Meat technology update

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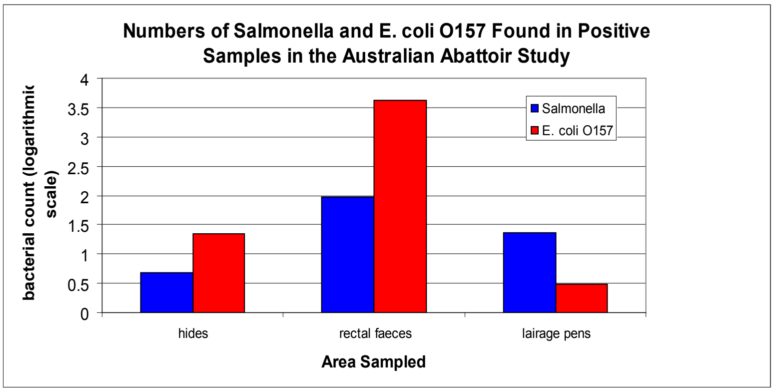
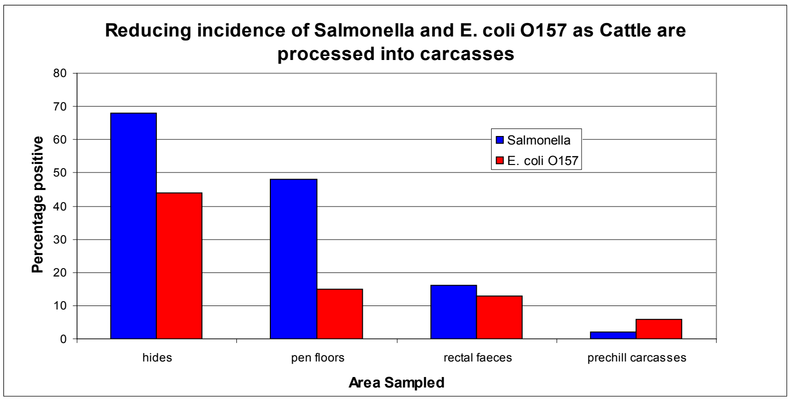
MEAT TECHNOLOGY UPDATE
Cutting-edge technology for the meat processing industry

Spread of foodborne pathogens during feeding, transportation and holding prior to slaughter

Pathogens such as *Salmonella*, *Escherichia coli* O157, *Campylobacter* and *Listeria* can be carried in the intestines of healthy livestock and are deposited into the environment with the faeces. This environmental contamination can then be transferred onto the hides of the carrier animals and others, and from there onto the carcases. Much work is being carried out in research centres in Australia and the rest of the world in order to understand the factors that contribute to the spread of pathogenic organisms between animals prior to slaughter. This work aims to identify the potentially vulnerable areas on which to focus control strategies.

Recent work in Australia found *Salmonella* in 48% of samples from holding pen floors at an abattoir, and on 68% of cattle hides. *E. coli* O157 was found in 15% of holding pen samples and on 44% of the cattle hides. Even though the actual numbers of the organisms were quite low, 6% of carcases had *E. coli* O157 on them before they were chilled, and 2% had *Salmonella*. All carcase isolations were associated with a particular group of cattle where the organisms had been found on the hides and in the faeces. After chilling, no *E. coli* O157 were found on carcases, but the *Salmonella* contamination was still present. While this study, which was carried out at a single abattoir, may not be representative of the situation across Australia, it demonstrated that if the pathogens are present on the cattle hides, *Salmonella* and *E. coli* O157 can be carried across to the carcases.





Abattoir operators are implementing good hygiene practices to minimise cross-contamination during slaughter and dressing, but if the incoming contamination on animal coats and in the intestines could be reduced, further reductions in the incidence of foodborne pathogens on fresh meat should be achievable. In an abattoir, there is usually a good correlation between the microbial load of the coat and that of the pre-chill carcases. The abattoir surveyed in the studies reported above, effectively reduced the pathogen incidence from high—prior to slaughter—to very low on the hot carcases, and ultimately to zero post-chilling—a very good outcome.

Feed and feed additives

A number of studies have considered the effect of diet on the prevalence of foodborne pathogens in livestock, with inconclusive results. In 2005, Australian researchers reported that cattle fed on a high grain diet (80% grain) had 2 to 2.5 log cfu/g more *E. coli* in the faeces than cattle fed a high roughage diet (50% roughage). These authors used a number of different ingredients in the diets: the forages including pasture hay, Rhodes grass and oat

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chaff; and the grains including barley, sorghum and cotton-seed meal, so the effects of individual components could not be elicited. Cattle were fed the diet for 30 days, to be sure that they had fully acclimatised to the diet, and that the results were a reflection of the diet, rather than the change in diet. The results, however, clearly show that high grain diets can lead to high *E. coli* counts in the faeces.

