UNDER THE MICROSCOPE

E. coli O157 and *Salmonella* in Meat and Poultry

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Biographical details

Ewen C. D. Todd graduated with a Ph. D from Glasgow University before immigrating to Canada in 1968, and has worked in the Bureau of Microbial Hazards, Health Protection Branch, Health Canada ever since. He is currently a Research Scientist 5 and Head of the Contaminated Foods Section, Bureau of Microbial Hazards. Over the years he has worked in methods development for VTEC and Salmonella; studied the microbiology of various food items, e.g., barbecued chickens, cheese and cream pies; analysed native foods for botulinum toxin and seafoods for paralytic shellfish poison and other seafood toxins; reported on foodborne disease outbreaks in Canada and their costs; conducted risk assessments for *Salmonella* in eggs, *E. coli* O157 in ground meat, and *Vibrio vulnificus* in oysters; and advised on the production of videos and pamphlets on food safety education. He was the recipient of the ADM of the HPB's 1998 Excellence in Science Award.

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The first infectious and toxigenic pathogens transmitted through food have been recognised for over 100 years. However, by the mid-20th century, many experts were saying that infectious diseases would soon be a thing of the past, and priorities were shifted to other areas such as chemical contamination that could give rise to chronic conditions or cancer. Up till about the 1970s, the main pathogens of concern were *Salmonella, Staphylococcus aureus* and *Clostridium perfringens*. *C. perfringens* was not always looked for because it required anaerobic conditions to grow. Even if people were infected by these, illnesses were considered to be mild and more of nuisance that a threat to life. Botulism outbreaks were known, but assumed to be rare events that could be dealt with as they occurred. This neglect of foodborne and other enteric diseases led to limited research being done on virulence factors of existing pathogens, or thorough investigation of outbreaks that would make us aware of new pathogens. By the time that the 1980s came in, we were beginning to be a little more concerned with agents like *Campylobacter, Listeria monocytogenes* and *E. coli* O157:H7, but it took several years for health authorities to recognise that these had the potential to cause serious complications or death and could be transmitted by a variety of products, and there were limited control mechanisms in place to reduce such foodborne disease. After a large listeriosis outbreak in 1985, however, the US introduced in 1989 a zero tolerance policy for *L. monocytogenes* in ready-to-eat processed meat. By 1993, it was claimed that this policy had reduced illnesses and deaths by almost 50% through industry clean-up programs (Tappero et al., 1995). That same year, the Jack in the Box multi-state outbreak became a turning point for concern over another pathogen - *E. coli* O157 - not only because many hundreds of persons were ill, but because 4 children died. Soon after, a zero tolerance policy for *E. coli* O157:H7 in ground meat was implemented. The Canadian approach to control has not been as stringent, but overall policies for all pathogens of raw food of animal and plant origin are being developed. This concern is borne out by the fact that illnesses for most pathogens, seem to be on the rise with outbreaks of *Cyclospora, Cryptosporidium, E. coli* O157, *Salmonella, Shigella* and small round structured viruses, being associated with a variety of foods including produce, dairy products, eggs, ice cream and shellfish.

What about meat? Are we seeing increasing concerns in the safety of meat and meat products? Let's look at two pathogens, *E. coli* O157:H7 and *Salmonella.*

E. coli O157:H7

This bacterium was first identified as a foodborne pathogen in 1982 from two outbreaks involving hamburgers served in McDonald's restaurants in Michigan and Oregon. The first outbreak in Canada was in August in Montreal with 4 persons ill, one with severe bloody diarrhea. Then, 3 months later in November, 33 persons in a home for the aged in Nepean, Ontario, were infected; 4 cases were hospitalised, 7 had relapses and one died, the first known fatality from this pathogen. In both these outbreaks, hamburgers were the implicated food. The scene was set for increasing numbers of outbreaks across Canada, most involving hamburgers that were undercooked or served rare, and thus the name hamburger disease (Annual summaries, 1986-1998). The same situation occurred in other parts of the world, with the largest such outbreak in 1993 when over 700 persons in four US states were ill with 4 deaths after eating hamburgers served in a fast food chain. In subsequent years, the majority of outbreaks were associated with hamurgers, but some were from other meats, such as steak pies, roast beef, sliced beef, pork souvlaki, spaghetti and meat sauce and spiced ground beef. In 1985, the most serious outbreak recorded in Canada occurred in a London home for the aged where 70 were ill and 17 died after eating ham sandwiches probably contaminated by an infected food worker. The infections contributed to the deaths since these were all old people. Factors contributing to outbreaks identified during the outbreak investigations were mainly undercooking, improper or inadequate cooling, infected food preparer, eating raw ground beef, contaminated equipment and kitchen surfaces. The first time that a donair or gyro had been implicated was in 1997 in Norway after a woman ate a donair in a snack bar and was hospitalized with bloody diarrhea (Anon., 1998). In 1996, the largest documented *E. coli* O157 outbreak occurred in Scotland with 496 cases and 160 hospitalizations (Pennington Group Report, 1997). The butcher had acted as a caterer and many of his prepared meat dishes caused infections, with 20 deaths mainly in institutions. The organism was found on a boiler used for cooking meat and a vacuum-packaging machine for cooked and raw meats. He was fined £2,250 for food hygiene and safety breaches and law suits are expected (Quinn, 1998).

