Animal science and the safety of food for human consumption

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Summary

Food safety is not just the responsibility of food handlers but relies on controls at all levels in the food industry. There are many examples of food contamination resulting from diverse animal management systems. Foodborne illness is a serious problem even in industrialised countries, with the emergence of new pathogens and changes in food production, distribution and eating habits. The animal scientist is vital in the development of control systems on–farm.

Introduction

Although it has been estimated that perhaps 97% of human foodborne disease cases are caused by improper preparation of food immediately prior to consumption (Biddle et al. 1997) it is a simplification to think that food safety solely rests with food handlers. As animal scientists we also are an integral part of the food industry and as such must realise that decisions we make may influence the safety of food. We may think that our field of research could not possibly have any effect, but the history of human disease associated with contaminated food shows that the cause has often been unexpected.

Food contamination associated with on–farm management strategies

Meat meal from ruminants was seen as a good source of protein for cattle and the rendering process was believed to destroy potential pathogens. What wasn’t known was that the herbivorous bovine eating the meat meal apparently easily absorbed an ‘indestructible’ infectious particle, the prion, and the process of producing and feeding meat meal had an amplifying effect, spreading the infectious prion in the cattle population. The disastrous consequence of this was the emergence of the Bovine Spongiform Encephalitis epidemic in the UK and its spread into Europe. In turn it led to the emergence of new variant Creutzfeldt Jacob Disease (nvCJD) in humans who had consumed affected meat. The original source of the infectious prion has been the subject of much scientific research and debate. At first it was thought to have come from scrapie–infected sheep. It has now been shown to be a different infectious agent and may well have come from cattle, or another species, because some meat meal used in the UK was imported from Africa.

The intensification of the livestock industries particularly poultry and pigs, but also dairy and beef feedlots, has led to high carriage rates of zoonotic Salmonella species and Campylobacter species. It has been postulated that the enterohaemorrhagic Escherichia coli O157:H7 may have emerged in the USA in the cattle feedlot industry because it had a survival advantage by being acid tolerant, could survive the high carbohydrate/low pH levels in the rumen, and was able to become established in a dense population of cattle. Current intensive animal husbandry methods help maintain these organisms in the animal populations through contaminated feed (often by rodents or birds), environmental (soil and water) contamination, and ease of transmission in a dense population.

Andersson and Nilsson (1991) postulated that the use of cultures of Salmonella spp. earlier this century as rodenticides to control rats and mice, may have introduced the species Salmonella typhimurium, S. enteritidis, and S. dublin into the ecosystem and food chain. The geographical spread of Salmonella spp. worldwide has been related to spread from infected herds and flocks to uninfected herds and flocks and through the distribution of contaminated feedstuffs (particularly S. enteritidis and S. dublin). Stored feed, especially grain, is commonly contaminated by the droppings of rodents. Organic feedstuffs such as bone meal and fish meal have been incriminated in the spread of salmonella (Bensink 1979) including rare strains (Durand et al. 1990). For example S. agona causing human salmonellosis in the USA, UK, Israel, Sweden and the Netherlands was attributed to contaminated Peruvian fish meal fed to livestock and thus entering
the human food chain (Fox 1974). Most of the contamination occurs after heat sterilisation. The rendering process destroys organisms such as salmonella, but there is a risk of recontamination unless the feed is handled hygienically. Both animal and vegetable proteins may be contaminated during processing and storage and therefore may be a source of Salmonella spp. The recent outbreak in South Australia of salmonellosis in people associated with drinking orange juice has been blamed on the spraying of the orange trees with fish–based fertiliser.

The use of antibiotics in feed as growth promotants is now in serious question and poses a food safety risk. In both animals and humans the use of antibiotics needs to be rationalised to extend the useful life of these chemicals. The range of effective antibiotics available for human and animal therapy is gradually being eroded by the emergence of antibiotic-resistant bacteria. The threat of transmission of antibiotic resistance from animals is very real. Organisms that have developed resistance to a certain family of antibiotics can transmit that resistance to other non–related bacteria, and if these are pathogenic bacteria the consequences can be disastrous. In the northern hemisphere, Salmonella typhimurium DT104 (Threlfall et al. 1994; Johnston 1995) has developed a multiple resistance to antibiotics, causing difficulties in treating human suffering from this foodborne disease. The incidence of this organism is rising in humans and agricultural livestock in Great Britain and the US, but it has not yet been identified in Australia.