With particular regard to *E. coli* O157, researchers around the world have noticed that different forage crops in the diet may affect the course of *E. coli* O157 carriage following artificial infection, but little information is available about the effects of different forages on natural infection. Some authors believe that changing the diet can increase shedding of foodborne pathogens, but there are so many other factors involved that it is difficult to say whether diet change alone is causing the increase in shedding.

Most changes in diet coincide with a change in management practice, with or without a transportation phase. For example, diets change when animals first arrive at a feedlot, or—in the Northern Hemisphere —when moving from housing to pasture. After the animals have acclimatised to the new diet, shedding of pathogens decreases. The actual content of the diet seems to have little bearing on the level of shedding, but diets low in dry matter result in faeces that are more readily distributed widely in the environment and onto other animals. In sheep, diet change also tends to increase shedding of foodborne pathogens, particularly if the sheep are starved for more than 48 hours and then fed.

There is no real difference between the prevalence of faecal *E. coli* O157 in cattle from Australian feedlots and those from grassland production systems when the content of the hind gut is sampled after slaughter.

The search continues for feed additives such as probiotics ("good bacteria") that may reduce the carriage of foodborne pathogens by livestock. Some microorganisms produce factors (bacteriocins) that inhibit pathogens such as *E. coli* O157. There are other bacteria that parasitise organisms such as *Salmonella*, and also microbial viruses (bacteriophages) that will attack pathogens. Currently, few of these types of pathogen inhibitors are commercially available, although some probiotic mixes are in use in the USA for controlling *E. coli* O157 in calves. Some research in the US has found promising results using a cocktail of *Lactobacillus* organisms as probiotics, fed to feedlot cattle. The cattle receiving the probiotic mix NP51 had lower incidence of *E. coli* O157 in faeces and on hides at slaughter, than cattle not fed the probiotic mix. When the mix was fed in greater quantities, the reduction in faecal *E. coli* O157 incidence was enhanced. Faecal incidence at slaughter was estimated at 31.7% in control cattle, compared with 12.5% in cattle on low levels of NP51 and 8.2% in cattle on high levels of NP51. Similarly, hide incidences were estimated at 8.7%, 5.9% and 3.4% respectively. The main challenge seems to be in getting the probiotics, bacteriocin-producers and bacteriophages to the main sites of pathogen colonisation. *E. coli* O157 seems to settle very close to the end of the rectum, by the anus, and *Salmonella* may be lodged in the gall bladder and lymph nodes, while the feed additives enter the rumen, and do not necessarily move on.

Research is also underway into producing a vaccine against *E. coli* O157, but it is very difficult to produce a vaccine that will prevent the organism from colonising the host. Most vaccines prevent the host developing any symptoms, but the organism is still there and being shed as an infectious agent. Also, vaccines tend to be very specific to a particular strain of organism, so a vaccine that prevents *E. coli* O157 would not necessarily protect against another pathogenic *E. coli*, and definitely not against separate organisms such as *Campylobacter, Yersinia, Listeria* or *Salmonella* (and there are over 2,500 different strains of *Salmonella*). Trials on a vaccine against *E. coli* O157 are underway in North America, and preliminary work does show some success in reducing faecal shedding, but further work is needed before the food safety benefits can be understood.

Contamination in feedlots and on farms

As stated above, when animals arrive at the abattoir, many are carrying foodborne pathogens such as *Salmonella* or *E. coli* O157 in their faeces or on their hides. The organisms originate from the farm or feedlot where the animals are first colonised. Cross-contamination is inevitable between penned livestock in feedlots. The introduction to a pen of a single animal shedding a foodborne pathogen can rapidly lead to contamination of the coats of the others in the pen, and to shedding of the pathogen by the others. This is due to direct contact with the contaminated faeces produced by the shedding animal, or through mutual grooming.

Pathogens can also be transferred onto the coats from surfaces that look clean. Foodborne pathogens are quite persistent, and will persist in dried faeces and on visually clean surfaces for a number of days. Direct sunlight can limit this survival where the organisms are not shielded by a dried crust of faecal matter.

Water and feed troughs have also been identified as potential reservoirs of contamination in feedlots. *E. coli* O157:H7 can survive for more than three months in water, allowing contamination to be carried over between groups of animals subsequently housed in the same pen. Wet weather can contribute to cross-contamination, by lifting microorganisms stuck to the pen structures into suspension, allowing them to be rapidly spread within the pen and via surface run-off into adjacent pens.