Not only undercooked food, but meat that is considered ready-to-eat has also been a vehicle for infection. Fermented sausages have been implicated with transmitting both *E. coli* O157 and *Salmonella* to consumers: in 1994, 23 were ill and 4 hospitalized in two US states from Genoa salami (Alexander et al., 1995); in 1995, 23 children were ill with HUS and 1 death occurred in Australia from mettwurst containing *E. coli* 0111 (Cameron et al, 1995); and in 1998, 27 were ill and 11 hospitalized, after they ate salami made in Hamilton, Ontario (The Spectator, 1998). In 1995, 83 persons were infected with *Salmonella typhimurium* in Italy ill after eating salami (Pontello et al., 1998); the main risk factor was reduced ripening time of the salami, shortened because of a strong market demand for the product, that allowed *Salmonella* in the comminuted meat to survive the curing conditions. In all these situations, the pathogens survived any acidity developed during the fermentation processes.

For all *E. coli* O157 and other VTEC infections (rare), most cases are sporadic and do not arise from outbreaks. Risk factors for such cases show similarities, mainly associations with farm animals, and manure on farms or in gardens. The seasonal peak for infections is in the summer months. In Ontario, risk factors include eating undercooked ground beef, contact with cattle, small cattle herds controlled by traditional management practices, consumption of well water, and exposure to rural environments (Wilson et al., 1997). The rate of infection is

highest in south-west Ontario, and there was a statistically significant association between VTEC infection and cattle density.

All of the above examples show that *E. coli* O157 is a major pathogen often associated with meat products or cattle producing them. However, there are also two pieces of good news. Firstly, on a follow-up on 29 children with hemolytic uremic syndrome (HUS) arising from the Jack in the Box outbreak in 1993 showed that most were doing well (Guthrie and Anderson, 1998). None required kidney transplants but 8 showed continued kidney abnormality, with the most serious condition being the development of gallstones; 3 children had surgical operations to remove their gallbladders. Secondly, cranberry juice may reduce urinary tract infections (which account for 7 million doctor visits each year in the US alone) by condensed tannins in the juice preventing attachment of the *E. coli* to the urinary tract or bladder (Howell et al., 1998).

To help determine management strategies for this pathogen, risk assessments can provide valuable information. A semi-quantitative approach was taken by Todd and Harwig (1996) to look at hazards of raw foods of animal origin with a number of assumptions. The number of poultry-borne and meat-borne cases was estimated at 227,000 and 76,000, respectively. More recently, quantitative risk assessments (QRA) using mathematical modelling are being considered for a variety of pathogens in different foods. A proposed QRA for *E. coli* O157 in beef and ground beef in the US will model human illnesses and compare with national estimates from surveillance, quantify effects of mitigation strategies on illnesses, identify future research needs, and document methods and evidence for future assessments. Much of this has already been done in Canada. In a QRA by Cassin et al. (1998), a process risk model was developed from cattle to consumption of ground beef as hamburgers. This predicted a probability of illness from a single meal for adults of 5.1×10^{-5} and for children of 3.7×10^{-5}, a probability for HUS in children of 3.7×10^{-6} and a probability for death in children of 1.9×10^{-7}. These probabilities could be reduced if certain mitigation strategies were implemented: 1) a lower storage temperature of patties (80% reduction in illness), preslaughter screening to avoid cattle with high levels of the pathogen in their feces (46% reduction in illness), and an education program to encourage people to cook ground beef more thoroughly (16% reduction in illness).

Salmonella

Insufficient facilities and food safety knowledge in home or volunteer catering groups can lead to undercooking and improper cooling. For instance, in Pasadena, California, salmonellosis occurred in about half of 90 guests gathered for a large family Thanksgiving meal in November, 1997, and 13 were hospitalized (Los Angeles Times, 1997). The kitchen was inadequate for catering for such a large number of people and the turkey was left out because of insufficient refrigerator space. There were 10 confirmed and 40 probable cases of *S. java* over a month in the spring of 1998 associated with an outdoor pursuit centre in England where paint-ball games are played (Eurosurveillance Weekly, 1998). After the games were over for the day, many of the participants ate roast pork from a whole pig roasted on a spit. The pig had been stored at room temperature for 38 hours before roasting and inner parts may not have been completely cooked. More than 50% of participants at a church supper were ill in Maryland in 1998 (750 cases and one death) after eating ham (Russell, 1997; Shields, 1997; Washington Post, 1997). The hams had been packed too tightly into cooking pots, creating uneven cooking conditions. Then, they were packed too tightly into the freezer to allow rapid cooling, and the salmonellae had opportunity to grow. One slicer was used to cut all the hams without any sanitation between the slicing process, thus allowing the transmission of salmonellae to many of the ham pieces served.