The animal industries not only produce meat and milk but also produce manure and effluent which are in turn used as fertiliser for pasture and crops. Manure and effluent are potential sources of contamination by enteric pathogens to crops (both for animal and human consumption) and waterways. E. coli O157:H7 has not only been associated with meat but has also caused food poisoning via juices, cider, and sprouts. Animal manure has been implicated as the vehicle for contamination. The upsurge in organic farming with increased use of manure for cropping and pastures has been postulated to be a source of increased contamination.

Additionally we must take into account that many human organisms entering the environment can infect the animals we use for food. An outbreak of Salmonella paratyphi occurred in people and dairy cows in Yorkshire in 1972. Cows became infected by drinking water contaminated with sewage effluent from a village where a human carrier lived. People in turn became infected by drinking contaminated raw milk (Bell 1981).

**Food safety is a real issue**

The number of cases per year of foodborne illness in the USA alone has been estimated to be between 6.3 million and 81 million (Todd 1990) with associated costs up to $10 billion annually (Todd 1989). Annual costs in Australia are estimated at between $1 billion and $1.9 billion, a similar rate to other industrialised countries (Crerar et al. 1996). It appears paradoxical that foodborne disease is increasing in industrialised countries. The factors involved in this increasing incidence are complex: new pathogens have emerged or been identified over the last 20 years, and production and distribution systems for food have changed as have people's eating and cooking habits (Altekruse and Swerdlow 1996). Larger distribution systems, and modern consumers, demand longer storage of food but this increases the risk of bacterial proliferation, particularly for organisms such as Listeria. It must also be recognised that modern methods of microbiological detection and epidemiological investigation and recording have allowed us to diagnose foodborne illness more easily.

**Biological agents responsible for foodborne illness**

The biological agents responsible for foodborne illness are diverse and include bacteria, viruses, protozoa, fungi and toxins, with bacteria being the most common cause. Bacterial pathogens associated with the consumption of meat products include Salmonella spp., enteropathogenic Escherichia coli, Listeria monocytogenes, Campylobacter jejuni and C. coli, Yersinia enterocolitica, Clostridium perfringens and Clostridium botulinum, Staphylococcus aureus, and Bacillus spp. Some of these organisms, including Salmonella spp., enteropathogenic E. coli, L. monocytogenes, Campylobacter spp., and Y. enterocolitica, may be present in the production animal and be a potential source of contamination. The chain of events from killing, processing, storage and food preparation can allow multiplication of these contaminating organisms. Other bacteria such as C. botulinum, S. aureus, and Bacillus spp. are generally regarded as secondary contaminants that may contaminate meat during processing; some organisms (e.g. S. aureus) produce toxins that cannot be destroyed by cooking. Many of the pathogens associated with human food poisoning are not species–specific and humans share pathogens with many mammalian species as well as with birds, reptiles and amphibians.

The recently emerged agents of foodborne disease include: the prion of BSE, Salmonella typhimurium DT104 with multiple antibiotic resistance, Salmonella enteriditis of poultry, and the enterohaemorrhagic Escherichia coli such as E. coli O157:H, E. coli O111.

**The enterohaemorrhagic E. coli (EHECs)**

EHECs are a sub–class of enteric E. coli that have been associated with epidemic and endemic diarrhoea, haemorrhagic colitis and haemolytic uraemic syndrome in humans. The most notorious EHEC identified is...
**Salmonella**

The largest known outbreak of foodborne illness in the world involved improperly pasteurised milk in the USA in 1985 in which there were 16,659 confirmed cases and up to 197,581 suspect cases with several deaths (Todd 1990). Australian figures indicate that nearly 40% of bacterial foodborne disease outbreaks over the last 15 years were due to salmonellosis. Historically, *S. typhimurium* has been the most common cause of human salmonella food poisoning and still is in Australia (Murray 1994; Barton 1997) although in the northern hemisphere, *S. enteritidis* (from poultry but not yet identified in Australian poultry) is now more common. Occasionally salmonella infections will cause death or chronically debilitating arthritis.

