RISK MANAGEMENT ON THE FARM AND IN THE ABATTOIR

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In recent years food safety has been encouraged at the primary production stage through advice and mandated during food processing by legislation. On the farm, several pre-harvest interventions such as competitive inhibition, reduction in hide soiling, vaccination as well as diet manure and slurry management have been explored to control pathogens like Escherichia coli O157. During slaughter chemical dehairing, hide decontamination and carcass decontamination activities have been researched. The objective of this paper is to present a short review of these suggested controls in a risk management framework with E. coli O157 as the target pathogen.

INTRODUCTION

Bovine spongiform encephalopathy (first reported in 1986) and to a lesser extent the well publicised Escherichia coli O157:H7 outbreak in Lanarkshire in Scotland focused attention on food safety. As a consequence of the associated media interest and hype, bacterial pathogens like Salmonella have become household names and are of keen consumer focus. Consumer demand in turn resulted in government action and authorities responsible for food safety have been established in most European countries as has the European Food Safety Authority (EFSA). Considerable research resources have also been directed at food safety risk analysis. Risk assessments have been reported for a variety of bacterial pathogens in associated food products. Risk management systems such as hazard analysis and critical control point (HACCP) have been legally mandated and risk communicators have spent millions of euro on consumer food safety education and motivation. Despite this investment of resources, nobody would have been legally mandated and risk communicators have spent millions of euro on consumer food safety education and motivation. Despite this investment of resources, nobody would have suggested that the contamination of food with pathogens has been successfully understood and controlled. Using E. coli O157 as the target pathogen, this paper will discuss risk management on farms and in the abattoir and conclude that while the former is difficult to achieve the latter may prohibitively expensive. The key to successful risk management at present lies therefore, not in a lack of effective intervention technologies, but in the absence of a suitable cost structure.

PRE-HARVEST INTERVENTIONS

Many cases of human illness caused by E. coli O157 have been traced to beef products or other foods or water contaminated with cattle faeces [Chapman et al., 1993; Hancock et al., 1997]. Thus the farm is the ultimate source of these pathogens. Eradication would seem to be futile for an agent that is ubiquitous and not host specific. Efforts to remove infected animals, for example, would seem pointless for an agent with a short detectable infection period and which survives well in the environment. Furthermore, animal testing would be complicated by the fact that non-carriage animals may have contaminated hides, which are the primary source of bacterial contamination on carcasses.

However, simulation models have predicted that preharvest reductions of E. coli O157 prevalence in cattle would result in substantial reductions in the contamination of beef [Jordan et al., 1999; USDA:FSIS 2000] and consequent human disease [USDA:FSIS 2000]. These models have been borne out in several studies, which demonstrate a moderately high correlation between prevalence of E. coli O157 in cattle (faeces and hide) at slaughter plants and carcass contamination rates [Elder et al., 2000].

The seasonal pattern in human infection has been attributed to growth and multiplication of the pathogen in feed and water. If the rates of human illness decline in Winter due to the cyclical decline in prevalence in the reservoir, this suggest that controlling E. coli O157 in feed and water could be effective preharvest interventions to reduce human illness.

Cattle are exposed to faecal organisms in feed and water. Lynn et al. [1998] reported E. coli concentrations of up to 10^4 per gram in feed mixes fed directly to cattle. Considering that a high yielding dairy cow will consume 35 kg or more or feed per day, at 10^4 per gram the total intake of generic E. coli from feed would be 3.5 x 10^9. A recent US study by Hancock et al. [2001] reported E. coli O157 in 1.8% of cattle feeds and 3.8% of water troughs. Several on-farm pre-harvest controls have been suggested including competitive inhibition, reductions in hide soiling, vaccination, diet, manure and slurry management and other controls.
Competitive inhibition. In competitive inhibition, animals are fed or orally inoculated with bacteria that compete with the target organism. This approach has been demonstrated in poultry [Nisbet, 1993] and Zhao et al. [1980] reported similar work in cattle, although a definite product is not yet available. If competitive exclusion only reduced the incidence of carriage and shedding by 50%, this would have a significant impact on the ecology of E. coli O157 and environmental exposure.

Reductions in hide soiling
As hides are the primary source of bacterial contamination on beef carcasses, several countries have introduced ‘clean cattle policies’. However, at least 3 studies have cast doubt on the potential effectiveness of such a policy. Van Donkersgoed et al. [1997] found little correlation between visible soiling and carcass bacterial counts. Jordan et al. [1999] estimated that, based on the best available information, the effects of an industry wide reduction in visible hide soiling would be small. Byrne et al. [2000] found that power-hosing the hide for 3 minutes significantly reduced E. coli O157 counts on hides but did not decrease carcass contamination levels.

Vaccination
There are currently no food-borne human pathogens controlled by vaccination of the animal source. Vaccination therefore represents a novel approach to controlling the risks associated with E. coli O157. To date at least two such vaccines have been developed in the USA by the United States of America – Agricultural Research Service (USDA-ARS) and by the University of British Columbia. The former was unsuccessful, possibly due to interference with the bovine immune system by E. coli O157, while the latter reduced shedding but did not prevent carriage. Both were based on the live organism.