Cross contamination also occurred in the above

ham outbreak, as in another that occurred in England with 9 cases of *Salmonella agona* after they ate precooked turkey, beef, chicken, ham and sausage (Synnott et al., 1998). One batch of cooked turkey must have been contaminated and other products were probably cross-contaminated with *S. agona* at the retailers since only there were the cryovac packages opened. In another *S.* Agona outbreak, 18 of 59 cases in Texas from May to October 1995 were identical by PFGE typing. These lived in San Antonio, Austin and Houston (Taylor et al., 1998). All those in San Antonio and Houston had eaten food in a San Antonio Mexican restaurant. The same PFGE strain was isolated from machacado (air-dried raw beef), which had been shredded in a blender and cross-contaminated other foods like salsa. The Austin residents had eaten at a similar Mexican restaurant in Austin; machacado was suspected but none was available for testing. Both restaurants had purchased the beef from the same supplier in Corpus Christi. Although blenders had been implicated in outbreaks before, without PFGE typing of isolates, these outbreaks would not have been detected. Six confirmed and 5 presumptive cases of *E. coli* O157:H7 were associated with consumption of home-made deer jerky (Keene et al., 1997). The deer had been shot, eviscerated, dragged to truck, and hung at 1-16 °C for 5 days. The carcass was then skinned and dismembered by the family, with 10 kg of meat cut into thin strips, marinated and dried in a food dehydrator (51-57 °C for 12-14 h). Isolates of *E. coli* O157 were found in the patients, jerky, uncooked deer meat, a saw used on the carcass, deer hide and deer fecal pellets. The jerky contained 3 CFU/g and uncooked venison 150 CFU/g. It was shown that dehydration reduced counts, but there were some survivors. It was clear from the investigation that the hunters in this scenario were not hygienic in storing or dressing carcasses and preserving meat. Since there are 10 million deer hunters in US alone, an educational program should be considered.

Acute illnesses aren't the only problems arising from salmonellosis and other enteric diseases. For example, in 1984, 423 provincial police officers were infected with *S. typhimurium* after eating contaminated meat sandwiches provided to them as they lined the route to Midland during the Pope's visit. Twenty-seven of these (6.4%) had acute reactive arthritis (RA), one third resolving within 4 months, and the majority continued to have mild symptoms in their joints for the following 5 years (Bourrie, 1998). Four had sufficient damage to force them to change jobs. The risk factors identified were severe diarrhea at the time of the outbreak and presence of specific genes that code for HLA-B27 and HLA-CREG antigens. Of the more than 700 ill from eating pork rolls produced by a bakery in Melbourne, Australia, in March, 1997, 2 died and 3% developed RA (Rouse, 1998). One half of those with arthritis (1.5%) continued to have it 12 months later. In another outbreak in August from the same product, 5% developed RA. The difference in percent affected may be due to the ethnic background of those ill who may have a differing proportion of susceptible genes (Vietnamese in March and Cambodian in August). Sequellae such as RA are more frequent and are more long lasting than previously recognised.

Salmonella typhimurium DT 104 is a major problem in the UK, because it is resistant to a wide range of antimicrobial agents (WHO, 1997; Eurosurveillance Weekly, 1998). It is associated mainly with cattle but also pigs, sheep and poultry. No effective treatment of infected animals has yet been found. In humans, there is a relatively high mortality rate of 3%, especially in the elderly. In 1994, it accounted for 60% of *S. typhimurium* and 30% of all *Salmonella* incidents in cattle. It is spread from farm to farm by water and is difficult to eradicate since it survives well in both dry and wet environments. This organism is expected to continue to spread throughout the UK and other countries. It has been found in beef, pork, salami, chicken and cereals. Foodborne disease outbreaks have been associated with hamburgers, sausages, and sausage rolls, all

products involving comminuted meat. In the UK, there is no specific strategy for control, but food factories need to operate effective GMP and HACCP programs, and put safe cooking and handling instructions on retail packs of raw product. This pathogen will be in poultry flocks and other meat animals and extend down the food chain from farm to fork. Because of its ability to colonise many farm animals and be in the environment, its impact will be worse that of *Salmonella* Enteritidis. In the US, there has been a dramatic increase in multi-resistant *S.* Typhimurium strains from 7% in 1990 to 28% in 1995 (83% of these were DT 104) (Glynn et al., 1998).

