Ensuring safety and quality in the production of beef

Volume 1: Safety

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Introduction

Beef production faces a range of challenges. There is an ongoing need to ensure safety in the face of threats from zoonoses and other contaminants, particularly in more intensive beef production systems and with more complex supply chains (allowing potentially broader transmission). At the same time, consumers have ever higher expectations of sensory quality. There has been a wealth of research to address these challenges, for example in developing more rapid and sensitive methods for detecting pathogens. These challenges are addressed in the two volumes of Ensuring safety and quality in the production of beef production. Volume 2 reviews developments related to quality. This first volume reviews current research on identifying and managing key hazards in the supply chain for fresh beef, from the farm through to slaughter, packaging, retail display and consumer handling.

Part 1 Ensuring safety on the farm

The first group of chapters review current research on zoonoses related to cattle. Chapter 1 summarises what we currently know about zoonotic parasites, viruses and pathogens. Pathogenic organisms are highly variable and adapt well to a changing environment. Surveillance and eradication programmes have worked well to control some zoonotic diseases, particularly where the illnesses are acute and symptoms in animals are easily recognisable. However, some zoonotic remain less easy to recognise. More research is still needed to reduce pathogens in the cattle production environment and minimise transmission to humans.

In the case of each pathogen, the chapter provides a concise review of current knowledge on growth conditions, mechanisms of transmission and causes of recent outbreaks. The chapter begins with zoonotic diseases related to cattle: anthrax, bovine spongiform encephalopathy (BSE), brucellosis and tuberculosis. It then covers zoonotic parasites and viruses: Cryptosporidium, Giardia and haemorrhagic fevers. Finally, it reviews the major zoonotic pathogens related to cattle: Escherichia coli, Salmonella, Campylobacter, Leptospira, Listeria and other pathogens.

Good animal husbandry has significantly improved the safety of beef supply. The chapter discusses pathogen control using animal management and biosecurity practices. These aim to prevent the introduction of infection, the survival and spread of infection within the herd or flock and, where necessary, reduce or eliminate an established infection. After a detailed review of the effectiveness of the use of vaccines, the chapter discusses non-traditional interventions such as probiotics, direct-fed microbials (DFM), competitive exclusion (CE) cultures and prebiotics to reduce pathogens in livestock animals. As the chapter points out, the bacterial microbiota in the gastrointestinal tract is highly complex and the scientific community is just only starting to understand the beneficial and antagonistic interactions between microorganisms in the gut and opportunistic pathogens.

As discussed in Chapter 1, the main food-borne pathogens of concern in the beef chain are Shiga toxin-producing Escherichia coli (STEC) and Salmonella. Other pathogens, including Listeria monocytogenes and Campylobacter spp. are also important. The occurrence and development of antimicrobial resistant (AMR) pathogens in the beef chain
is also a concern. Though both accurate and reliable, traditional culture-based methods are laborious and time consuming. Rapid methods, including nucleic acid-, immunologic-, and biosensor-based techniques can be very sensitive and specific and provide more timely information regarding the presence of pathogens in the beef chain. Chapters 2 and 3 review these methods as well as recent advances in next generation sequencing technologies.

As the chapter describes, many types of rapid methods, including nucleic acid- and immunologic-based methods, have been developed and are commercially available for detection of pathogens, including STEC and *Salmonella*. Nucleic-acid-based methods rely on detection of specific DNA or RNA sequences of the target organism. The most commonly used DNA-based methods utilise the polymerase chain reaction (PCR) that involves amplification of specific sequences of the pathogen and detection of the ethidium bromide (or other stain)-stained PCR products by agarose gel electrophoresis. Nucleic acid-based methods, particularly PCR methods, are commonly used since they have high sensitivity and specificity, can be automated, allow detection of multiple pathogens, and provide reliable results. However, sample processing is necessary to remove inhibitors of the PCR assay or other nucleic acid-based method.

