Technical Annex

Generic RMP: Slaughter, Dressing, Cooling and Boning of Sheep

Prelims

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Website

A copy of this document can be found at http://www.nzfsa.govt.nz/animalproducts/index.htm

1 Introduction

This document was originally published in 1998 as separate annexes to the *Generic HACCP Plan for Slaughter and Inverted Dressing of Sheep and Lambs* and the *Generic HACCP Plan for the Cooling and Boning of Beef*. These annexes have been combined to align with the revised scope of the *Generic RMP for the Slaughter, Dressing, Cooling and Boning of Sheep*. Some of the information is out of date, e.g. data from the National Microbiological Database (NMD), but the hazard analysis remains valid and provides the scientific basis for the application of HACCP principles in the generic RMP.

This document is presently being updated to include the latest NMD results, and information from recent scientific trials and literature.

2 Foodborne Illness Associated with Mutton and Lamb

Foodborne illness directly attributed to the consumption of sheep and lamb products is rare in comparison to other types of meat. However, there have been isolations of important food pathogens, including *Salmonella, Escherichia coli* O157:H7 and *Campylobacter* spp., from lamb and sheep products (Doyle and Padhye, 1989; Stern and Kazmi, 1989).

In New Zealand, nearly 10,000 cases of food or waterborne illness were notified in 1995 (Gilbert *et al.*, 1996). The highest incidences were for campylobacteriosis (7525 cases) and salmonellosis (1363 cases). Fifteen cases were notified for listeriosis and six cases for verotoxin-producing *Escherichia coli*. Sources of the foodborne illness were not identified in the report. Over recent years, the incidence of campylobacteriosis and yersiniosis has been increasing in New Zealand. In addition, other foodborne diseases have emerged, for example, verotoxin-producing *Escherichia coli* infection was first identified in New Zealand in 1993 (ESR, 1997).

3 Biological Hazards

Biological hazards associated with the consumption of sheep and lamb products are briefly discussed in the following sections.

3.1 Pathogenic Bacteria

***Salmonella* spp.**

Salmonella and other enteric pathogens are typically associated with faecal material and have been isolated from sheep and lambs. The prevalence of these organisms in the live animal is likely to be higher in association with intensive farming practices and stressful conditions such as overcrowding and transportation to slaughterhouses (D'Aoust, 1989). The prevalence of asymptomatic infection in sheep and cattle in New Zealand is probably in the region of 1-5% (Wilks and Humble, 1997). *Salmonella* can be transferred onto the carcass during slaughter and dressing through contact with the pelt, ingesta, contaminated hands and equipment.

In a survey of New Zealand lamb slaughter premises from 1993-1995, Salmonella was detected in 0.65% (n=5/772) and 0.3% (n=10/3300) of samples from lamb carcasses and lamb boning room products, respectively (Armitage, 1995). The latest National Microbiological Database summary (January 1998) for ovine shows that *Salmonella* was not detected in 322 carcasses and 1268 samples of primal cuts and bulk products.

***E.coli* O157:H7**

E.coli O157: H7 is an enteric pathogen that in recent years has increasingly been implicated in a number of foodborne outbreaks in several countries. Meat related outbreaks of *E.coli* O157:H7 infection have been attributed largely to ground beef (Padye and Doyle, 1992).

E.coli O157: H7 infection was first identified in New Zealand in 1993. To date, there have been a total of 22 cases of infection in humans (ESR, 1997). A source of infection has not been identified for any of these cases.

Surveys of retail fresh meat products in North America have found *E.coli* O157:H7 in 2% of the 205 lamb samples tested (Doyle and Schoeni, 1987).

Campylobacter

Campylobacter can be isolated from the faeces of all animals, almost always without signs of clinical disease (Johnston, 1990). Since healthy sheep and lambs may be carriers of *Campylobacter* spp., faecal contamination of meat represents a potential route leading to human infection.

In New Zealand, the most significant factors associated with cases of campylobacteriosis are the consumption of raw or undercooked foods (notably poultry, but also unpasteurized dairy products) and the consumption of untreated drinking water (ESR, 1996). *Campylobacter* is far less frequently associated with red meat consumption. This appears to be due to the lower carriage rate of mammals compared to birds and the fact that the bacteria appear to die off on the dry carcass surface (Hasell, 1994). Freezing also significantly reduces the number of viable organisms (Hasell, 1994).

At the retail level, *Campylobacter* has been isolated in 0 to 8% of lamb products (Harris et al., 1986; Stern and Kasmi, 1989; Wallace, 1997).

Listeria

The presence of *Listeria monocytogenes* on carcasses has long been attributed to contamination by faecal matter (Johnson et al., 1990). However, a New Zealand study by Lowry and Tiong (1988) suggested that animal hides and pelts are a more important source of *Listeria* than faecal contamination. They failed to isolate *Listeria* from the faecal contents of 33 cattle and lambs, but found 17% of beef hides and 43% of lamb pelts to be positive for *L. monocytogenes*.

