969,932	33,588,697

7.3.2 Burden of food-borne disease in terms of human sickness and death

The burden of diarrhoeal diseases in terms of human and sickness and death for Nigeria has been estimated by the WHO's GBD study (Table 35). This uses DALY, the standard method for measuring the burden of human disease which reflects life years lost from premature death and disability. The burden of diarrhoeal illness in Nigeria is 6,487,000 DALY and Table 35 gives the breakdown by age and sex as well as the associated mortality.

Table 35: The burden of diarrhoeal disease in Nigeria by age and gender

Sex	Age group	Deaths ('000)	% of total deaths	DALY ('000)	% of DALY
Female	All	98.6	100%	3,210	100%
	0 – 14	79.3	80%	2,871	89%
	15 – 59	10.4	11%	275	9%
	60+	8.9	9%	64	2%
Male	All	101.1	100%	3,277	100%
	0 – 14	81.7	81%	2,947	90%
	15 – 59	11.4	11%	275	8%
	60+	8.1	8%	55	2%
Female & male	All	199.7	100%	6,487	100%
	0 – 14	161	81%	5,818	90%
	15 – 59	21.8	11%	550	8%
	60+	17	9%	119	2%

(Source: WHO, 2008)

However, the estimated lost DALY for Nigeria is based on heroic extrapolations. WHO categoriZes it as level 4, the lowest level of evidence, meaning country specific information is not available and estimates are predicted using models (WHO 2008).

Making the same assumptions about the attribution of food-borne disease (that is, 50% is due to food-borne disease and 20% of this is due to beef: see Chapter 6 for the justification), given a total burden of diarrhoeal disease of 6,487,000 DALY, we calculate the disease burden of food-borne diarrhoea as 3,243,423 DALY and of beef-borne diarrhoea as 646,685 DALY.

Health economics frequently employs cost-benefit analysis in identifying and planning health, particularly public health, interventions. This often entails assigning a monetary value to human health, specifically where suffering, disability or death result from inaction or in a baseline scenario. Although controversy surrounds both the ethics of such valuation and the practicality of methods used (Heinzerling and Ackerman 2004), the approach has gained acceptance largely due to the absence of alternatives. The Value of a Statistical Life (VSL) was developed to assess the impact of health, environmental, or work safety interventions. VSL is an estimate of the cost of saving an additional life. Often measured by willingness-to-pay survey or inferred from employment or expenditure behaviour, VSL embraces the controversial concept of valuing health based on differential income levels and strategies available to diverse income groups. The rationale for using economic valuation of health and life is that choices need to be made in the presence of constraints on public finance, knowledge and information, and in the presence of many competing uses of public funds (e.g. transport infrastructure, education, and national defense). To that end, decisions need to be informed regarding the benefits available from identified courses of action; comparisons of individuals' well-being are not implied.

Miller (2000) draws on 68 studies from 13 different countries, finding income elasticities of the VSL between 0.95 and 1.00. Projecting beyond the range of his sample, he estimates the VSL at about US$ 40,000 for Nigeria in 1997, when gross domestic product per capita was about US$ 250 (both numbers are in 1995 dollars).

Given the life expectancy in Nigeria of 47.9 years (HDI 2009), the DALY lost from diarrhoea correspond to 67,712 with a statistical value of US$ 2.7 billion while the DALY lost from beef-associated disease correspond to 13,542 with a statistical value of US$ 542 million. This is a considerable under-estimate as the VSL reflects 1995 data and given increases in GDP.

7.3.3 Costs of non-diarrhoeal food-borne and beef-borne disease

For many years, food-borne illness was regarded as a common, but not especially serious, disease. This perspective is changing as diseases emerge or re-emerge which are untreatable (e.g. *Cryptosporidium*), deadly (e.g. tuberculosis) or both untreatable and deadly (e.g. new variant Creutzfeldt Jakob syndrome and avian influenza). The Food and Drug Authority of the United States Department of Agriculture estimates that 2 to 3% of people with acute food-borne illness go on to develop secondary long-term illness and the long-term consequences to human health and the economy may be more detrimental than the initial acute disease (Lindsay 1997).

These non-trivial diseases include ankylosing spondylitis; arthropathies; renal disease; cardiac disease; neurological disorders; abortions and developmental abnormalities; and nutritional and other mal-absorptive disorders (incapacitating diarrhoea). We can reasonably assume that the costs associated with non-diarrhoeal symptoms of beef-borne disease are at least equivalent to those attributable to diarrhoea (Kimoto et al. 2006).

If we combine the three costs (costs of diarrhoeal disease associated with beef, cost of non-diarrhoeal disease associated with beef, and value of lost statistical lives associated with beef) then the total is US$ 854 million per year.

7.4 Discussion

The Centers for Disease Control estimates that approximately 76 million new cases of food-related illness – resulting in 5000 deaths and 325,000 hospitalizations – occur in the United States each year. The most recent analysis estimates the total economic impact of food-borne illness across the nation to be a combined US$ 152 billion annually (Scharff 2010).

Another study found the total cost to New Zealand society from food-borne *Campylobacter, Salmonella, Listeria, E. coli, Yersinia* and norovirus infections to be US$86 million (New Zealand has a population of 4 million compared to 153 million in Nigeria). Over 90% of the burden in New Zealand is due to zoonoses transmissible through meat and 90% of this cost can be attributed to lost productivity caused by workforce absence. The cost of food-borne illness in Australia is estimated at about US$ 487 million to US$ 1.9 billion per year. These studies did not take into account values of statistical lives.

A large-scale study in Nigeria found that rural households spent 7% of their income on direct costs of illness; other experts believe that 10% of household income is spent on health care (Onwujeke et al. 2000; Russell 2002). From the World Bank (2009) Atlas method per capita income for Nigerians (US$ 1140), the number of households in 2010 (30,775,712) and the number of households members (5) (NMCP 2007), this equated to an annual income in Nigeria of US$ 175 billion. The total direct expenditure on health in Nigeria, which is 7-19% of this, accordingly, is US$ 12-$17 billion. Our model estimates the direct costs from diarrhoea at US$ 3 billion or 17-25% of the total costs from all illness. Given that diarrhoea is the most common sickness and the leading cause of death (see literature review in Chapter 3) this is at least within an order of magnitude of our estimates, though perhaps larger than anticipated. There are few studies on the relative importance of cost of diarrhoea; one from Burkina Faso found diarrhoea accounted for 9% of all household out of pocket expenditure on health care (Mugisha et al. 2002) which is somewhat lower than our estimate (17-25%).

So, given the high population of Nigeria, and that developing countries suffer a higher burden of diarrhoeal disease than developed countries, our estimates are compatible with other international and national studies. However, several of the assumptions are based on relatively small sample sizes and further research is recommended to validate and improve the accuracy of model predictions.

It should be noted that our calculations do not include some potentially important costs because there were insufficient data. These include:

- Care-giver costs (for people who are ill): We did not include these as we could not find credible evidence on costs.

- Costs of averting behaviour (boiling food for a long time etc.): In the absence of high levels of food-borne disease people would be able to reduce averting behaviour such as consuming beef soon after purchase and boiling beef for a long time. The associated saving was not evaluated.
- Spillover benefits of averting behaviour (non-cross contamination of water and other products, improved animal health, enhanced industry returns from higher quality).
- Costs to government of providing infrastructure (arguably Nigeria is under-provided so this should not be included because if there were fewer cases of diarrhoea, hospital infrastructure and personnel would shift to other problems).
- Costs to the livestock sector in terms of reduced production: Many food-borne diseases cause few or no signs in the animal reservoir but others may be responsible for sickness and death (e.g. salmonellosis).
- Costs to the meat industry: In developed countries there are large costs associated with assuring food safety and from recalls when food safety problems escape control; these may be less important in Nigeria given the low levels of traceability.
- Other unassessed costs can be seen in Figure 11.

7.5 How much of this burden is readily preventable?

An unpublished study by ILRI and partners among meat retailers in Ibadan gives an idea of what can be achieved by relatively simple and cheap meat safety interventions. In Ibadan, an interactive training workshop was held for representatives of butchers' associations who were selected to pass on information and training to their group. Meat hygiene KAP was assessed before and after the workshop (*n* = 63): After the workshop, participants significantly improved KAP in key food safety aspects, specifically, understanding sources of contamination and food-borne diseases, use of bleach and disinfectant, and hand-washing. Participants also shared information with an average of 18 other group members and improvements were seen in group members who did not attend. Microbiological quality of meat sold also significantly improved after the intervention with an average of 31% improvement in the number of samples failing microbial standards. This relatively cheap and simple intervention led to a 30% reduction in samples failing to meet microbiological criteria.

