Introduction to Interventions

Despite the extensive scientific progress and technological developments achieved in recent years, microbial foodborne illness remains a global concern. Specific sources that contribute microbial contamination to animal carcasses and to fresh meat during slaughter and dressing include the faeces, the hide, oil, water, air, intestinal contents, lymph nodes, processing equipment, and humans. The types of microorganisms and extent of contamination present on the final product are influenced by sanitation procedures, hygienic practices, application of food safety interventions, type and extent of product handling and processing, and the conditions of storage and distribution (Sofos 2005).

Cattle are a major reservoir for *E. coli* O157:H7, which is carried in the intestinal tract of healthy animals and excreted in faeces (Chapman *et al.* 1993). Other organisms of concern to meat processors throughout the red meat supply chain (particularly during packaging and retail) include spoilage microorganisms and pathogens such as *Salmonella enterica*, *Listeria monocytogenes* and *Clostridium perfringens*. All these may be found in the faeces and on the hides of cattle presented for slaughter (Reid *et al.* 2002; Nightingale *et al.* 2004; Fegan *et al.* 2005a; 2005b) and can be transferred to the carcass during harvest, particularly through hide removal and evisceration (Bell 1997).

Australian meat processors have generally relied upon strict hygienic practices during processing to ensure that fresh meat is safe and wholesome. With new information on the public health implications of low levels of contamination with pathogenic microorganisms, however, and with regulatory bodies applying increasingly stringent performance criteria, it is becoming increasingly difficult to design systems that can be shown to consistently result in product that meets these requirements – particularly requirements of 'zero tolerance'. Some food safety intervention strategies are already in place in Australian abattoirs. For example, knife-trimming is common practice in Australian abattoirs and is required by AQIS for the removal of visible contamination of the carcass, such as ingesta, milk, hair/wool and faeces. Steam vacuuming is also commonly used in sheep processing plants to specifically target wool fibres and wool dust. Hot water decontamination is used in some beef abattoirs. These food safety technologies may be used in conjunction with new technologies that you may be considering as part of a whole of supply chain, food safety strategy.

Many countries such as the USA have implemented intervention-based HACCP, where a specific procedure is applied to the product during processing in order to reduce the microbial load present. An intervention is a procedure or process (mechanical or human) that significantly reduces the number of pathogens and other microorganisms present on a meat surface, be it a carcass or carcass piece. Using interventions can consequently lead to improvements in shelf life of the fresh or further processed product. Such interventions include knife trimming, hot water washes, organic acid washes, and steam vacuuming. These technologies and new food safety technologies are continually being developed to help processors to meet the increasingly stringent microbiological criteria that are being applied through the red meat supply chain. Regulatory bodies in a number of countries are accepting the use of intervention technologies as part of the fresh meat processing chain. For example, the US Food Safety and Inspection Service (FSIS) document '*E. coli* O157:H7 contamination of beef products' (USDA/FSIS 2002) and accompanying guidance documents were published in the Federal Register in October 2002. *Inter alia*, they stated that beef slaughter establishments should consider interventions that can be validated and verified as CCPs for reducing or eliminating *E. coli* O157:H7.

Food safety technologies such as hot water/steam pasteurisation have been implemented in Australian abattoirs, mainly because this technology is acceptable to the EU market as it only uses potable water on the carcass during the washing process, but Australian processors are also considering and trialling interventions such as acidified sodium chlorite, rinse-and-chill and ozone. At present, if these establishments are also processing product destined for the EU, the EU product is not treated with the non-approved intervention. EU Regulation 853/2004, provides a legal basis to permit the use of a substance other than potable water to remove surface contamination from products of animal origin. Previously, such a legal basis did not exist in the EU legislation for red meat and for poultry meat. The regulation provides guidance to Decision 1999/468/EC (Article 5) that a committee shall deliver an opinion on any proposal requiring amendment to the regulatory procedure. For example, the European Food Safety Authority recently posted the opinion of the AFC Panel (Panel on Food Additives, Flavourings, Processing Aids and Materials in Contact with Food) related to treatment of poultry carcasses with chlorine dioxide, acidified sodium chlorite, trisodium phosphate and peroxyacids. AFC is a panel providing comment on food additives, flavourings, processing aids and materials in contact with food. The Panel concluded that processing of poultry carcasses (washing, cooking) would take place before consumption, and therefore treatment with trisodium phosphate, acidified sodium chlorite, chlorine dioxide, or peroxyacid solutions, under the described conditions of use, would be of no safety concern.