It has long been recognised that *Salmonella* spp. from animals can be pathogenic for humans, either directly or via food. The incidence of salmonella food poisoning has increased worldwide. For example in England and Wales the number of *Salmonella* spp. isolations reported has risen from under 5000 in 1965 to over 25,000 in 1989. Similar trends have been recorded in other developed countries (Cooper 1994). The usual vehicle of human infection is food contaminated with serotypes which are principally of animal origin, but there is much debate about the relative importance of the livestock and the role of the human food handler. Food handlers are able to spread organisms mechanically (Smeltzer et al. 1980), as well as becoming carriers of the organisms. In the USA, England and Wales an estimated 0.20–0.25% of the general human population are asymptomatic carriers and excretors of salmonellae (Paxton 1974). The organisms in these human carriers are believed to originate from food animals and the human carriage rate would be expected to drop if salmonellosis in animals could be reduced substantially (Meara 1973).

*S. enteritidis* has been associated with a dramatic rise in cases of human foodborne illness in Europe and America, particularly related to the consumption of poultry products, both meat and eggs (Cox 1995). This organism is not present in the Australian livestock and poultry industries but there are increasing numbers of human cases in Australia in people coming from or returning from Asia (Powling et al. 1995). *S. enteritidis* can invade the intestinal mucosa and cause severe illness and septicaemia in man.

**Predisposing factors in the animal or human host**

The most comprehensive studies have been done on *Salmonella* spp. The factors which affect the susceptibility of the host to infection by salmonellas include: the pH of the stomach, abomasum and rumen of the host, intestinal motility, microbial flora of the intestine, age, nutritional status and health. The food material carrying the organism can also affect survival of the organism and infectivity. It is generally believed that the numbers of salmonella bacteria needed to cause infection in healthy people are high (hundreds of thousands to millions), however in foods containing high levels of fat the infective dose can be much lower (1 and 100 organisms) because the fat protects the bacteria against gastric acid (Lacey 1993). Food can...
have a protective effect on bacterial survival in the gastric bactericidal barrier (Peterson et al. 1989). The pH of rumen contents has been shown to significantly affect the number of salmonellae surviving passage through the rumen. A high volatile fatty acid content and a low pH are unfavourable to salmonellae passing through the rumen (Chambers and Lysons 1979). Conditions that alter the ruminal flora may predispose to salmonellosis. For example, salmonellosis was observed in ram hoggets previously dosed with zinc and it was postulated that changes in appetite and ruminal conditions favoured the proliferation of *S. typhimurium* (Allworth et al. 1985). Similarly in a study of salmonellosis in sheep being transported by ship from Australia to the Middle East it was concluded that sheep with inappetence were prone to the disease (Higgs et al. 1993). Grau et al. (1968) demonstrated increased numbers of salmonellae in the rumen after a period of starvation in holding pens; this finding has led to reduction in holding times in lairages prior to slaughter. Lactobacilli have been shown to inhibit the growth of salmonellae and their adherence to the intestinal wall (Bernet et al. 1994, Perdigon 1993).

A study by Frost et al. (1988) demonstrated that feedlot cattle being fed a high energy diet including grain were free of salmonellae in both ruminal fluid and mesenteric lymph nodes after being fed feedlot rations for 80 days although *Salmonella* spp. were isolated from the environment. Two other groups of cattle were tested: one group of cattle purchased at saleyards, taken to the feedlot and slaughtered within 2 days, and a second group similarly purchased but fed feedlot rations for 18 days. From both of these groups salmonellae were isolated from ruminal fluid and mesenteric lymph nodes although there were differences between these groups in the rate of isolation. The authors postulated that the changes in rumen fluid caused by the introduction of a high grain diet had an inhibitory effect on the growth of salmonella and eventually resulted in the clearing of these organisms from the ruminal fluid and mesenteric lymph nodes. Perhaps the proliferation of ruminal lactobacilli associated with feedlot rations affects the survival of salmonellae. Further study is required on the effect of the ruminal environment on the survival of salmonella. This has obvious implications in the possibility of producing ‘clean’ cattle for slaughter.

