factsheet

FOOD SAFETY

June 2015

Shiga toxin-producing *Escherichia coli* and beef production

Introduction

Meat & Livestock Australia is a key contributor to internationally recognised research on STEC (Shiga toxin-producing *Escherichia coli*). Its Food Safety Program brings together public health, science and stakeholders to assess the health risk of STEC in meat and to determine the most effective risk mitigation strategies to protect human health and market access.

MLA hosted a symposium at the Charles Sturt University, Wagga Wagga, New South Wales, on 9 and 10 March 2015 to share current issues and recent research with beef industry representatives, regulatory authorities and academics. This factsheet presents an overview of the discussion.

STEC and public health

The public health impacts of STEC are an important consideration for government policymakers. STEC O157 and non-O157 causing kidney failure and haemolytic uraemic syndrome (HUS) result in a high cost to the health system because of the severe disease caused even though there is not a high incidence of infection. In 2014, there were 0.4 cases of STEC infection per 100,000 head of population in Australia, which is much lower than other causes of diarrhoea.

An MLA-funded study of STEC in Australia between 2001 and 2009 where the same rates were reported and 12% of an average 15 cases of HUS/year died. STEC outbreaks have previously been linked with meat and meat products in Australia, although from 2001 to 2009 few were linked with a food source and these did not include meat dishes. The health costs of STEC infections in Australia are estimated to be $2.6 million per year.

In the United States (US), the evidence is different. In 2013, the STEC infection rate was 2.32 cases/100,000 population. It was estimated that more than 30% of STEC infections were linked with beef, mostly with undercooked ground beef hamburgers. The total health cost in the US is estimated to be more than US $300 million a year.

The ‘Jack in the Box outbreak’

In 1993, a large outbreak of foodborne illness in the United States (US) was attributed to undercooked hamburgers. This outbreak – commonly referred to as the ‘Jack in the Box outbreak’ – included more than 700 cases, many of whom were children. Four people died and 178 were left with permanent injury. The bacterium causing the infections was *Escherichia coli* O157:H7 commonly found in the faeces of ruminants. This bacterium had caused illness previously, but the size and severity of this outbreak, the involvement of children, and the link with the iconic hamburger made this outbreak a landmark event in food safety in the US beef industry. *E. coli* O157:H7 is only one of a group of Shiga toxin-producing *E. coli* (STEC) that now affects US domestic and international beef trade.

At the symposium held at the Charles Sturt University, Wagga Wagga, New South Wales.

Market access in an age of increasing specification

The meat industry is Australia's largest manufacturer of export goods. Food safety is a key aspect of market access for the beef industry. Australia exports beef to over 100 markets, each with individual food safety specifications. The principles of the Hazard Analysis Critical Control Point (HACCP) system and its prerequisites have been the most widely adopted approach to pathogen control in meat during processing; however, HACCP also has to be fine-tuned. For example, the intended use of our meat and different eating habits in importing markets have to be considered.

In Australia, there is no requirement to test meat for pathogens although, if tested, positive lots are not suitable for human consumption unless heat treated. In contrast, the US has strict liability laws and specific STEC serotypes are considered adulterants (not allowed to be present) in beef. To be accepted into the US, Australian meat must be deemed of an equivalent standard to US domestic product.

Beef is tested at the US border under defined sampling and testing programs, and detection of positive lots can lead to recalls, tracebacks and increased inspections.

Our export destinations require continuing attention. Requirements change over time and both the specifications and the fate of failed lots require negotiation. Some recent challenges include changes in STEC testing programs and the recognition of high-risk periods that could be due to extreme weather or processing highly contaminated animals.

Dr John Langbridge, AMIC, emphasised that the international landscape of food safety is ever-changing and that the whole industry needs to be informed and ready to react to, and negotiate change. To do this, we need to understand the underpinning science and biology and be innovative in our approaches to pathogen intervention in the beef chain.

Dr John Langbridge said, "The international landscape of food safety is ever-changing. We need to understand the underpinning science and be innovative in our approaches for intervention."