Animal coats absorb moisture, and the microorganisms contained in that moisture are carried below the level of the guard hairs, to a sheltered position next to the skin. In this site, skin secretions and body warmth can support the survival of microbes and protect them from the lethal effects of drying and sunlight. Sheep, in particular, act as walking sponges, and the bacterial count of sheep fleece increases dramatically once they are wetted.

Researchers in North America and Europe report that some bacterial pathogens, for example *E. coli* O157, show a marked seasonality in shedding by livestock. High numbers of organisms are shed by large numbers of animals in the warmer summer months. In Australia, however, no such seasonality has been demonstrated, so stock must be considered to be of equal risk all year round. Most studies consider a single pathogen, but it may be that animals carrying one pathogen may not also carry another, so it is worth considering that if we apply an intervention to remove one pathogen, for example a vaccine against *E. coli* O157, we may allow the emergence of another pathogen just as important.

Sheep being loaded onto a clean truck

Transportation of livestock

When animals are transported, they may lose 7–8% of their initial body weight over a 15 hour period. Most of the loss is intestinal content. This is deposited, with its microbial load, into the truck or rail wagon. Intestinal transit time is reduced by stress. Transportation—being a stressful situation —results in greater amounts of faeces being produced by the animals in a confined space. Thus contamination between one animal and another through direct application of faeces and indirectly via the floors and walls of the truck or wagon is inevitable. It is important that trucks are clean before animals are loaded to prevent pathogens being carried over from one transport load to the next.

Feed withdrawal prior to transportation has been advocated in order to reduce the initial volume of gut content. It will not only reduce the amount of faeces deposited in the transporter but will also reduce the stress associated with transport. Some researchers believe that sheep and cattle feel travel-sick. Monogastrics such as pigs, humans, cats and dogs are visibly travel-sick. If a ruminant were physically sick, the vomiting mechanism would deposit the abomasal (4^{th} stomach) contents back into the omasum (bible or 3^{rd} stomach) and reticulum (2^{nd} stomach). An observer would not see any visible sign of sheep or cattle being 'sick', although the animals may well feel the stress of sickness.

The management of feed withdrawal (curfew) prior to transportation should be carefully considered in light of the livestock management practices to be used at the destination. Resuming feeding can increase the shedding of foodborne pathogens. This may happen, for example, where transport and water deprivation times are such that the animals must be rested with water and feed either during the journey or at the destination. At present, there is no clear guidance on best practice in curfew, as this phase impacts many considerations, such as food safety, meat quality and animal welfare. Researchers are now studying this area in detail to develop sound guidelines for the livestock industry.

Lairaging of livestock

The levels of coat contamination and faecal excretion of foodborne pathogens increases the longer animals spend in lairage. As mentioned above, foodborne pathogens are quite persistent, and will survive in dried faeces and on visually clean surfaces for a number of days. Routine lairage-cleaning practices may be insufficient to remove pockets of contamination containing foodborne pathogens. This means that contamination brought in on one processing day could be transferred onto animals processed on subsequent days.

When animals arrive at the abattoir, they may be fatigued from their journey, and wish to rest. They also want to explore their new surroundings, however, and, in the first ten minutes, there are numerous incidents of animals contacting each other and the structures of the holding pens. Activity then reduces and tired animals may lie down. Young veal calves and lambs will lie down very quickly after a journey, while cattle may stand for three hours or more. Different species respond differently to events occurring in the lairage. When humans pass the pen, sheep will flee and huddle in the far end of the pen, but cattle will probably ignore the people, unless they are noisy or moving quickly. When other cattle pass the pen, however, those in the pen will push forward to see and sniff those passing by; while sheep tend to ignore other sheep.

In a situation where animals are moved rapidly to slaughter and there is little time spent in the holding pens, the main sources of contamination of the coats are neighbouring animals and the pen walls. Where animals are held for longer periods, the impact of the floor as a source of contamination becomes more important and mutual grooming and licking of the pen walls will contribute to intestinal colonisation. Intestinal colonisation of the animals only becomes significant to food safety when the animals are held for 24 hours or more, and they begin to shed the organisms themselves and thus contaminate their surroundings and other animals in the pen. When intestinal colonisation occurs, the organisms can multiply in the gut, so in time, even more organisms are shed into the environment. If animals are likely to lie down, for example if they are held for three hours or more, it is important that the floor surface is clean and dry, as moisture will enhance contamination, and the parts of the hide in closest contact with the floor are the breast, belly, flank and hind legs—all areas of significance during the skinning process.

Cattle in a group holding pen

Where animals are penned together, it is inevitable that they will rub together, and thus cross-contamination can occur. Direct cross-contamination between cattle within a holding pen and indirect contamination between groups of cattle passing through raceways has been clearly demonstrated through use of marker organisms, and these organisms were subsequently found on the carcases produced.