In our study of meat samples from Enugu and Abuja, we found that Enugu had both higher quality meat and fewer reported cases of diarrhoea. An increase of one third in the number of acceptable meat samples corresponded to a decrease of 31% in reported cases of diarrhoea in the preceding two weeks.

Several countries have succeeded in significantly reducing food-borne disease over relatively short periods. Between 2000 and 2005, the UK reduced food-borne disease by 19.2%. The main strategies were: targeting high risk value chains; improving slaughterhouse hygiene; private-sector targeted food management systems (HACCP based) and a food hygiene campaign (FSA, 2006). In Iceland, measures at production, retail level and in the household were introduced to prevent *Campylobacter* spp. transmission. Flocks were comprehensively tested and birds from positive flocks could only be sold frozen. This was accompanied by consumer education campaigns and improvements in hygiene and biosecurity on farm. Parallel declines (>70%) were subsequently observed in the *Campylobacter* in broiler flocks and in human infections (Stern et al. 2003). In Denmark, a focused and integrated program reduced *Salmonella* by up to 95% in eggs, poultry and pork, by monitoring herds and flocks, eliminating infected animals, and diversifying animals (animals and products are processed differently depending on *Salmonella* status) and animal food products according to the determined risk. Given experiences in Nigeria and other findings from interventions to improve food safety, we assume that between 20 and 70% of the beef-borne pathogen exposure is avoidable by achievable improvements in knowledge and practice and provision of infrastructure.

7.6 Summary and conclusions

We used data from a systematic literature review, value chain survey and hospital survey to estimate the cost of beef-borne illness in Nigeria. Cost of medical treatment and lost productivity was estimated using Monte Carlo stochastic simulation to take into account uncertainty and variability. The total cost associated with food-borne diarrhoea was estimated at US$ 3.6 billion; and the cost associated with beef-borne diarrhoea at US$

156 million. We then used data from the GBD to estimate additional costs from loss of statistical lives. DALY lost from diarrhoea are estimated at 67,712, corresponding to a statistical value of US$ 2.7 billion, while the DALY lost from beef-associated disease correspond to 13,542 with a statistical value of US$ 542 million.

We discuss the other aspects of cost of beef-borne illness which were not captured because of inadequate data but which are likely to be similar or greater to the costs calculated. Chronic and non-gastrointestinal illness associated with food-borne disease is less common than gastrointestinal illness but more severe, and experts consider it to have an equivalent cost. Other costs of beef-borne disease, which were not quantified, include reduced animal productivity, costs of control and trade impacts. This initial estimate suggests beef-borne disease costs Nigeria US$ 854 million per year. Furthermore, a reduction of between 20-70% in beef-borne disease is feasible.

CHAPTER 8

8. Overall summary, conclusions and recommendation

This chapter presents and discusses the overall key findings of the study including potential (risk-based) approaches to improve meat safety in Nigeria. We do this bearing in mind that the conventional solutions – provision of infrastructure, control and command regulation, inspection and penalties – have self-evidently failed to deliver food safety, and provision of 'more of the same' is unlikely to have different outcomes.

8.1 Summary of key findings

The study reveals a high cost of illness associated, in Nigeria, with food-borne disease in general (US$ 3.6 billion per year) and beef-borne disease in particular (US$ 854 million per year). It also reveals poor hygienic practices at slaughterhouse and during sale and preparation. These problems are typical of food in the traditional, self-organized food sectors in developing countries which account for the great majority (80-90%) of food sold. Other key findings of the study are as follows:

i. There is a lack of information on the risk to human health, cost of illness, the relative importance of different hazards, or risk factors for food-borne diseases in Nigeria. In Nigeria, as in most developing nations, there is no organized system for monitoring outbreaks of food-borne infections in humans. Food-borne diseases in Nigeria appear to occur predominantly as isolated sporadic cases rather than taking the form of outbreaks and many, if not most, cases of food-borne infections are unrecognized, un-investigated and undocumented. Moreover, many patients do not seek help from hospitals but may rather engage in self-medication or use medicinal herbs. It is, therefore, difficult to determine the actual incidence of food-borne infections. However, diarrhoea is a good indicator of food-borne disease and better data exist for the prevalence and impact of diarrhoea in Nigeria. In developing countries, typically 50-60% of diarrhoea cases are bacterial in origin. In Nigeria, the proportion may be higher at 65-80%. Most of the bacterial causes of diarrhoea are zoonotic, that is, transmissible between animals and humans.
ii. Evidence indicates there are high levels of zoonotic and food-borne disease in Nigeria, likely to impose a huge burden of health on consumers as well as all actors involved in food value chains. Our review suggests that the general public is at high risk of contracting food-borne pathogens through the consumption of contaminated animal products, and people working closely with animals are at even greater risk of exposure. However, because the number of consumers of meat is much greater than the number of people working closely with animals and their products, the greatest burden of health is borne by consumers.
iii. It appears that bacterial pathogens are the biggest problem and the most important of these, as elsewhere in the world, are zoonotic. The most important bacterial zoonoses are: toxigenic *E. coli* infection, campylobacteriosis, cryptosporidiosis, *Staphylococcus aureus* infection, salmonellosis, listeriosis, toxoplasmosis, and *Bacillus cereus* infection.
iv. There is a high and unacceptable risk of illness from toxigenic *E. coli* or *Salmonella* from beef consumption each year and a high level of consumer concern over the quality of the meat they buy. Consumers who have less concern are most likely to report gastrointestinal illness. The conclusion of the review is that there are very high levels of biological and other hazards in foods sold in Nigeria and that meat is particularly risky. This study found the majority of meat sampled contained unacceptable levels of one or both of the important pathogens surveyed (toxigenic *E. coli* and *Salmonella* spp.). It suggested that the dynamics of the two pathogens are different and further investigation would be needed to understand this and identify critical control points. Meat at the abattoir was highly contaminated and this is obviously a critical point for preventing contamination down the chain. Cooking is considered an important risk-mitigating strategy, but although it halved the risk of contamination, presence of pathogens was still unacceptably high (60%). An important finding was that a relatively small proportion of actors generated the majority of risk. This makes a risk-targeted strategy attractive where, by identifying the chains

and actors where there is greatest potential for contamination, scarce resources can be allocated to where they will have most impact. Risky practices of beef sellers include: selling meat over a long period; retaining meat for sale the next day; tasting raw meat; inadequate washing of surfaces; and negligible use of disinfectants. Beef-sellers reported more incidences of diarrhoea than customers, suggesting they are an at-risk group but also providing an incentive for changing behaviour.

v. Information asymmetries between beef sellers and consumers may result in value chain failures in delivering safe meat. Most beef-sellers agreed that '*price is more important than quality to consumers*' but most consumers disagreed with this statement. Additionally, 92% of beef-sellers believed that customers would complain if there were problems with beef but only 45% of customers agreed.

vi. Abattoirs appear to be a key point where contamination occurs. The abattoir environment and slaughtering processes play vital roles in determining the wholesomeness and safety of meat. Unhygienic practices in abattoirs and during post-process handling are associated with potential health risks to consumers due to the presence of pathogens in meat and environmental contamination. Abattoir operations generate large quantities of waste which constitute a major source of environmental pollution. Improper management of water is responsible for pollution of water bodies with an increased risk of water-borne disease in humans. Working in abattoirs can also result in occupational disease and injury. Most butchers are poor and have not received occupational training; there is no compensation if meat is condemned and butchers may strongly and even violently resist condemnation of diseased and unwholesome meat. Moreover, the QMRA model found that the rate of contamination at the slaughter slabs was consistently correlated to the risk of illness from consuming contaminated beef.

vii. Traditional approaches to food safety centred on infrastructure provision and command and control regulation have not led to sustainable improvements in food safety. The study shows the importance of butchers' associations and suggests they may be good entry points for interventions to improve food safety. It also finds that even under the difficult conditions of Bodija market, Ibadan, some groups can achieve better food safety and better health outcomes. This study shows a clear relation between meat of poor microbiological quality and higher incidence of gastrointestinal disease (23% more illness in groups with poor quality meat).