"No single O157 STEC strain were present in a herd of cattle. Multiple genotypes of O157 STEC fluctuated within the beef herd and were detected in waves," said Dr Jane Heller.

Risk management begins on farm

Cattle are the primary reservoir of STEC, and the prevalence and concentration of STEC in faeces and on hides are important risk factors for carcass contamination. In previous MLA-supported studies of O157 STEC carriage and interventions in cattle, some unexplained observations presented challenges, e.g. herd prevalence was irregular and some individual animals (supershedders) shed more than 10^4 cfu/g faeces. To investigate how and why these phenomena occur and their impact on food safety, dairy herds at the University of Sydney, Camden Campus, and a beef herd at Charles Sturt University, Wagga Wagga, were studied.

In longitudinal studies of both herds, O157 STEC was almost always present (endemic) and shedding was highly dynamic; 10–94% dairy heifers and 0–56.5% beef cattle were shedding at any one time during the study (over 6 and 9 months respectively). Furthermore, beef herd prevalence and concentration in individual animal faeces varied each day or within a day. Supershedders were detected in both herds and some beef cattle were found to be supershedding on one or two consecutive days. The herd prevalence and individual animal shedding status was generally unpredictable, although some possible risk factors were observed. Weather and environmental conditions were linked with high-shedding events; humid and wet conditions in Camden and previous rain in Wagga Wagga. In the dairy herds, animals were progressively moved through the system to the milking herd and younger dairy heifers had higher herd prevalence than older cows. On the other hand, shedding by individual cattle within the beef herd was clustered in time and an increase in stress preceded peaks in prevalence and faecal concentration.

The recto-anal junction (RAJ) has been suggested to be the site of colonisation of O157 STEC in cattle; however, specific RAJ sampling in the dairy herd failed to support this and transient infection appeared likely.

There is not a single O157 STEC strain present in a herd of cattle. Multiple genomic types of O157 STEC fluctuated within the beef herd and were detected in waves during the study.

According to simulation models, the shedding status of animals on farm and the rate of transfer of faecal contamination from hides to carcasses have the greatest influence on the rate of carcass contamination during processing. The performance of even the best processors will be challenged when an extreme event occurs on farm.

The on-farm risk factors could be further investigated for their potential to contribute to reducing the risk of carcase contamination during processing.

Managing carcase contamination during processing

STEC status of animals presenting at slaughter

In 2013, a survey of 1,500 cattle presented at slaughter was funded by MLA and CSIRO. While overall O157 STEC was detected in 7% of faeces, different animal groups presented varying risks. The prevalence was 4.9% in adult beef and 3.1% in adult dairy cattle, 10.5% in vealers, 8.4% in young beef and 5.6% in young dairy cattle. In addition, 7.5% of grass and 4% in grain-fed animals were positive.

The concentration of O157 STEC was highest in younger animals, with some adult – although mainly younger – animals identified as supershedders. Previous CSIRO studies have shown that cattle in mobs with the highest faecal prevalences and concentrations are most likely to result in contaminated carcasses.

Not all STEC are equal

Although *E. coli* O157 is a single serogroup they are quite diverse in their genetic types and disease-causing potential.

MLA and CSIRO have supported studies characterising O157 STEC isolated in Australia and overseas using a variety of genomic subtyping methods. The key observations have been that the main cattle and human strains in Australia differ from those from other countries, such as the US, as they belong to different O157 subtypes, produce a Shiga toxin type not associated with the most severe human disease, and belong mainly to types found in bovines but not so often in humans.

Genomic subtyping tools are becoming increasingly sophisticated but it is unclear if they will be used to redefine types considered to be adulterants or will offer any market access benefit in the future.

The non-O157 STEC presenting the highest human health risk are defined in the US as the 'Big6': serogroups O26, O103, O111, O145, O121 and O45. In the European Union (EU), O91 replaces O121 and O45. When the 1,500 cattle faecal samples were surveyed, 1.3% were positive for the Big6, mainly O26 and O111, with highest prevalence in the vealers, young beef and dairy cattle groups with at least one O26 supershedder.