Immunological methods involve the use of monoclonal or polyclonal antibodies that bind to an antigen of the bacterium or to a toxin. Types of immunoassays include enzyme-linked immunosorbent assays (ELISA) or enzyme immunoassays, fluoroimmunoassays, radioimmunoassays, chemiluminescence immunoassays and lateral flow immunoassays. Immunologic-based assays can also be designed to be specific, can be automated, are easy to perform, and allow detection of bacterial toxins. However, sensitivity may be lower than that of nucleic acid-based assays, and cross-reactivity of the antibodies with closely related antigens can occur. Improvements in these rapid methods will continue to be made, with the goal of being able to obtain real-time or near real-time results.

Biosensor-based methods consist of devices that have a bioreceptor that can be an antibody, enzyme, nucleic acid, or cells and a transducer that converts the interactions into a measureable signal. Examples are optical, electrochemical, or mass-based biosensors, surface plasmon resonance, multianalyte array/evanescent wave, quartz crystal microbalance or surface-enhanced Raman scattering biosensors. As noted, rapid methods are very useful as screening methods targeting specific pathogens in large numbers of samples. However, positive results are still often regarded as presumptive and need to be confirmed by traditional culture methods which remain the gold standard. More still needs to be done to refine sensitivity, specificity and reliability.

Chapter 2 also reviews methods for detecting AMR in pathogens. As the chapter points out, the scientific study of the factors influencing AMR occurrence in cattle production and processing environments is in its infancy. No single method, culture or culture-independent, can fully illuminate these factors. There is a need for well-designed studies of cattle production and processing environments, using a combination of culture-dependent and culture-independent methods, if we are to understand and identify the factors responsible for the occurrence of AMR.

Building on Chapter 2, Chapter 3 provides a detailed review of the best methods for detecting particular pathogens, including *E. coli* O157:H7 and non-O157 STEC, *Salmonella*, *Listeria*, *Campylobacter*, *Clostridium*, *Bacillus cereus* and *Mycobacterium avium subsp. paratuberculosis* (MAP). It discusses sampling regimes, best practice and ways of improving sensitivity and specificity. The chapter looks in particular detail at methods for detecting *E. coli* O157:H7. Methods for detection of *E. coli* O157:H7 are...
used throughout the beef chain, from monitoring the pre-harvest colonisation of cattle and their environment to harvest and post-harvest processing of meat as well as final beef cuts and products. The chapter describes sampling methods, sample enrichment and screening using rapid methods based on immunoassays or molecular detection (DNA or RNA amplification), often followed by culture isolation.

As Chapter 3 points out, to monitor *E. coli* O157:H7 in the farm environment, only the most robust rapid methods are useful. In addition to having a high interfering background, samples collected on farms (pastures or feedlots) contain a number of complex molecules that inhibit many PCR reactions. However, properly performed, *E. coli* O157:H7 detection assays can both determine if the organism is present and provide quantitative results. This aids, for example, in identifying ‘super-shedder’ cattle that harbour and shed high levels of *E. coli* O157:H7 and can spread contamination across a whole herd. The chapter concludes by looking at developments in standardised methods for pathogen detection, looking at the example of the US Food Safety and Inspection Service (FSIS) Microbiology Laboratory Guidebook for testing for non-O157 STEC.

As well as effective methods of detection, the production of safe, high-quality beef requires both good farming practices and additional measures targeted against specific hazards to human or animal health. Building on Chapter 1, Chapter 4 provides an overview of current best practice for managing safety on beef cattle farms. Good farming practices (GFPs) need to control infectious and parasitic agents (biological hazards), chemical contaminants and residues (chemical hazards) as well as physical hazards such as foreign bodies. GFP guidelines typically cover such areas as: general farm management, animal health, using veterinary medicines, and management of animal feed as well as animal and product handling.

The chapter puts particular emphasis on biosecurity, animal welfare and the importance of clean cattle policies. In the latter case, the chapter reviews programmes targeted on preventing contamination of hides and grading of cattle sent to slaughter. Based on this assessment, additional measures are taken such as washing, clipping and separation of cattle for slaughter. There is also a detailed review of the effectiveness of using vaccines. The chapter then discusses hazard-specific control measures for one important hazard: *E. Coli* O157. Finally, it reviews key components of quality assurance programmes for beef production.