There will always be continued improvements during the slaughter process, but an alternative long-term strategy may be to minimise the presence of human pathogens on the incoming live animals. However, this approach requires changes to farm management practices and supported by scientific research. At present, many of these potential food safety technologies are still at the 'research' stage. In terms of microbial reductions, the results of scientific research, both under laboratory scale and commercial scale systems, is highly variable regardless of the food safety technology evaluated. A decision on which technology to implement will rely entirely on the required outcome, the constraints of the market, whether export or domestic, and on space availability and infrastructure in the existing premises.

The reason for implementing an intervention is to reduce the likelihood of pathogenic micro-organisms being present on the carcasses and meat. *Salmonella* and *E. coli* O157:H7 are the main target organisms in contemporary fresh meat production. No single intervention technology can provide 100% assurance of the safety of a food product, and systems that provide reductions of 1-2 log units would be considered to provide appropriate improvements in the microbiological status of the product. One cannot emphasise sufficiently the need for good hygienic practices throughout the meat supply chain, supported by proper temperature control. No intervention can be expected to correct a highly contaminated product. Interventions such as those described in this review should form part of a multiple-hurdle approach to the production of safe, wholesome meat. Operators should not view any of these technologies as a way of rendering product with an initially high microbial loading "clean" and therefore pay less attention to the strict hygiene procedures necessary.

Food Safety Technologies

The technologies described in this package have been categorised as physical interventions or chemical interventions, and includes those that are currently available and novel technologies. Each intervention treatment is considered in terms of its microbial efficacy, food safety issues, advantages and limitations of the technology, the current regulatory status, market access and potential customer issues. The food safety technologies described can be applied at one or more points in the supply chain: pre-slaughter, slaughter, chilling, packaging and retail.

Most of the technologies have been focused at the slaughterhouse phase because studies have shown that most contamination of faecal origin occurs during hide/skin removal and evisceration processes (Newton *et al.* 1978; Bell 1997; Sofos *et al.* 1999), and is best removed immediately, before bacteria attach firmly to the meat surface. The extent to which carcasses are contaminated with bacteria varies between plants, and is influenced by many factors including plant design, speed of slaughter, degree of adherence to good handling practices, and the skill of the operators (Biss and Hathaway 1996; Hudson *et al.* 1998; Vivas-Alegre and Buncic 2004). Other factors that also contribute include the type and age of animal slaughtered, the feed provided, the season and the lairage conditions prior to slaughter (Davies *et* *al.* 2000), so there are good justifications for applying intervention technologies on the farm and prior to slaughter as well as during slaughter and dressing.

In applying a microbial reduction step to a carcass, the efficacy of the method used is influenced by factors such as water pressure, temperature, chemicals present and their concentration, time of exposure, method of application and equipment design, and the stage in the process at which the method is applied (eg. before hide removal, after hide removal, after evisceration, after chilling etc) (Bacon *et al.* 2000; Koohmaraie *et al.* 2005).

When choosing an intervention step, there are issues other than microbial efficacy to be considered. They include the influence of the process on product and worker safety, product quality, the environmental contribution in terms of waste and effluent disposal, and cost or value for money. Acceptable intervention systems should not have adverse toxicological or other health effects on workers during their application, or on consumers as a result of their use.

Even if intervention technologies are applied at pre-slaughter or slaughter, the product may still incur microbiological contamination through subsequent handling and packaging operations (Gill *et al.* 2001; Aslam *et al.* 2004). Therefore, further intervention or preservation treatments may be of benefit during chilling or packaging of primals or for retail sale.

Chemical Interventions

Chemical interventions involve the application of food grade chemicals to the animal or carcass surface to inhibit or kill microorganisms. Typically, the mode of action of these antimicrobials is by altering the pH of the meat surface, with organic acids, such as lactic or acetic (giving a low pH), being the most commonly used chemicals. The concerns with the use of any chemical intervention process are both the potential to induce resistance in possible human pathogens and the potential to select for resistant organisms out of the overall microbial population – if resistance becomes widespread, more organisms will survive and the process becomes less effective. Other negative aspects of chemicals, both short and long term, are that they can have an occupational health and safety effect on workers, corrosive effects on equipment, and sensory effect on meat.