In some countries, cattle are penned singly, in divided races. This is used where the farming industry is based on small family units which perhaps have only half a dozen cattle and the animals are sent individually to slaughter. Single penning reduces the incidence of DFD (dark cutting) in the carcases because it avoids hierarchical contests between unfamiliar cattle. Such contests deplete glycogen and cause dark cutting. Single penning also stops direct cross-contamination from animal to animal, but indirect cross-contamination is a common occurrence, as the cattle are held in races and repeatedly contact the bars and gates of the race. Also, the races are not easily cleaned between animals, and faecal material is easily transferred from one rump to the next, so this option possibly gives worse cross-contamination, particularly between groups of cattle, than the Australian system of group holding.

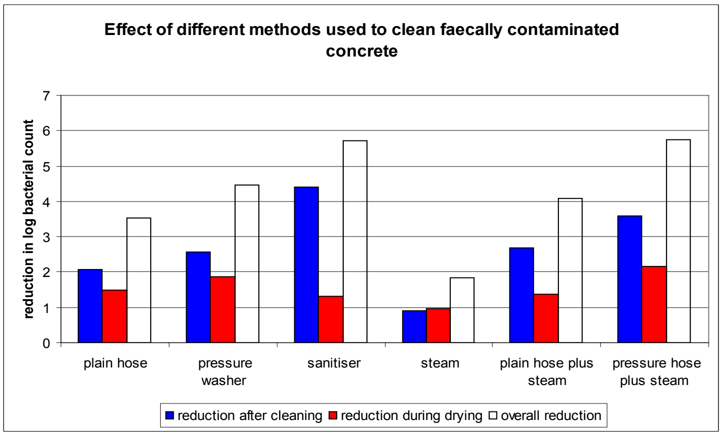
While cross-contamination between animals within a holding pen is inevitable when they rub together during their exploration of the unfamiliar surroundings, cross-contamination between batches of animals passing through the lairage and stunning facility can be reduced by effective between-batch decontamination of the structures.

Cleansing between each batch may not be practicable in a busy facility during the working day, but when the lairage is cleaned at the end of the day, it should be cleaned to a standard that will limit carry-over of foodborne pathogens from one processing day to the next. The cleaning procedure for the lairage should be incorporated into the routine end-of-day cleaning schedule. There are numerous chemical formulations available for cleaning but UK researchers recently found that in a lairage, pressure washing followed by steam application was just as good at reducing the bacterial counts on holding pen floors as was using a proprietary meat-plant sanitiser at maximum recommended concentration. The steam application was important, as it effectively and quickly dried the concrete surface. This caused further reductions in bacterial numbers after the pressure washing, and stopped contam-ination oozing back onto the surface within the residual water. Where a plain hose or pressure wash

A clean and dry holding pen.

was used, the initial reduction in bacterial numbers was 2–2.5 log cycles, but allowing the pen to dry exposed to air for one hour almost doubled the reduction; however, the overall reduction (3.5–4.5 log cycles) was less than that found with the pressure-hose and steam method (5.5 log cycles).

Having accepted that the abattoir lairage environment is a significant source of Salmonella contamination in pig meat production, some US scientists have advocated removing the lairaging phase entirely. A study was carried out looking at holding pigs on the transport vehicle, so that the pigs were moved directly from the truck to the stunning area. The prevalence of Salmonella in the intestines of the slaughtered pigs was reduced compared with pigs that had been held in the lairage under normal conditions. Both groups were held for 1½ hours after arrival of the vehicle at the abattoir yard. In a commercial situation, however, ensuring a constant flow of animals to the slaughter line would be impossible, and there would be the potential for animals to suffer from heat stress or hyperthermia if held on a stationary wagon in hot conditions.



Conclusions

Cross-contamination between animals is inevitable, but indirect cross-contamination between groups can be limited by thorough cleaning of the holding facilities and trucks between lots.

Thorough cleaning does not have to involve the use of large amounts of expensive chemicals; drying the surfaces after cleaning gives good reductions in bacterial load, even if the drying is no more than leaving the surface exposed to air for an hour or so.

On-farm strategies for reducing carriage of food-borne pathogens need to consider all foodborne pathogens, not just one in isolation. By focussing on a particular organism and controlling that, we may allow another pathogenic organism to emerge or become dominant.

It is possible that some forage plants may contain substances that can inhibit certain pathogens, such as E. coli O157, so that different diet constituents may be beneficial in controlling shedding, but at present, there is no clear message available.

Any strategy to control foodborne pathogens should consider events later in the chain. An effective reduction at one point may not be carried through and might not result in a reduction in prevalence on carcases. When designing pre-slaughter systems for control of foodborne pathogens and contam ination, we need to take an "holistic" approach and look at the complete chain.

Contact us for additional information

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