viii. Newer approaches based on risk rather than hazard, and taking into account incentives for behaviour change as well as governance structures are 'better bets' for sustainably improving the safety of beef value chains. Moreover, while contaminated food is always a hazard, the risk to human health depends on the risk-enhancing and risk-reducing processes and practices along the 'point of sale' to 'point of consumption' risk pathway. For example, in parts of East Africa raw milk is highly contaminated with *Brucella* pathogens but because the practice of boiling milk is almost universal the risk to consumers is low. In the past, food regulation and inspection was mainly based on the level of pathogens in food. It is increasingly realized that this is a blunt approach and that assessing the risk to human health is much more constructive and useful. An important concept from risk analysis is that there is no such thing as 'zero risk' and because risk reduction has costs, there is an 'appropriate level of protection' which society is willing to support. For example, when the nutrition of many poor consumers is dependent on cheap food and the livelihoods of many poor producers are dependent on marketing animals, it may be unrealistic to demand highly costly standards of food safety.

ix. Because gender influences engagement in all aspects of the 'farm to fork' risk pathway, gender-aware strategies are likely to be more effective. The study found that women had significantly better hygienic practice and groups with higher proportions of women had better quality meat.

x. This study showed that marked and significant differences exist between regions, implying food safety interventions should be targeted for regions. Risky practices (e.g. eating cold leftovers; frying for less than seven minutes; giving leftovers to animals; eating raw meat) were reported by a minority of consumers but have potentially large impacts on health. False beliefs were common, for example, 88% of people believed that you can tell unsafe beef by its appearance and 96% that cooking beef makes it safe. Most customers (81%) were concerned about the meat they bought (especially hygiene and quality) and 81% disagreed with the statement that customers cared more about low price than quality. Consumers who had concerns about safety reported much fewer cases of illness, and those who believee price is more important than quality reported much more.

8.2 Conclusions

The slaughterhouse is a critical control point at which massive contamination occurs and diseased animals are not effectively identified. Adherence to hygienic principles during food processing, storage, marketing and preparation as part of the measures to promote good health and prevent the transmission of pathogens from animals to humans cannot be over-emphasized. Training of abattoir workers should be accompanied by provision of adequate and functional facilities that will limit meat contamination during processing, storage and transportation.

In Nigeria, butchers' associations have an important role in the meat value chain. Members have some education and, for most, meat processing is their primary occupation. Slaughter, processing and sale of beef take place under unhygienic conditions and meat sold by association members is of unacceptable quality. However, some groups have consistently better quality meat and this is positively correlated with the proportion of women members. Given the two-week period previous to the interview as recall time, 85% of meat sellers reported illness and 47% reported gastrointestinal illness. Eating beef, eating chicken, eating offal, consuming one's own products, and belonging to a group with poor quality of meat were all strong and significant predictors of self-reported gastrointestinal illness.

Despite the uncertainties associated with the prediction of the risk of illness due to the consumption of beef contaminated with *E. coli* O157 and *Salmonella* beef, as a result of uncertainties in some of the parameters, the model provides a scientific basis for the awareness of the importance of the risk. In addition, the model provides the foundation for risk managers and public health professionals to gain a better understanding of the prevention strategies against illnesses associated with the consumption of contaminated beef.

Four factors showed consistent correlation with the probability of illness from the consumption of beef contaminated with *E. coli* or *Salmonella*, namely,

- initial concentration in the faeces before the animal was processed;
- contamination rate at the slaughter slabs;
- rate of presence of the pathogen in roast beef (efficiency of preparation); and
- susceptibility of the host.

Analysis indicates four related and potential critical control points to reduce the incidence of the disease burden in the population as follows:

1. Controlling the likelihood of shedding the pathogen in faeces by introducing intervention strategies at the production site. One factor to consider before implementing such an intervention is the cost of the strategy. For example, in some parts of the world vaccination against *E. coli* O157:H7 has been implemented to reduce the incidence of shedding of this pathogen. We are not sure that would be a strategy of choice in the Nigerian situation, irrespective of the economic assessment [free market (benefit cost ratio) or cost-effectiveness].
2. Improving abattoir environment and slaughter processes through an elective mix of public-private investment, stakeholder-centred and incentives-based risk management, targeted education and awareness creation.
3. Reducing the incidence of diarrhoea in the population in general. A strategy like increasing awareness about the risk of illness coupled with education on improved sanitary and hygiene practice would decrease the risk of illness.
4. Reducing the bacterial count in roast beef through education on cooking through either increasing the temperature, time of cooking or a combination of both, without compromising taste.

8.3 Recommended approaches

The conventional solutions – provision of infrastructure, control and command regulation, inspection and penalties – have self-evidently failed to deliver food safety, and provision of 'more of the same' is unlikely to have different outcomes. However, the risk-based approaches which have emerged in the last few decades, and are now widely acknowledged as best practice, offer the potential of more sustainable solutions.

Some over-arching principles are suggested below and these could be developed into more detailed strategies with inputs from stakeholders. Costing of implementation of chosen approaches needs to build in processes of engagement with the main people involved in the points identified and their present and future participation in change – conflict management and change management specialists are needed. A very specific example is the lack of adequate slaughter facilities where just building the right facility is unlikely to solve the problem. A process of engagement and discussion with butchers' and meat sellers' associations is required before an investment is made. There is a clear need to mix a good understanding of stakeholders with the ability to finance a change that both improves food safety and is acceptable to the local community.

- *Manage risks not hazards*: In the past, food regulation and inspection was mainly based on the level of pathogens in food. It is increasingly realized that this is a blunt approach and assessing the risk to human health is much more informative. For example, milk may have high levels of hazards but if 99.9% of milk is consumed boiled in tea, then the risk posed to people is low. As a first step, food safety authorities should shift from hazard-based to risk-based management. While risk assessment can be resource- and time-consuming, ILRI is pioneering rapid and participatory methods for assessing risk at low granularity.

- *Risk targeting and targeted education campaigns*: This study found that, as is typically the case, a small number of actors, chains and products are responsible for a disproportionate amount of risk. Education and public awareness programs are important measures in sensitizing the general public and people at risk; the greatest improvements of meat hygiene have been demand-led, following on from public outrage over inadequate facilities. These are essential strategies to forestall outbreaks of food-borne infection and limit the spread of infection should outbreaks occur. Identifying and then targeting persons with risky attitudes and practices and at-risk people will maximize the efficiency of risk management.

- *A farm-to-fork approach*: Hazards enter the value chain at different points and increase or decrease as the result of conditions and practices. A pathway approach is needed to understand where and how to tackle key hazards. The importance of farm-level interventions is increasingly recognized. In many cases, multiple barriers are needed to reduce the risk to people.

- *Appropriate levels of protection*: Zero risk is unobtainable and, as risk reduction has costs, there is an 'appropriate level of protection' which society is willing to support. Understanding the benefits of the traditional and informal food sector and the costs of food safety must inform the development of food safety objectives, which set out appropriate standards.

- *People-centered and incentive-based risk management*: Our studies highlight the importance of institutions, norms, beliefs and traditional practices in mitigating and increasing risk. Working with existing institutions, understanding socio-economic determinants of current practices, and creating food safety systems that reward risk reducing behaviour at all levels is an essential component of improving food safety in Nigeria.

- *Mixed public-private investment*: For investment to be sustainable, there is a need to involve the private sector from conception through to implementation. Nigeria can rely on its experience in the construction of model livebird markets to improve biosecurity and break the infection chain of the avian influenza virus and control the disease. For that project, fowl sellers' associations that accepted the concept contributed 15-20% of the construction cost and ran the model livebird markets on their own once completed and commissioned. The model livebird markets have been rated as satistfactory, successful and sustainable. This experience could be deployed to improve the abattoir environment as well as towards running transparent compensation schemes for condemned carcasses.

- *Monitoring and evaluation of pathogen load in the chain*: Prevention of many food-borne zoonotic infections in humans can best be achieved by reducing the infection rates in animal reservoirs. Epidemiological surveillance and periodic monitoring provide good understanding of the dynamics of food-borne pathogens in animal populations and help in the assessment of the factors that contribute to the distribution and persistence of the pathogens in animals as well as their transmission to humans. This could be achieved through outbreak investigations. The culture of outbreak investigation improved markedly in Nigeria as a result of activities linked to avian influenza control. This needs to be further strengthened and institutionalized by incorporating ongoing monitoring of pathogen load in the chain at critical points and analysis aimed at evaluating the impact of change.