Deaths from salmonellosis are rare but they do occur and not just in elderly people. After contracting salmonellosis from a contaminated Chinese meal in Manchester, England, a mother went into premature labour; triplets were born of which two died in a few weeks, and the third has brain damage confined to a wheel chair (Bunyan, 1997). She was given a £1 million out-of-court settlement. A10-year old girl in Norwich, England, died after eating home barbecued food in August, 1997 (PA News, 1997). Since the meat came from a reputable source, the verdict was misadventure by death from multiple organ system failure due to a *Salmonella* infection. The parents also had salmonellosis but were not seriously ill.

Because *Salmonella* is the pathogen that is the most widespread and causes more outbreaks than any other, control is not easy. Current strategies of HACCP and GMPs are trying to reduce its presence on meat and poultry. The USDA claims some success. It conducted a HACCP survey of 300 large plants that implemented HACCP system in January, 1998, for *Salmonella* contamination. The results showed that 1) for ground beef samples, 7.5% were positive before HACCP and 4.3% after HACCP (a 40% decline); 2) for chicken samples, 20.0% were positive before HACCP and 10.7% after (nearly a 50% decline); and for swine, 8.7% were positive prior to HACCP and 6.2% after (a decline of >25%). In Australia, fecal contamination and presence of pathogens on beef did not appear to be excessive when 1063 beef carcasses were examined over 12 months (Vanderlinde et al., 1998). There were on average, 3.13 log total aerobic CFU/ sq. cm and 13 MPN of *E. coli*/sq. cm. The contamination rates of export samples for different pathogens were: *Campylobacter* 0.16%, *Salmonella* 0.22%, *E. coli* O157 0.45%, *L. monocytogenes* 0.59% and *S. aureus* 29%. In addition, 929 cartons of frozen boneless bulk packed beef over 12 months were examined; these contained a mean of 2.5 log total aerobic CFU/ sq. cm and 15 MPN of *E. coli*/sq. cm. There were no samples with *E. coli* O157, and 0.38% contained *Salmonella.*

Conclusion

Problems with *E. coli* O157 and *Salmonella* are clearly going to be around for some time to come. We can also expect non O157 VTEC to become more important as the virulence factors are determined and methods are developed to identify these organisms. In the next few years, illnesses from *Salmonella typhimurium* DT 104 and other antibiotic resistant strains are going to have a large impact on the acceptability of microbial contamination of meat and poultry carcasses by the public and government alike. At the moment HACCP appears to be the best approach to reduce this, but it will not eliminate pathogens completely. Industry will at least have to consider end-product decontamination steps, such as irradiation. For the immediate future, it is best to plan ahead and invest in research, do product surveys, find out about public concerns, work with government, and search out alternate means of delivering a safe product to the consumer. The very fact that the UK Parliament is expected to approve a measure in March, 1999, that would make British farmers directly liable for compensation for any illness caused by the food they produce (ProMED, 1999) should be a wake-up call for all involved in the production of meat and poultry. Doug Powell of the Department of Plant Agriculture, University

of Guelph, has stated that consumers are more aware of food safety in recent years because of increased media attention with headlines about food recalls, outbreaks and killer germs, and public concern about food safety is now an issue for farmers as well as producers (Western Producer, 1999). They need to explain to consumers what they're doing to prevent foodborne illness. They must recognize the risks, minimize them, vigilantly monitor them and show consumers they care. In other words, everyone from farm to fork plays a role in food safety and needs to know this.

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MEAT YIELD AND QUALITY :

MARITIME STUDY FINDS NO DIFFERENCE IN MEAT QUALITY BETWEEN LOCAL AND WESTERN BEEF

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Over 70 % of beef consumed in the Maritimes originates outside the region. This is in spite of the fact that the Maritimes has a severely underutilized land base that could easily raise more than enough beef for the plates of Atlantic Canada. The reasons for this conundrum are many fold. However, there is a belief that locally produced beef is inferior to beef "from away".

As part of a co-ordinated plan to increase consumption of Maritime beef, the three provincial departments of agriculture, Agriculture and Agri-Food Canada and Hub Meat Packers, Moncton, conducted a comprehensive study of beef quality. A western supply beef was secured from a local supermarket chain and compared with beef from the local packer. Locally packed beef originated from three sources: Maritime finished on either potato-based rations, Maritime finished on non-potato-based rations and beef raised in Quebec. All beef was Canada grade AA and was aged for 14 days. The results gathered from almost 200 carcasses confirmed that there were no major differences in beef quality when assessed using trained taste panels and instrumental analysis. Where significant differences were found these were very small and considered too small to influence consumer preference. In addition, these differences did not consistently favour one type of beef over another. These results show convincingly that Maritime-raised beef Is not inferior to other beef when grade and aging are standardized. The Maritimes can produce great beef. This information should help increase market share for Maritime beef.

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