The efficacy of chemical treatment methods varies depending on the length of time the bacteria have been in contact with the meat surface and whether the bacteria are protected on the surface by fats, small cuts or in hair follicles and the chemical is unable to come into contact with the cell. Also the temperature of the carcass surface, presence of moisture, and solidification of fat surfaces during cooling, are all likely to affect the ability of a chemical treatment to effectively decontaminate a carcass.

In general, chemical intervention steps are applied immediately after dehiding/evisceration but before chilling. The aim is to inhibit further attachment of any bacteria that may have come from the hide or intestines. There are also intervention steps that can be applied before hide removal eg. chemical dehairing/hide washing.

Any chemical applied to meat will be regarded either as a processing aid (where there are no residual effects of the chemical), or as a food additive. Food additives must be declared on the product label.

<u>Processing Aid</u>

The Australia New Zealand Food Standards Code (FSANZ 2006) (Standard 1.3.3) defines a processing aid as “a substance listed in clauses 3 to 18, where –

(a) the substance is used in the processing of raw materials, foods or ingredients, to fulfil a technological purpose relating to treatment or processing, but does not perform a technological function in the final food; and

(b) the substance is used in the course of manufacture of a food at the lowest level necessary to achieve a function in the processing of that food, irrespective of any maximum permitted level specified.”

<u>Food Additive</u>

The Australia New Zealand Food Standards Code (FSANZ 2006) defines a food additive as: “any substance not normally consumed as a food in itself and not normally used as an ingredient of food, but which is intentionally added to a food to achieve one or more of the technological functions specified in Schedule 5.” It or its by-products may remain in the food. Food additives are distinguishable from processing aids (see Standard 1.3.3) and vitamins and minerals added to food for nutritional purposes (see Standard 1.3.2). Food additives must be declared on the package label.

Novel technologies

Traditional food processing has relied on thermal treatment to kill/inactivate microbiological contaminants. Unfortunately, thermal processing can induce physical and chemical changes in the food. Novel technologies are those technologies that use little heat to preserve the product while minimizing the quality and nutrient losses. Examples include high hydrostatic pressure processing (HPP), pulsed electric field (PEF), high-intensity light, electrolysed water treatment, ultrasonics and irradiation. Chemical treatments such as organic acid spray may not involve heat, but are not considered to be "novel technologies", as they are widely accepted in some countries.

For many of these technologies much research is still required before commercialisation because: (*i*) the mechanisms(s) of microbial inactivation requires clarification so that the critical processing parameters can be reliably monitored; (*ii*) existing regulatory issues must be adequately addressed to accommodate commercial application processes; and (*iii*) current costs of some of these technologies may be prohibitive to some customers. Most are directed at small volumes of product, such as primal cuts, retail cuts or processed meats.

According to USDA/FSIS (2003) "new technology" is defined as new, or new applications of, equipment, substances, methods, processes or procedures affecting the slaughter of livestock and poultry or processing of meat, poultry, or egg products which could affect product safety, inspection procedures, inspection program personnel safety, or require a waiver of a regulation.

Currently, there are no specific regulations for the novel technologies discussed below. In general, the approach is that standard health regulations apply, and that the process should demonstrate equivalence with traditional processes (eg. pasteurisation). As a rule, good manufacturing practice and a demonstration that the process (i.e. validation and verification) is under control will be required. The EU stance is that if it is possible to show that the new treatment is substantially equivalent to a treatment already in use commercially, then the treatment can be authorised at a national regulation level and the product will not need to comply with the EU "novel food" regulation (CE 258/97). There is also substantial opposition to any decontamination treatment, partially due to fears of residues in the food, but mainly due to the fear that use of decontamination will encourage poor hygienic practice during production. In the USA, the standard health regulations are applied.

To date, high hydrostatic pressure processing appears to be the most promising novel technology (outside of food irradiation) because of its well-established knowledge base and currently available products in the global market-place (Guan 2005).

References

Aslam, M., Greer, G. G., Nattress, F. M., Gill, C. O., McMullen, L. M. (2004) Genotypic analysis of *Escherichia coli* recovered from product and equipment at a beef-packing plant. Journal of Applied Microbiology **97**: 78-86.