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Appendix 1: Literature review summary

Problems reported at slaughtering house

Hazards considered	Product	Processing method	Risks Identified	Method of laboratory test	Prevalence of food-borne disease (FBD)
Probable meat contamination	Beef	Slaughtering and dressing of carcasses	Unhygienic and crammed transportation Unhygienic pre-slaughter handling, use of brutal force Slaughtering on bare ground and dressing amidst ingesta Proximity in slaughtering sick and healthy animals, with animal owners concealing lesions Transportation of meat on uncovered head pans, careless sales practices in open air Improper waste disposal	Visual appraisal	N/A Adeyemo et al. 2009
Probable meat contamination	Beef	Slaughtering and dressing of carcasses	No ante mortem examination Dressing on bare floor together with viscera and ingesta Hasty postmortem examination Inadequate waste disposal, and filthy environs attracting pests Unhygienic and inadequate transport systems Display of meat in open air	Visual appraisal, interviews and records	N/A Adeyemo, 2002
Probable meat contamination	Beef	Slaughtering and dressing of carcasses	Lack of control and inspection of animals in transit(approx only half of the populations in transit for slaughter are inspected) Inhumane handling and slaughter Slaughter of animals in close proximity to accumulated waste, and lack of water Absence of sanitary inspection Stiff and or violent resistance of meat condemnation by butchers Dragging of dressed carcasses on the ground or carrying carcasses on shoulders, loading onto unconventional vehicles like hired taxicabs Open air marketing with poorly dressed merchants in the presence of flies	Visual appraisal, interviews and records	Tuberculosis 4.42% Fascioliasis 8.00% Okoli et al. 2006
Salmonellosis	Bacon	Slaughtering and dressing of carcasses	Overcrowding in poorly designed holding pens and during transportation predisposes the animals to flare-up of silent infection Possible carcass contamination from the abattoir environment. Cross contamination of meat by the abattoir workers	Samples from slaughter tables, hand washing basins worker's hands, holding pens and butcher's knives. Standard bacterial isolation procedures and antigenic characterization.	Slaughter tables 20%, Hand washing basins26.7% Worker's hands 26.7%, Holding pens 20% and butcher's knives 15.4%. Amaechi and Ezeronye, 2006
Salmonellosis	Meat	Packing	Not disclosed	Samples from the premises and processed carcasses. Standard isolation procedures	25.9% and 29% in the two plants respectively Addo and Dialo, 1982
Probable meat contamination	Beef	Slaughter and dressing	Poor pre- and post-slaughter handling of cattle and carcasses. Inadequate equipment and maintenance. Lack of running tap water and proper waste disposal. Absence of stunning Beef marketing chain had poor preservation and storage facilities.	-	General Joseph 1999

Food-borne disease in people

Name of disease	Method of identifying the sick	Any risk factors identified	Method of lab. Test	Prevalence/ Incidence
Acute diarrhoea in adults	Clinical diagnosis by physician (more than three watery stools a day)	Limited access to potable water EHEC EAEC *Entamoeba histolytica*	Macroscopic examination for blood and mucus.Followed by direct microscopy for parasites and erythrocytes; and culture for enteric pathogens, DNA hybridization and serotyping.	EHEC (20.4%) EAEC (15.4%) *Entamoeba histolytica* (35.4%) (Okeke et al. 2003)
Campylobacteriosis	Clinical diagnosis by physician (diarrhea)	*Campylobacter jejuni, C.coli*	Standard culture for enteric pathogens, DNA hybridization and serotyping.	16.5% (Coker and Adefeso, 1994)
Diarrhoea	Clinical diagnosis by physician	*Cyclospora cayetanensis* HIV status, all seropositive patients were infected	Concentration of samples using the sedimentation technique, staining with Zehl-Nielsen stain followed by microscopy and confirmation by autoflorescence	0.01% (Alakpa et al. 2003)
Protozoan infection	Clinical diagnosis by physician	*Giardia lamblia, Entamoeba histolytica, Chilomastix mesnili* from consumption of contaminated vegetables	Fecal staining and examination	*Giardia lamblia* 47.8%, *Entamoeba histolytica* 28.3% and *Chilomastix mesnili* 19.7% (Nzeako, 1992)
Acute diarrhea	Clinical diagnosis by physician	*E.coli* *Shigella* *Salmonella* *Klebsiella* *Aeromonas* *Plesiomonas*	Standard bacterial isolation, biochemical characterization and serotyping procedures	*E.coli* (45.6%) of which, EPEC was 59%, ETEC 20.5%, EIEC 12.1% and EHEC 8.4%. Shigella 20.9% *Salmonella* 17% *Klebsiella* 8.8% *Aeromonas* 4.4% *Plesiomonas* 3.3% (Akinyemi et al. 1998)
Diarrhea	Clinical diagnosis by physician	EHEC O157:H7	Stool culture on sorbitol McConkey agar. Cytotoxicity of isolates was determined in Vero cells, antimicrobial sensitivity and serotyping done.	6% all the isolates induced cytotoxicity but were susceptible to antimicrobials. (Olorunshola et al. 2000)
-	-	EHEC O157:H7	Stool culture on sorbitol McConkey agar. Cytotoxicity of isolates was determined in Vero cells, antimicrobial sensitivity and serotyping done.	31.8% (Smith et al. 2009)
Toxoplasmosis in antenatal women	Serology	*Toxoplasma gondii* Tasting of meat while cooking. Drinking of untreated water from wells. Increased with age.	Serology using anti-*T.gondii* IgM and IgG commercial kits (enzyme immunosorbent assay)	29.1% for IgG and 0.8% for IgM (Ishaku et al. 2009)
Toxoplasmosis in pregnant women	Not disclosed	*Toxoplasma gondii* Poor environmental sanitation conditions and considerable contamination of cat	Serology by the dye test	78% had dye test titres of 1/16 and 47% had titres of 1/128 or greater. (Onadeko et al. 1992)

		faeces.		
Cholera	Clinical diagnosis (diarrhoea)	*Vibrio cholerae* O1 *Vibrio cholerae* non-O1 *V. parahemolyticus* Consumption of fishery products and left over foods, improper sewage disposal and contact with sea water.	Microbial culture using thiosulphate citrate bile salts sucrose	*V. cholerae* O1 (75) *V. cholerae* non-O1 (10) *V. parahemolyticus* (21) (Eko et al. 1994)
Paragonimiasis	Not disclosed	*Paragonimus uterobilateralis* Consumption of crabs, especially during the dry season.	Microscopic examination of sputum and enumeration of *P.uterobilateralis* eggs	16.8% (Udonsi, 1987)
Diarrhoea	Clinical diagnosis	*Aeromonas* spp. *Plesiomonas shigeloides*	Standard bacteriological culture and biochemical characterization	*Aeromonas* 2.26% *P. shigelloides* 0.68% (Alabi and Odugbemi, 1990)
Childhood diarrhoea	Clinical diagnosis by physician	*E.coli* ETEC EPEC EAEC EHEC *Salmonella* *Shigella* *Yersinia enterocolitica* *Aeromonas hydrophila* *Entamoeba histolytica* *Giardia lamblia* *Trichomonas hominis* *Trichuris trichura*	Standard culture and biochemical testing of isolates, Serotyping and cytotoxicity assay in Vero and HEp-2 cell lines	ETEC 14.4% EPEC 10.7% EAEC 9.3% EHEC 5.% *Salmonella* 3.3% *Shigella* 5.1% *Y.enterocolitica* 0.9% *A. hydrophila* 1.4% *E. histolytica* 0.5% *G. lamblia* 0.5% *T. hominis* 0.5% *T. trichura* 0.9% (Ogunsanya et al. 1994)
Taeniasis	Not disclosed	*Taenia solium* ova	Human infection was assessed by examining iodine-stained stool samples collected from patients	8.6% (Onah and Chiejina, 1995)
Helminthiasis	Not disclosed	*Ascaris lumbricoides* *Trichuris trichiura* *Necator americanus* *Strongyloides stercoralis*	Direct faecal examination.	*Ascaris lumbricoides* (54%), *Trichuris trichiura* (43.7%) *Necator americanus* (42.7%) *Strongyloides stercoralis* (33%) (Udonsi et al. 1996)
Cryptosporidiosis	Clinical diagnosis by physician	*Cryptosporidium*	Direct faecal examination for oocysts	2.3% (Reinthaler et al. 1987)
Gastroenteritis and diarrhea	Clinical diagnosis by physician	*Cryptosporidium*	Direct faecal examination for oocysts after staining with Safranin methylene blue	21% (Kwaga et al. 1988)
Cryptosporidiosis with diarrhea	-	*Cryptosporidium*	Direct faecal examination for oocysts after staining with ZN stain	13.5% (Tairuwa et al. 2007)
Diarrhea	Clinical diagnosis by physician	*Cryptosporidium*	Direct faecal examination for oocysts	5.6% (Alaribe et al.1998)
-	-	*Cryptosporidium* *Balantidium coli* Pigs scavenging and defecating, defective environmental hygiene & usage of untreated pig faeces as manure	Direct faecal examination for oocysts	*Cryptosporidium* 5.7% *Balantidium coli* 1.8% (Yatswako et al. 2007)
Salmonellosis	Clinical diagnosis by physician	*Salmonella typhimurium* from the consumption of sandwich	Standard bacterial isolation	20 people died (Ojeniyi and Montefiore, 1987)
Brucellosis	Not done	Improper carcass inspection and Direct contact of butchers with carcasses, blood, aborted foetuses	Serology by Rose Bengal plate agglutination test	31.82% (Cadmus et al. 2006)
Yam flour poisoning	Patients presented with diarrhoea,	Inclusion of lethal preservatives in yam	Not disclosed	5 families