Diet
Diez-Gonzalez et al. [1998] and Russell et al. [2000] proposed switching cattle from a grain-fed diet to an all hay diet several days prior to slaughter as this would lower levels of organic acid in the colon, selecting for E. coli strains that are less acid resistant. In theory, if these strains were subsequently ingested by humans they would not survive the human gastric barrier. However, an all hay diet may increase the average duration of E. coli O157 shedding [Hancock et al., 2001]. Furthermore an all hay diet would result in reduced volatile fatty acids which are inhibitory to other pathogens such as Salmonella.

Cattle on grain based diets shed greater numbers of the pathogen and switching from grain to forage based diets could reduce E. coli O157 and other Enterohemorrhagic Escherichia coli (EHEC) [Callaway et al., 2003]. Corn silage or barley increased the risk of EHEC shedding while feeding whole cottonseed had the opposite effect [Hancock et al., 1994; Herriot et al., 1998; Buchko et al., 2000]. Furthermore, E. coli O157 recovered from the faeces of grain-fed cattle were 1000-fold more resistant to extreme acid shock (such as that encountered in the human stomach) as compared to cattle fed only hay [Diez-Gonzalez et al., 1998]. When cattle were abruptly switched from a 90% grain finishing ration to a 100% hay diet, faecal coliform populations decreased 1000-fold and the population resistant to extreme acid shock declined 100,000 fold within 5 days [Diez-Gonzalez et al., 1998].

Feed withdrawal or starvation during transport increased the total E. coli and Enterobacter populations throughout the intestinal tract [Buchko et al., 2000] including an increase in E. coli O157 in the rumen. Fasting animals are more susceptible to colonization with pathogenic E. coli [Cray et al., 1998] and in some cases previously negative animals become positive when feed is removed for any period of time [Kudva et al., 1997].

Manure and slurry management
Manure and slurry management practices may also influence the prevalence of E. coli pathogens on farms. Data from several sources indicate that E. coli O157 may persist for long periods of time in manure [Wang et al., 1996; Bolton et al., 1999; Maule, 2000]. Kudva et al. [1998] recovered E. coli O157 from an ovine manure pile after 21 months. Survival of E. coli O157 was observed in soil cores containing rooted grass for 130 days [Maule, 2000]. However, manure slurry containing E. coli O157 spread onto arable land and pasture land lost viability with less than 1% recoverable after 29 days. E. coli O157 population decreased in pasture soil by 4 to 5 log units after 50 days but the pathogen was still detectable after 99 days [Bolton et al., 1999]. Composting of manure at temperatures as low as 45°C will rapidly kill E. coli O157.

Other controls
Research by Sargeant et al. [2004] suggested that the removal of cats from the animal production environment would significantly decrease E. coli O157 carriage rates in cattle. Nielsen et al. [2002] suggest that non-organic bedding such as sand had lower E. coli O157 prevalence as compared to animals on organic materials including sawdust.

SLAUGHTER AND PROCESSING CONTROLS
A study of the prevalence of E. coli O157 in faeces, hides and carcasses of cattle at processing plants in the late summer months found that 28%, 11% and 45% were contaminated respectively. Interventions on the slaughter line reduced the latter to 20% post evisceration and 2% post all interventions. Hides are the major source of carcass contamination [Bell, 1997; Small et al., 2000; Barkocy-Gallagher et al., 2003; Rivera-Betancourt et al., 2004] and the first potential intervention targets the hide.

Chemical dehairing
There are conflicting reports as to the effectiveness of chemical dehairing in reducing subsequent carcass contamination levels. Schnell et al. [1995] reported that the dehairing process resulted in visually cleaner carcasses, but the bacterial load on carcasses were not significantly reduced. In contrast, both Castillo et al. [1998] and Nou et al. [2003] reported reduced aerobic bacterial, coliform and E. coli counts. Data from the latter also implied that any hide intervention process incorporated into beef processing procedures would significantly reduce carcass contamination by E. coli O157.
Conclusions

Control on the farm may be difficult given the ubiquitous nature of bacterial pathogens. Research is required to provide a greater understanding of the ecology and epidemiology of pathogens such as E. coli O157 on farms. The key issue for risk management in the abattoir is not technology, but the operation of some shared cost (primary producers, processors, retailers & consumers) framework so that currently available decontamination technologies can be applied and will no longer remain prohibitively expensive.

References

13. Dorsa et al., 1996a; Dorsa et al., 1997] and has been implemented in most US beef plants at several stages along the slaughter-line. However, this technique cannot be efficiently applied to the entire carcass [Dorsa et al., 1997].
14. Gill & Bryant, 1997; Nutsch et al., 1998) may be applied to the carcasses to reduce the bacterial counts. These technologies are particularly effective against gram-negative pathogens such as E. coli. Organic acids are widely used in the USA and there are varying reports in the literature on their decontaminating effect [Snijders et al., 1985; Prasai et al., 1991; Avens et al., 1996]. Lactic acid is the most commonly used organic acid and is often used in combination with hot water or steam treatments. Indeed, because none of these interventions are 100% effective, beef processors often use multiple hurdles intervention systems at various processing stages to ensure the safety of their products [Bacon et al., 2000].
15. Ionizing radiation has been approved for use in the USA for treating refrigerated or frozen uncooked meat. Traditionally performed by irradiating large lots of cuts or ground beef, the effectiveness of this treatment is well established. More recently, low dose, low penetration electron beam technology has evolved to allow whole carcass treatment. This technology, when applied in conjunction with the multiple hurdles discussed above, has the potential to eliminate most bacterial pathogens on meat carcasses including E. coli O157.


43. Small A., Reid C.-A., Avery S., Buncic S., Potential for the spread