Bacon, R. T., Belk, K. E., Sofos, J. N., Clayton, R. P., Reagan, J. O., Smith, G. C. (2000) Microbial populations on animal hides and beef carcasses at different stages of slaughter in plants employing multiple-sequential interventions for decontamination. Journal of Food Protection **63**: 1080-1086.

Bell, R. G. (1997) Distribution and sources of microbial contamination on beef carcasses. Journal of Applied Microbiology **82**: 292-300.

Biss, M. E., Hathaway, S. C. (1996) Effect of preslaughter washing of lambs on the microbiological and visible contamination of the carcasses. The Veterinary Record **138**: 82-86.

Chapman, P. A., Siddons, C. A., Wright, D. J., Norman, P. Fox, J., Crick, E. (1993) Cattle as a possible source of verocytotoxin-producing *Escherichia coli* O157 infections in man. Epidemiology and Infection **111**: 439-447.

Davies, M. H., Hadley, P. H., Stosic, P. J., Webster, S. D. (2000) Production factors that influence the hygienic condition of finished beef cattle. The Veterinary Record **146**: 179-183.

Fegan, N., Higgs, G., Vanderlinde, P., Desmarchelier, P. (2005a) An investigation of *Escherichia coli* O157 contamination of cattle during slaughter at an abattoir. Journal of Food Protection **68**: 451-457.

Fegan, N., Vanderlinde, P., Higgs, G., Desmarchelier, P. (2005b) A study of the prevalence and enumeration of *Salmonella* enterica in cattle and on carcasses during processing. Journal of Food Protection **68**: 1147-1153.

FSANZ (2006) Australia New Zealand Food Standards Code, consolidated version including amendment 85. http://www.foodstandards.gov.au/foodstandardscode/ Accessed 8th March 2006.

Gill, C. O., McGinnis, J. C., Bryant, J. (2001) Contamination of beef chucks with *Escherichia coli* during carcass breaking. Journal of Food Protection **64**: 1124-1837.

Guan, D., Hoover, D. G. (2005) Emerging decontamination techniques for meat. In: Improving the Safety of Fresh Meat (Ed: Sofos, J. N.) Woodhead Publishing Limited, CRC Press, New York, pp 388-417.

Hudson, W. R., Mead, G. C., Hinton, M. (1998) Assessing abattoir hygiene with a marker organism. The Veterinary Record **142**: 542-547.

Koohmaraie, M., Arthur, T. M., Bosilevac, J. M., Guerini, M., Shackelford, S. D., Wheeler, T. L. (2005) Post-harvest interventions to reduce/eliminate pathogens in beef. Meat Science **71**: 79-91.

Newton, K. G., Harrison, J. C. L., Wauters, A. M. (1978) Sources of psychrotrophic bacteria on meat at the abattoir. Journal of Applied Bacteriology **45**: 75-82.

Nightingale, K. K., Schukken, Y. H., Nightingale, C. R., Fortes, E. D., Ho, A. J. Her, Z., Grohn, Y. T., McDonough, P. L., Wiedmann, M. (2004) Ecology and transmission of *Listeria monocytogenes* infecting ruminants and in the farm environment. Applied and Environmental Microbiology **70**: 4458-4467.

Reid, C. A., Small, A., Avery, S. M., Buncic, S. (2002) Presence of foodborne pathogens on cattle hides. Food Control **13**:411-415.

Sofos, J. N., Kochevar, S. L., Bellinger, G. R., Buege, D. R., Hancock, D. D., Ingham, S. C., Morgan, J. B., Reagan, J. O., Smith, G. C. (1999) Sources and extent of microbiological contamination of beef carcasses in seven United States slaughtering plants. Journal of Food Protection **62**: 140-145.

Sofos, J. N. (2005) Improving the Safety of Fresh Meat. Woodhead Publishing in Food Science and Technology, CRC Press, New York.

USDA-FSIS (2002) *E. coli* O157:H7 contamination of beef products. United States Department of Agriculture, Food Safety and Inspection Service. Federal Register. **67**: 62325-62334.

USDA-FSIS (2003) FSIS procedures for notification of new technology. United States Department of Agriculture, Food Safety and Inspection Service. Federal Register **68**: 6873-6875.

Vivas-Alegre, L., Buncic, S. (2004) Potential for use of hide-carcass microbial counts relationship as an indicator of process hygiene performance of cattle abattoirs. Food Protection Trends **24**: 814-820.