	vomiting, abdominal pain, convulsion and loss of consciousness	flour during processing		(Adedoyin et al. 2008)
Food poisoning from insecticide treated beans	Patients presented with symptoms of food poisoning	Insecticide treated beans	Not disclosed	9 adults (Amene, 1986)

Hazards reported in foods in Nigeria

Name of hazard(s)	Variation by season/practices	Type of food matrix	Method of sample collection used	Method of laboratory test	Prevalence or incidence of hazards
Enteropathogenic *E.coli*	Higher during the dry season in *Amaranthus* spp.	Vegetables	Random aseptic	MacConkey agar plate culture and enumeration, Biochemical tests (IMVIC), ileal loop test.	
Salmonella	Higher in dry than wet season in one location only	Vegetables		Enrichment in selenite F broth, Culture on *Salmonella Shigella* agar, Slide agglutination test	
Vibrio	No variation	Vegetables		Enrichment in alkaline peptone water, Isolation on TCBS, Slide agglutination test.	
Salmonella Hiduddify		Poultry meat	Stratified random sampling with strict observation of asepsis	Bacterial isolation by enrichment in selenite F broth, Biochemical tests (IMVIC, triple sugar iron (TSI), urease, oxidase and hydrogen sulfide) were done on presumptive *Salmonella* isolates. Out of 130 isolates 41 were selected and serotyped by 'O' and 'H' antigens using hyperimmune serum. 41 isolates were tested for antimicrobial susceptibility. Pulsed-field gel electrophoresis technique was used to detect genetic relatedness	15% prevalence of *Salmonella*; with 95% of the isolates being *S.* Hiduddify. A low level antimicrobial resistance was observed in all isolates. (Raufu et al. 2009)
Yersinia enterocolitica (ail +ve) bioserotype 2/O:9		Cow milk Soup	Random aseptic	Inoculation of sample into phosphate buffered saline, then incubation for 21 days followed by alkali treatment and plating on McConkey agar. Identification of *Yersinia* colonies using oxidase and Christensen's urea. PCR targeting the *ail* gene to identify pathogenic *Y. enterocolitica*. The pathogenic *Yersinia* were biotyped with pyrazinamidase, esculin, salicin, tween, indole, xylose and trehalose tests , serotyped using antisera and characterized using pulsed-field gel electrophoresis	1.2% (milk) 3% (soup)
Yersinia pseudotubeculosis (inv		Cow milk Fish(raw)		Inoculation of sample into phosphate buffered saline,	1.6% (milk) 4% (raw fish)

+ve) bioserotype 1/O:1		Fish(roasted)		then incubation for 21 days followed by alkali treatment and plating on McConkey agar. Identification of *Yersinia* colonies using oxidase and Christensen's urea. PCR targeting the *inv* gene to identify pathogenic *Y. pseudotubeculosis.* The pathogenic *Yersinia* were biotyped with melibiose, raffinose and citrate tests, serotyped using antisera and characterized using pulsed-field gel electrophoresis.	3% (roasted fish) (Okwori et al. 2009)
Shiga toxin producing *E.coli.*	Significantly less in milk from farms that practiced pre-milking examination and washing of udders (milking hygiene)	Milk	Multistage cluster sampling, with asepsis	Culture on agar plates to determine total plate counts and coliform counts. PCR was done on all *E.coli* isolates to identify the presence of the virulence gene *Stx2d.*	40% of the *E.coli* isolates ha the virulence gene. (Waziri et al. 2010)
Salmonella paratyphi A *S.typhimurium* *S.typhi* *S.gallinarum*		Beef	Random, aseptic sampling into bottles of nutrient broth	Culture, biochemical testing and serotyping) Pre enriched cultures were inoculated in selenite F broth, subcultured on deoxycholate citrate and propylene glycol deoxycholate citrate agar. *Salmonella* typical colonies were cultured onto TSI agar, urea agar and lysine broth. Suspected *Salmonella* colonies that were H_2S+ve, urease-ve and lysine+ve were re-cultured to PGDA plates. Biochemical tests and serotyping using polyvalent 'O' and 'H' specific anti-serum were done.	4.2% 2.1% 8.3% 2.1% (Orji et al. 2005)
Bacillus cereus	Storage of foods at ambient temperatures for several hours and the prevailing high humidity at the time of sampling. Food vendors without shelter had a higher prevalence than vendors with shelter	Fried fish, soup, boiled rice and bean meal	Random, aseptic collection into wide mouth sterile containers.	(Isolation and biochemical testing)Inoculation of culture on mannitol/egg yolk/polymyxin agar. Biochemical testing of presumptive *B.cereus* colonies with VP, catalase, citrate, spore stain and motility tests.	26.3%
Staphylococcus aureus	Holding foods for long periods of time without reheating and post cooking handling. Food vendors without shelter had a higher prevalence than vendors with shelter	Bean meal and fish	Random, aseptic collection into wide mouth sterile containers.	Isolation on mannitol salt agar followed by biochemical tests. Tube coagulase test, haemolysin test and enterotoxin production testing was done.	15.0% of these, 48% were hemolytic while 18% were enterotoxigenic. (Umoh and Odoba, 1999)

Campylobacter fetus subsp *jejuni*	Immersion of slaughtered birds in hot water reduced the recovery rate of the organism	Poultry meat	Aseptic swabbing of the cloaca of carcass?	Culturing on colistin/amphotericin/keflin agar. Identification of organism was based on morphological, cultural and biochemical criteria.	7.1% (Adekeye et al. 1989)
Faecal coliforms (unspecified)	Lengthening of the storage time increased the faecal coliform counts significantly	Ogi-fermented cereal weaning food	Random aseptic	Bacterial culture with determination of faecal coliform counts pH was also determined	31.3% of the samples had high coliform counts (Odugbemi et al. 1993)
Staphylococcus aureus and *Klebsiella* sp *Escherichia coli*, *Salmonella* sp. and *Klebsiella* sp.	N/A	dairy foods (wara) (nono)	Random aseptic	Standard isolation and characterization procedures. Antimicrobial sensitivity testing	100% resistance to ampicillin
Bacillus subtilis, *E. coli*, *S. aureus, Klebsiella* sp. and *Enterococcus faecalis*		Cereal based fermented foods (ogi and kununzaki)		Standard isolation and characterization procedures. Antimicrobial sensitivity testing	100% resistance to penicillin, ampicillin and chloramphenicol. (Olasupo et al. 2002)
ibrio parahemolyticus *V.cholerae* non-01 *V.alginolyticus*	Trimodal variation that coincides with hot periods of the year	Shellfish	Random aseptic	Standard isolation and characterisation procedures	13.6% 9.4% 7.1% (Eja et al. 2008)
Enterotoxigenic, coagulase positive *Staphylococcus aureus*	Minimal or no post-processing hand contact greatly reduced prevalence of the hazard, particularly in akara and moinmoin.	Ready-to-eat meat, fish and vegetable foods.	Random aseptic	Standard isolation and characterisation procedures and testing for production of enterotoxins	62% with 48%of the isolates being enterotoxigenic (Sokari, 1991)
Alfatoxin B_1 *Aspergillus flavus, A.niger* and *Penicillium*		Dried yam chips	Random, aseptic	Determination of moisture content, pH, fungal contamination and aflatoxin B_1 by thin layer chromatography.	4% had aflatoxin above the tolerance levels The fungal colony forming units exceeded the tolerance levels. (Bankole and Mabekoje, 2004)
Aflatoxin B_1	The seeds from the forest region had a higher moisture content, spoilage and aflatoxin levels than those from the savanna region.	Shelled melon seeds	Random, aseptic	Isolation of moulds on potato dextrose agar and aflatoxin analysis by thin layer chromatography.	3.5% had aflatoxin above the tolerance levels (Bankole et al. 2004)
Aflatoxin B_1 Ochratoxin A	Not disclosed	Maize based gruels	Random	Analysis for aflatoxin and ochratoxin	Aflatoxin B_1 25% Ochratoxin A 8% (Oleyami et al.1996)
Total bacterial count,	High beef	Dried sliced	Aseptic in	Moisture content was	TBC 2.4-3.5x10^4