Because of their ruminant digestive system, beef cattle are able to eat and digest a wide range of feed products, including by-product or alternative feeds not utilised in other livestock production systems. It is important to ensure that the various feed products provided to cattle do not pose a food safety risk to the people who consume beef products. Chapter 5 provides an overview of the three major areas where food safety risks can be introduced via feed material: purchase of contaminated feed products, contamination during storage and contamination of feed due to mixing or delivery errors. In each case, measures to prevent unacceptable risk are reviewed. Echoing Chapter 4, it highlights the importance of hazard analysis and critical control point (HACCP) systems, prerequisite programmes, standard operating procedures (SOPs) and good production practices in managing feed safety.

Echoing chapters 2 and 3, Chapter 6 highlights the importance of effective detection of contaminants, this time in cattle feed. The chapter reviews methods for sampling and detection of antibiotic residues in animal feed, using the example of distillers’ grains. The chapter reviews the use of distillers’ grains as animal feed and provides an overview of multiresidue methods for analysing residues in feed, with particular attention to
Part 2 Ensuring safety at slaughter

The second part of the book focuses on maintaining meat safety during slaughter and the preparation of fresh meat. Written by a former meat inspector, Chapter 7 begins by providing an overview of the purposes and importance of meat inspection programmes in the United States in addressing hazards to both human and animal health. Subsequent sections cover the design, implementation and results of ante-mortem and post-mortem inspection, and provide a review of some important procedures used by veterinary services to inspect cow heads, viscera and carcasses.

Chapter 8 reviews the slaughter process and the mechanisms of bacterial attachment to meat tissue. Contamination of animal carcasses during slaughtering procedures is undesirable, but unavoidable in the conversion of live animals to meat for consumption. Internal muscle tissues are essentially sterile, and most initial contamination of red meat carcasses is contributed by the hide during removal. The chapter reviews decontamination methods such as knife trimming, water washing and steam vacuuming, and evaluate their effectiveness. The chapter also considers hot water, organic acid and other decontamination treatments, reviews the potential for contamination during fabrication, and finally discusses the role of packaging, storage and shelf-life estimates in ensuring the safety of meat delivered to consumers.

Beef spoilage is primarily caused by bacteria, and maximising shelf-life is dependent on a multiple hurdle approach to generate conditions that inhibit microbial growth. This chapter begins by reviewing the factors which affect beef spoilage and microbial shelf-life, and the bacteria and processes involved in spoilage. Subsequent sections then consider methods for maximising the microbial shelf-life of beef products, including minimising the initial microbial burden in beef, chilling of beef carcasses, and the wide variety of packaging technologies. The latter include modified atmosphere packaging and low oxygen packaging. Packaging technologies also include active and intelligent packaging using oxygen scavengers, carbon dioxide scavengers/emitters, chlorine dioxide generators, moisture control agents and antimicrobial compounds.

While the industry has made great strides in reducing bacteria on raw beef products, improving safe consumer handling of beef remains a significant challenge. Factors such as the decline of some traditional cooking skills and the pressure to prepare food quickly will continue to challenge food safety educators in creating good and consistent food safety habits among consumers. Chapter 10 review the history of consumer beef preparation practices and food safety advice, research on compiling the best advice to give to consumers, and how awareness of food safety issues and food preparation behaviour has changed over time.

Traceability, or rapid access to knowledge of the history, treatment and location of cattle and beef products through supply chains, is of paramount importance to food safety investigations, corrective actions and product recalls. Chapter 11 defines traceability as applied to beef before describing in detail methods of unique identification for cattle, such as radio frequency identification (RFID) and DNA profiling. The chapter also explores
the traceability of beef offered by one- and two-dimensional barcoding. Cloud-based, distributed information systems for data entry, storage and retrieval are emerging as methodologies of choice for participants in the beef supply chain. The chapter provides a case study of cattle and beef traceability through a supply chain from farm to retail using a distributed network, the EPCglobal Network for cattle and beef traceability.
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