**Control of foodborne pathogens**

There must be control of foodborne pathogens at all stages of food production from the farm to the abattoir, food handling, storage and preparation. Hazard Analysis Critical Control Point (HACCP) systems are now being applied to abattoir and food-handling practices and in the future should also be applied to animal production systems. HACCP for food was originally developed to ensure food safety for American astronauts in the NASA space program. The aim was to identify the potential hazards for a particular food related to the nature of the raw ingredients and the process of manufacture and preparation, to identify those points in the process where stringent control would result in the most likely outcome of a safe final product, to decide what type of monitoring had to be put in place at those critical control points to ensure control was maintained, and to have a verification process to ensure the system was operating to requirements (Biddle et al. 1997).

Abattoirs in Australia have always been the most regulated sector of the industry with strict hygiene standards which up until recently were overseen by Government inspectors in all plants. More recently the domestic abattoirs have provided their own inspection under Government controls. The consequent concerns about food safety, particularly related to *E. coli* O157:H7 in the USA, have necessitated the adoption of HACCP plans. All Australian export plants were required to implement HACCP principles from 1st January 1997. The United States Department of Agriculture (USDA) developed a system of regulations for microbiological testing and sanitation in abattoirs which are a requirement for export to the USA. These ‘Mega Regs’ were operational in Australian export plants from the beginning of 1997. By mid 1997, HACCP plans were routinely operating within domestic plants. (Palmer 1998). The supermarket chain Woolworths ranks food safety as the number one customer concern and as such has developed the Woolworths Vendor Quality Management Standard, a HACCP based system to ensure the safest possible food from the supplier as well as the safest methods of handling and storage at the retail store.

HACCP systems need to be dynamic. Examples of this need are the banning of the feeding of mammalian meat meal to ruminants, as a result of the evolution of BSE, and the development of guidelines for the fermentation process in the production of salami because of the acid tolerance of enterohaemorrhagic *E. coli*. The HACCP system also needs to be relevant to local conditions and pathogens, ‘streamlined’, and financially feasible.

Control of the pathogen load of food producing animals will require a comprehensive understanding of the epidemiology of these organisms in the host. For organisms such as salmonella, many contributing factors have been identified: geography, climate, population density, age of animals, stresses (such as starvation, transport, pregnancy), diet and intestinal flora, contamination of prepared feeds, pasture and drinking water, and survival of the organism outside the host. For recently emerged organisms such as EHECs, much more needs to be known about contributing factors. Controls to limit these human pathogens in production animals include hygiene measures, vaccination, and techniques to clear pathogenic organisms from these animals. The study of *E. coli* O157:H7 on-farm is the subject of considerable research in the USA and some of these findings have been referred to earlier.
Current and future research

There are gaps in our knowledge of the foodborne pathogens. Further investigation should enhance this knowledge and provide information on how we might intervene to control these pathogens both in the production animal and from contaminating meat. Research is currently underway and further work is required on:

- Rapid and sensitive isolation and identification procedures, and identification of virulence factors
- More intensive monitoring of production animals and the farm environment and determination of factors which influence the acquisition and shedding of these pathogens
- The interactions of these organisms with the host immune system
- Improvement and/or development of vaccines against salmonellosis and EHECs; efficacy studies should continue or be instigated on currently available and potential vaccines
- The efficacy and safety of combinations of known control techniques such as vaccination, antibiotics, and sanitation
- Methods of producing clean cattle prior to slaughter by manipulating the intestinal environment, either through altering the intestinal flora (competitive exclusion) or altering pH or diet; the inhibitory effect of probiotics (e.g. lactobacilli) and bacteriacins on enteropathogens may have exciting prospects in pathogen control
- Educational programmes covering pre- and post-harvest food safety procedures in the animal and food production sectors of the beef industry

The Meat Industry Strategic Plan (1996) highlighted food safety as a high priority area for the Australian meat industry. The explicit industry goal is to have all enterprises, from producer to retailer, operate in accordance with accredited quality assurance systems based on HACCP principles. In response to the industry plan, the Meat Research Corporation established the Food Safety Key Program to study food safety at all levels of red meat production. NSW Agriculture are currently investigating ‘Pathogens in domestic meat animals on–farm’ as part of this Key program. The newly structured Meat and Livestock Australia (MLA) also recognises the importance of food safety and will continue research in this area. The pig and poultry industries also have key areas of research in food safety.

The aim of this review has been to highlight why we, as animal scientists, need to realise that we are in the food industry and can affect human food safety in both a negative and positive way. Animal scientists have the expertise necessary for future research into the carriage and reduction of foodborne pathogens in farmed animals.

References