Enterobacteriaceae, *Staphylococcus aureus, E coli, Klebsiella pneumoniae, Bacilllus subtilis* and *Pseudomonas aeruginosa*.	moisture content increased bacterial counts	beef	aluminium foil	determined, decimal dilutions of blended beef inoculum were spread on nutrient agar, McConkey agar, Baird Parker agar for enumeration of total bacteria, enterobacteriaceae and *S.aureus* respectively. Other bacterial genera were characterized by colony morphology and biochemical tests	cfu/g *Ent* 2.61-2.9x10^4 cfu/g *Staph*1.6-2.05x10^4 cfu/g *E.coli*1.2-3.8x10^4 cfu/g (Raji, 2006)

Name of hazard(s)	Variation by season/practices	Type of food matrix	Method of sample collection used	Method of laboratory test	Prevalence or incidence of hazards
Mean microbial load Coliforms *E. coli, Klebsiella pneumoniae Pseudomonas aeruginosa Enterobacter* spp. *Citrobacter freundii Salmonella* spp. *Serratia marcescens Proteus vulgaris*	Not disclosed	Beef meat	Random aseptic	Standard bacterial culture, isolation and biochemical characterization	Total 2.24-5.4x10^4 cfu/g Coliforms 1.05-3.72x10^3 cfu/g *E.coli* 11.1% *K. pneumoniae* 16.7% *P. aeruginosa* 11.1% *Enterobacter* 13.9% *C. freundii* 13.9% *Salmonella* 11.1% *S. marcescens* 11.1% *P. vulgaris* 2.8% (Ukut et al. 2010)
Antibiotic residues and antibiotic resistant bacteria	Not disclosed	Milk products (nono, yoghurt, evaporated milk, cheese and ice cream)	Random and aseptic	Determination of antibiotic residues using an atomic absorption spectrophotometer. Samples were cultured for pathogens and antibiotic sensitivity of strains done by the disc diffusion methods	All the milk products had antibiotic residues. Resistant bacteria: *Bacillus cereus* (penicillin and tetracycline), *Enterococcus faecalis* (streptomycin), coagulase negative *Staphylococcus* spp. (penicillin, erythromycin and tetracycline) and *Clostridium botulinum*, *E. coli* and *Proteus vulgaris* (tetracycline) (Adetunji 2008)

Name of hazard(s)	Variation by season/practices	Type of food matrix	Method of sample collection used	Method of laboratory test	Prevalence or incidence of hazards
Bacterial(*Staphylococcus* spp., *Pseudomonas* spp., *Bacillus* spp., *Salmonella* spp., and *Shigella* spp.) and fungal(*Aspergillus*, *Rhizopus* spp. and *Penicillium* spp.) contamination	-	Fish	Random and aseptic	Culture of swabs on nutrient a gar, Sabouraud's dextrose agar and *Salmonella*-shigella agar. Macroscopic and microscopic examination of colonies and biochemical tests.	Bacterial contamination 73.8% Fungal contamination 26.2% (Odikamnoro et al. 2009)

Polycyclic aromatic hydrocarbons (PAH)	Samples that were smoked with wood fire had more PAHs than those smoked on charcoal fire	Fish and meat	Random	Microwave-assisted saponification with simultaneous extraction followed by solid-phase extraction (SPE), high-performance liquid chromatography (HPLC) separation and spectrofluorometry	100% (Akpambang et al. 2009)
Enterohemorrhagic *E.coli* O157:H7	-	Meat Vegetables	Random and aseptic	Standard microbial culture biochemical characterization and serology	General prevalence 2.32% (Enabulele and Uraih, 2009)
Salmonella, *Proteus, Shigella, Staphylococcus aureus, Escherichia coli Clostridium, Streptococcus Klebsiella* and *Lactobacillus*	-	Sausages	Random aseptic	Standard bacterial isolation and characterization	- (Oluwafemi and Siliaye, 2006)

Name of hazard(s)	Type of food matrix	Method of sample collection used	Method of laboratory test	Prevalence or incidence of hazards
Staphylococcus aureus	Fermented milk (nono)	Random aseptic	Culture on mannitol salt agar plate and blood agar followed by Grams stain, catalase and cogulase tests.	25-45% (Nnadi, 2006)
Bacterial and fungal contamination	Shrimps	Aseptic and random	Microbiological isolation using the appropriate media for culture.	*Bacillus* sp. 16.7%, *Salmonella* sp. 15.0%, *Shigella* sp. 15.0%, *Enterobacter* sp. 10.8%, *Micrococcus* sp. 10.8%, *Escherichia coli* 10.0%, *Flavobacterium* sp. 4.2%, *Staphylococcus aureus* 4.2% and *Pseudomonas* sp. (0.8%. *Rhizopus* sp. 6.7% , *A. flavus* 2.5%, *A. fumigatus* 0.8%, *M. mucedo* 0.8%, and *Saccharomyces* sp. 0.8%. (Okonko et al. 2008)
Mycotoxins	Maize	Random aseptic	Quantification by HPLC-Mass Spectrometer	36.3% (Adejumo et al. 2007)
Hemolysin producing *Aeromonads*	Meat and offals	Random aseptic	Isolation and characterization	*A. sobria* 67.3% *A.hydrophila* 21.2% (Amadi et al. 2005)
Enteropathogenic bacteria	Processed and minimally processed ready-to-eat foods	Random aseptic	Isolation and characterization of bacteria	*E. coli* 46.6% *V. cholerae* 25.0% *Salmonella* typhi 10.0% (Bukar et al. 2010)
E.coli O157:H7	Beef meat	Aseptic and random	Isolation on sorbitol McConkey and serotyping by agglutination kits and antibiotic susceptibility testing.	61.2% of the total *E.coli* isolates and highly resistant to tetracycline (Olufemi, 2010)
Zoonotic bacteria	Dog meat	Aseptic random	Bacterial isolation and biochemical characterisation	*Staphylococcus aureus* 34%; *Salmonella* spp. 4%; *Brucella canis* 6%; *Clostridium perfringens* 2.8% and *E.coli* 26.8%. (Okolo, 1989)