Detection of non-O157 STEC in meat samples can be problematic as the genes used in testing can often be present in a number of different *E. coli* strains. Improvements are required: many samples will give a presumptive positive result that is not confirmed after time-consuming and expensive testing.

An innovative approach to processing intervention

There will invariably be some level of carcass contamination after hide removal. Various interventions can be applied at different processing points to reduce the contamination level, e.g. washing and sanitising hides, steam vacuuming carcasses, acid rinses before evisceration, thermal pasteurisation and chilled carcass acid rinses. None of these interventions produces more than a 100-fold reduction in the number of bacteria.

MLA has funded a project at the University of Tasmania to take a novel intervention approach exploiting the survival strategies of *E. coli*. The researchers observed during weekend chilling, *E. coli* numbers decreased then increased, even though they did not grow. Using molecular analyses to understand the cells' stress response and recovery in these conditions, they found cells were more susceptible to oxidative damage and hypothesised exposure to an oxidising agent would prevent the recovery process. Under commercial spray chilling conditions using the oxidising agent, chlorine dioxide, the researchers have achieved an about 100-fold reduction in cell numbers at 24h and a further 10-fold reduction at 72h.

Further validation studies, optimisation and evaluation with pathogens are planned and it is anticipated that an effective and reliable intervention during carcass chilling will become available.

Prof. Michael Ward said, "Animal shedding status was generally unpredictable, although some possible risk factors such as weather and environmental conditions were linked with high-shedding events."

Key messages from the symposium

The risk of STEC infection from beef consumption is managed through the production, processing and marketing chain by the collective effect of interventions that may depend on each other.

STEC are often found in cattle; however, high shedding events and increased herd prevalence occurs in association with varying factors related to the animal and environmental conditions. A better understanding of the factors could be exploited to minimise the load of contamination on animals going into processing and so as to not overcome the effect of processing interventions. Further innovation in processing interventions will achieve an even more effective reduction. The University of Tasmania will continue to work on a promising novel approach to intervention during spray chilling.

Not all STEC are the same and differentiating those presenting the highest risk for human infection is a complex task. Analysis of the risk potential of isolates reveals many Australian isolates of O157 STEC fall among those with lower risk.

Greater specificity is required in tests for the broader range of non-O157 STEC to reduce the number of presumptive and unconfirmed positive tests. CSIRO is continuing work on both risk and testing of STEC.

Testing for O157 STEC is useful in detecting highly contaminated lots; however, it may not detect all such lots or those lots with low contamination levels that might still cause infections. Increasing the sampling numbers or sample volume over those currently used for US market access will not significantly reduce the number of O157 STEC illnesses caused by eating Australian beef hamburgers in the US.

The beef industry is an important industry in Australia with an excellent food safety record. Food safety is a key aspect of market access that has to be maintained, despite the ever-changing landscape of specifications and testing. Effective risk management programs require continuous development based on updated evidence with investment in sound science and innovation.

STEC testing and safety

Australia exports large volumes of beef trim to the US for hamburger manufacture. Regulatory testing of beef trim and ground beef for O157 and other selected STEC is required in the US for verification of the effectiveness of process controls. Over time, the detection of lower numbers of O157 STEC has been achieved by increasing the sample volume and the use of more sensitive methods.

MLA funded a project to conduct a quantitative risk assessment to assess the risk of O157 illness from consumption of burgers made from Australian beef and consumed in the US, and the effectiveness of testing in risk mitigation. The risk assessment covered the beef chain from the cartonning of product to consumption. An estimated 55.2 illnesses/year were expected to occur if no testing was performed. This number was reduced to 50.2 under the current US export requirements; however, there was insignificant further decrease when the number of cartons sampled was doubled or the volume tested further increased.

This analysis demonstrated that sampling and testing has a role in verifying that food safety programs are working and in removing some, but not necessarily all, of the most contaminated lots. On the other hand, less contaminated lots that may cause fewer illnesses are harder to detect. It is emphasised that safety cannot be ensured by sampling, especially with low-level contamination.

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