Zoonoses and food-borne disease in animals in Nigeria

Disease/syndrome	Sampling method	Risk factors identified	Method of laboratory test	Prevalence/incidence of FBD
Salmonellosis in dogs	Random	*S.typhimurium*	Standard bacterial isolation and biochemical characterization	3.7% (Ojo and Adetosoye, 2009)
Salmonellosis in poultry	Random	*S.hirschfeldii*	Standard bacterial isolation and biochemical characterization	1.86% (Ojeniyi, 1984)
Salmonellosis in the grey duiker	Random	Antibodies to *Salmonella paratyphi* serotypes B and C and *S.typhi* serotype D	Serology to detect both 'O' and 'H' antigens in the grey duiker	44% and 6% had antibodies to the H and O antigens, respectively. 18% had antibodies to both the H and O antigens. Antibody titres of 1/320 were detected against *Salmonella paratyphi* serotypes B (12%) and C (2%) and *S. typhi* serotype D (8%) (Ogunsanmi et al. 2000)
Salmonellosis in pigs	Random	*Salmonella choleraesuis* *S. typhimurium* *S. enteritidis* *S. infantis*	Standard isolation from animal organs, biochemical testing and antigenic typing.	15.8% (Amaechi and Ezeronye, 2006)
Cryptosporidiosis in some domestic animals	Random	*Cryptosporidium*	Faecal samples were examined for *Cryptosporidium* oocysts using the modified Ziehl-Neelson (MZ) method	General prevalence 9.5% Pigs (4.1%) Sheep (2.1%), Goats (2.1%) and rabbits (0.0%). (Ohaeri and Iwu, 2003)
Cryptosporidiosis in capture wild animals and birds	Random	*Cryptosporidium*	Ziehl-Nielsen(ZN) and Safranin methylene blue (SMB) staining	ZN 18.2% SMB 12.1% (Ibrahimn et al. 2007)
Cryptosporidiosis and balantidiosis in pigs	Random	*Cryptosporidium* *Balantidium coli* Allowing of pigs to scavenge and defecate about	Not disclosed	*Cryptosporidium* 13.9% *Balantidium coli* 51.5% (Yatswako et al. 2007)
Toxoplasmosis in chicken	Random	*T. gondii*	Serologic testing by the indirect haemagglutination test	44.8% at a dilution of 1:64 (Aganga and Belino, 1984)
Toxoplasmosis in sheep and goats	Random	*T. gondii*	Serology by ELISA	6.7% in sheep and 4.6% in goats (Mani and Egwu, 2010)
Toxoplasmosis in pet dogs	Random	*T. gondii*	Serology by indirect hemagglutination	37% at 1:64 dilution (Aganga and Ortese, 1984)
Campylobacteriosis in sheep	Random	*Campylobacter*	Fecal samples were inoculated on CCDA agar followed by biochemical characterization and biotyping.	General prevalence 18.0% *C.jejuni* (79.6%) *C.coli* (11.8%) *C.lari*(6.4%) *C.upsaliensis* (2.2%) (Salihu et al. 2009a)
Campylobacteriosis in sheep	Random	*Campylobacter*	Standard isolation procedure for *Campylobacter*, biotyping and serotyping.	General prevalence 3.54% (Raji et al. 2000)
Campylobacteriosis in cattle	Random	*Campylobacter*	Fecal samples were inoculated on CCDA agar followed by biochemical characterization and biotyping	General prevalence 12.9% *C.jejuni* (65.1%) *C.coli* (23.0%) *C.lari* (7.9%) *C. hyointestinalis* (3.2%) *C.fetus* (0.8%) (Salihu et al. 2009b)
Camplobacteriosis in chicken	Random	*Campylobacter*	Standard culture procedures for *Campylobacter* and biotyping	General prevalence 77.6% *C.jejuni* (67.2%) *C.coli* (21.6%) *C.lari* (7.5%) *C.upsaliensis* (3.7%) (Salihu et al. 2009c)

Disease/syndrome	Sampling method	Risk factors identified	Method of laboratory test	Prevalence/incidence of FBD
Bovine cysticercosis	Random	*Cysticercus bovis*	Retrospective study using abattoir records and a cross-sectional study	0.7% and 9.2% for the retrospective and cross-sectional studies respectively (Ofukwu et al. 2009)
Bovine cysticercosis	Random	*C.bovis*	Carcass examination and macroscopic identification of cysts with evagination	13.4% (Quadeer, 2008)
Bovine cysticercosis	Random	*C.bovis*	Carcass examination and macroscopic identification of cysts	26.2% (Opara et al. 2006)
Bovine cysticercosis	Random	*C.bovis*	Serology by ELISA, and macroscopic examination of carcasses	By serology, 12.8% By visual examination, 3.4% (Faleke et al. 2004)
Bovine cysticercosis	Random	*C.bovis*	Carcass examination and macroscopic identification of cysts	26.14% (Okafor, 1988)
Bovine cysticercosis	Random	*C.bovis*	Carcass examination and macroscopic identification of cysts	4.0% (Okolo, 1986)
Bovine cysticercosis	Random	*C.bovis*	Retrospective study on abattoir records	0.41% (Onah and Chiejina, 1986)
Swine cysticercosis	Random	*C.cellulosae*	Antemortem examination of the tongue and thorough post mortem examination of the dressed carcass	20% (Onah and Chiejina, 1995)
Helminthiasis	Random	*Ascaris lumbricoides* ova *Strongyloides stercolaris* ova and larvae *Ancylostoma caninumova* and larvae *Toxocara canis* ova	Houseflies were examined for helminthes by centrifugation, dissection and direct smear.	*Ascaris lumbricoides* ova 0.2 and 0.81% ; *Ancylostoma caninum* 2.60 and 6.20% *Toxocara canis* 2.4 and 2.11% on their surface and GIT respectively. (Umeche and Mandah, 1989)
Helminthiasis in dogs	Random	*Toxocara canis*, *Ancylostoma* sp., *Trichuris vulpis, Dipylidium caninum, Taenidae* and *Strongyloides* sp.	Macroscopic and microscopic evaluation of dog feces for endoparasites	General prevalence 68.4% (Ogbomoiko et al. 2008)
Arcobacter infection in pigs	Random	*Arcobacter butzleri* *A.cryerophilus*	Standard bacteriological culture and multiplex PCR	*A.butzleri* (22.1%) *A.cryerophilus* (4.7%) (Adesiji and Oloke, 2009)
Brucellosis in goats	Random	*Brucella abortus* *B.melitensis*	Serology by Rose Bengal plate agglutination test and serum agglutination tests	General prevalence of 1.8% *B.abortus* 0.5% *B.melitensis* and *B.abortus* mixed infection 1.3% (Onunkwo et al.2009)
Brucellosis in cattle and goats	Random	*Brucella*	Serology by Rose Bengal plate agglutination test	Cattle 5.82% Goats 0.86% (Cadmus et al. 2006)
Tuberculosis in goats	Random	Tuberculous lesions	Macroscopic carcass examination for tuberculous nodules	0.08% (Ojo, 1994)
Staphylococcus in camels	Random	Enterotoxigenic *S.aureus*	Culture for *S. aureus* on Baird-Parker agar and determination of enterotoxin production by the double gel diffusion technique	18.6% of all *S.aureus* cultured produced enterotoxins (Adeyisun, 1985)
Q-fever in food animals	Random	Antibodies of *Coxiella burnetti*	Capillary agglutination test	Cattle 11%, sheep 16.5% and goats 8.8%. (Addo and Schnurenberger, 1977)

Appendix 2: Sampling strategies and questionnaires

Activities

A rapid assessment of meat value chain will be conducted at major abattoirs at Ibadan, Kaduna, Enugu and Abuja using structured questionnaire (according to the protocols to be developed at the meeting) and microbiological analysis to determine hazards and cost of illness. A questionnaire will be administered to a total of 400 respondents based on a systematic sampling proportional to the population served by abattoirs in each city as follows (Ibadan 200, Kaduna 100, Enugu 50 and Abuja 50). Two hundred meat samples will also be collected; 100 each from Enugu and Abuja (Ibadan and Kaduna having been covered in a previous ILRI study) from abattoirs, meat sellers, meat shops, restaurants and consumers and analysed (Figure A1 – to be validated for regional differences).

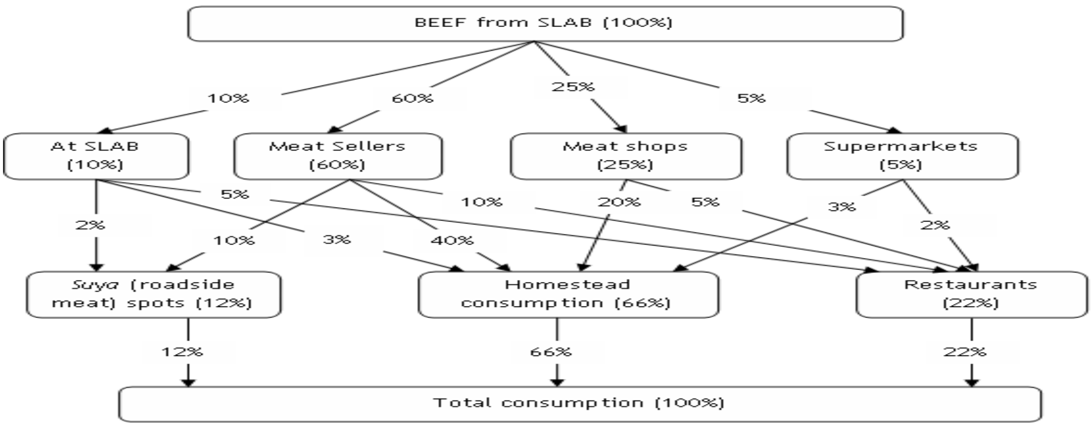

Figure A1: Provisional beef supply chain in Nigeria.

Sampling strategy for meat sellers -Questionnaire and observation check list

- Obtain a map of the selling area or make a sketch
- Draw a walking route which will take you past every meat sellers kiosk
- Count the total number of meat sellers = x
- Divide this by the amount of samples required = y and round x/y to the nearest whole number = n
- Select every n/x meat sellers e.g. if there are 90 sellers and you need 25 samples, then 90/25= 3.6 round to 4 and take every fourth meat seller starting with the first; when you reach the 90th you will have 22 samples. Take the remaining three: one from the first third, one from the middle third, and one from the last third.
- If any of the meat sellers are more than 10 times as big in terms of quantity of meat sold take 3 samples from them rather than 1 sample.
- Sample at the same time of day and note the time of day sampled
- Trace back to the slaughter-place for each butcher sampled and note where they obtain carcases

Sampling strategy for biological samples

From Enugu and Abuja

- Take 2 samples from each meat seller- early mid and late
- Take 20 samples from carcases at slaughter-place
- Take 15 samples from offal sellers
- Take 15 samples from ready to eat (RTE) food containing beef in markets

Put all samples immediately on ice and analyse in 4 hours

Present findings as cfu/gram

There must be a common number that allows slaughter place + meat seller + consumer + biological samples

Knowledge, attitude and practice of meat hygiene – Slaughter places

Name…………………………Location…………………………………………………
Enumerator……………………Date…………………………Q number…………………

1. Cuts/wounds on butchers covered with an appropriate, waterproof dressing. Yes [ ] No [ ] N.A [ ]
2. Smoking…..eating…….in the processing and marketing area (y or n in the dotted ….gap).
3. Clothes of butchers and meat-sellers on the slab clean Yes [ ] No [ ]
4. All equipment for slaughtering is clean Yes [ ] No [ ]
5. All equipment for carcase preparation are free from cracks and damage Yes [ ] No [ ]
6. Equipment for slaughtering and carcase preparation is cleaned: before _____after ….. use [write Y/N for each in the dotted gap]
7. How are cattle restrained, stunned and killed………….
8. Are animals hung to be processed or cut up on concrete………………………………..
9. Are animals cut up in their skin or on the floor……………………………………………..
10. How long between killing and first incision in the abdomen………….
11. How long does it take to cut up one animal from first incision……………..
12. Any visible contamination of the carcase with faeces Yes [ ] No [ ]
13. Possibility of contamination of the carcase with faeces Yes [ ] No [ ]
14. Any washing of carcase after killing
15. Source of water
16. Cleanliness of water
17. How many animals processed at one time………………..
18. How many times is equipment cleaned during cutting up of animal ……………
19. Equipment is sanitized: before____ after______ during ______use. [write Y/N for each].
20. What flooring used in processing meat_____________________________
21. Floors for processing smooth without cracks. Yes [ ] No [ ].
22. Floors are cleaned: before______ after____ during ______slaughter. [write Y/N for each].
23. Hand washing before_____ after________ processing, [write Y/N for each].
24. How many times are hands washed during processing of one pig………………
25. How are hands washed: Water hot….cold….running…..bucket……Soap….
26. Equipment rested on dirty surface during processing Yes [ ] No [
27. The cutting area is free of dirt. Yes [ ] No [ ].
28. Strict separation between clean and dirty areas . Yes [ ] No [ ].
29. Cattle to be slaughtered are all healthy. Yes [ ] No [ ].
30. Describe disposal of dung/manure.
31. Describe disposal of water used for cleaning Yes [ ] No [ ].
32. Toilets present……….,clean……….. with hand-basins …………. [write Y/N for each].
33. Clean water used to process the meat. Yes [ ] No [ ].
34. Veterinary inspectors present to examine the meat to be sold. Yes [ ] No [ ]
35. Veterinary inspectors oversee all animals
36. Area free from pests………….insects………….
37. Describe any abnormalities/health problems in beef or meat……………………….

Slaughter manager question list
How many cattle do you slaughter a week?
How many cattle do you slaughter a month?
How long on average do you hold cattle before slaughter?
How many employees do you have?
Have you received formal training in slaughtering?
What materials do you use for cleaning equipment?
What do you use for cleaning floors?

Slaughter personnel question lists
(Try to ask when slaughterhouse owner is not present)
What health problems do you mainly observe in cattle?
What signs have you seen in cattle carcases?
Have you been ill in the last 2 months? If so what symptoms?

Knowledge, attitude and practice of meat hygiene – Meat Sellers & Meat shops

Question
What is your name?
Gender? Male Female
How many years have you been working as a butcher?
How much beef do you sell a week in kilograms?
Where do you obtain your beef? Source 1 …………………… Source 2 …………………
How many customers on the average patronize you in a day? Regular customers …………… Occasional customers……………………
At what time do you start selling meat? …………………… At what time do you finish selling meat? …………………… How much meat (kg) do you keep for sale the next day? …………………..
Perfectly clean hands clothes equipment surfaces Yes No
How much beef (kg) do you eat a week in your household? How many people in your household eat beef?
Do you ever taste or eat raw beef?Yes b) No
How do you cook beef? And for how many minutes? Tick all that apply Boil □ ___________minutes Fry □ ___________minutes Roast □ ___________ minutes
Do you clean the surface on which meat is placed?a) Yes b) No
If the answer to 3 is yes, how often do you clean the surface? Less than once a day Once a day 2 to 5 times a day More than 5 times a day
How much water do you use each day for cleaning (utensils, kiosk and hands)? _________________ litres
What is the source of water a)Running water b) water stored in bucket c)other
Do you use any cleaning agent? Yes b) No
If yes, which of the below? (tick all which apply) Bar soap b) bleach c) detergent d) other
Have you had any health problems in the past 2 weeks?Yes b) No
If the answer is yes, what health problems? Diarrhoea and/or vomiting or constipation Fever Muscle pain or weakness Other
Is it possible to get sick from eating meat?Yes No
What sicknesses can you get from eating beef? 1 ………………………………… 2 …………………………………… 3 …………………………………
Do you agree or disagree with the following statements? Customers care more about price than about quality. Agree strongly Agree Neither Disagree Disagree strongly You can tell if beef is safe to eat by looking at it Agree strongly Agree Neither Disagree Disagree strongly Customers will complain if there is a problem with beef Agree strongly Agree Neither Disagree Disagree strongly

Knowledge, attitude and practice of meat hygiene – Household

Question
Gender? Male Female
How much of the following does your household consume a week in kilograms? Beef……………………….Other meat………………….. Vegetables…………………Dairy products Fish………………………
How many people in your household who eat beef?
At what time do you usually buy beef? At what time do you cook meat?
Do you ever tas□r eat raw beef?a) Yes b) No
How do you cook beef? And for how many minutes? Tick all that apply Boil □ ____________minutes Fry □ ____________minutes Roast □ ____________minutes
Where do you keep meat? a) Fridge b) kitchen c) others, please specify…………
What do you do with cooked beef leftovers? (tick all that apply) Eat them cold Eat them re-heated Give them to animals Throw away
Have you had any health problems in the past 2 weeks? a) Yes b) No
If the answer is yes, what health problems? a) Diarrhoea and/or vomiting and/or constipation and/or stomach pain b) Fever, or Muscle pain or weakness c) Other
Is it possible to get sick from eating beef? Yes No
Have you ever been sick from eating beef? Yes No
When did you last get sick after eating beef? (give date)
What do you do to prevent being sick from eating beef? a) Buy from a trusted source b) Cook well c) Other (please write)……………………… d) Other (please write)………………………
Do you have any concerns about the beef you buy? Please write these down. a)………………………………………………… b)………………………………………………….. c)…………………………………………………
Do you agree or disagree with the following statements? I care more about cheap price than about good quality beef Agree strongly Agree Neither Disagree Disagree strongly You can tell if beef is safe to eat by looking at it Agree strongly Agree Neither Disagree Disagree strongly I will complain to the butcher if there is a problem with beef Agree strongly Agree Neither Disagree Disagree strongly