The excretion of *L. monocytogenes* by farm animals has been linked to their diet, with animals fed entirely on hay or manufactured diets not excreting detectable levels of *Listeria* (Fenlon *et al*., 1996). In contrast, animals fed on silage, which is frequently contaminated with *L. monocytogenes*, commonly excreted the organism.

Several studies have shown that further processing of carcasses into boned cuts and ground meat significantly increases the level of *Listeria* contamination (Fenlon *et al*., 1996). For example, Lowry and Tiong (1988) observed an increased incidence of *L. monocytogenes* on boneless lamb (60%) compared with lamb carcasses (30%).

Staphylococcus aureus

Staphylococcal food poisoning results from the ingestion of food containing the enterotoxin produced by certain strains of *Staphylococcus aureus*. Staphylococci are widespread in the environment with major reservoirs being humans and animals. Raw meat products can frequently be contaminated with these organisms, primarily by human handlers but occasionally by animal-sourced staphylococci, e.g. from mastitic milk (Bergdoll, 1989). Animal strains of *S. aureus* have rarely been associated with outbreaks of staphylococcal food poisoning in man (Wilks and Humble, 1997).

S. aureus competes poorly with other bacteria and thus seldom causes food poisoning in raw meat products (ICMSF, 1996a). Foodborne illness due to *S. aureus* enterotoxin is primarily a result of contamination by food handling personnel and is generally associated with temperature abuse of cooked products (Bryan, 1980; Bergdoll, 1989).

Clostridium perfringens

Clostridium perfringens Type A is one of the most widely spread pathogenic bacteria in the environment. It is part of the microflora of the soil and can therefore be found on the hide and hooves of livestock. It has also been found in the intestinal contents of animals. Most commercially available meats are contaminated at some level with *C. perfringens* because of the organism's ubiquitous nature (Bates, 1997).

C. perfringens outbreaks are generally associated with cooked products that have been kept at inadequate holding temperatures in institutional and food service settings (Bryan, 1980; Bates, 1997).

***Yersinia* spp.**

Yersiniosis is an emerging foodborne problem worldwide. *Yersinia enterocolitica* has been identified as an important cause of gastrointestinal illness in New Zealand (Wright, 1995). A recent New Zealand study clearly shows that all species of ruminants can be clinically affected by *Yersinia* spp., with sheep, goats and cattle appearing to be the most commonly affected species (Fenwick, 1997). Intestinal prevalence rates of up to 30% have been found in clinically normal cattle, lambs and deer in New Zealand (Bullians, 1987; Wilks and Humble, 1997), including potentially human-pathogenic serotypes in lambs (Bullians, unpublished data).

Y. enterocolitica is often present in foods, particularly those of animal origin. A survey in New Zealand found *Y. enterocolitica* in 3.4% of 203 ready-to-eat flesh foods, including

processed meats, poultry and seafood (Hudson *et al*., 1992). Two of the three lamb products tested were found to be positive for the organism.

3.2 Parasites

Toxoplasma gondii

Toxoplasma gondii is a protozoan parasite that encysts in the tissues of a variety of mammalian hosts including sheep and lambs. Estimated prevalence rates in animals in New Zealand are in the region of 60-70% (Wilks and Humble, 1997). In sheep, toxoplasmosis is a common cause of placentitis, abortion and perinatal mortality. Human infection can be contracted from tissue cysts in foods such as raw or undercooked meat, or from oocysts originating from cats (Wilks and Humble, 1997).

4 Chemical Hazards

Chemical hazards that could be present in slaughter animals include agricultural chemicals (i.e. pesticides, herbicides, veterinary drugs) and environmental contaminants (i.e. heavy metals, organochlorines).

The New Zealand Food Safety Authority (NZFSA) maintains a National Residue Monitoring and Surveillance programme which monitors the residue status of animals slaughtered for human consumption. Random sampling ensures representative sampling of the national population. Positive results are investigated and the noncomplying farm is placed on a chemical suspect list. Animals from chemical suspect lines are identified at receiving before slaughter. Carcasses and products from chemically suspect animals are sampled and retained, as appropriate, until residue test results are available. Disposition of the products is then determined by the regulator.

5 Physical Hazards

Foreign objects, such as metal and bone, have the potential to cause injury such as cuts, broken teeth, chocking and intestinal perforation. Information from the USDA-FSIS (1996b) indicates that bone particles less than 10 mm are unlikely to pose as a food safety hazard. Bone particles from 10 to 20 mm may present a discomfort, but would be a low risk for a food safety hazard, and bone particles greater than 20 mm have the potential to be a food safety hazard and may cause injury to consumers.

The incidence of bone in boneless products is dependent on the skill of the boner, with highly skilled boners capable of producing products with minimal levels of bone. Adequate training of boners, therefore, plays a key role in controlling levels of bone in boneless products. It is common practice in New Zealand premises to inspect products for defects, including bone in boneless products, and rework those lots that are found to exceed the established limits.

Anecdotal evidence from New Zealand slaughterhouses suggests that shotgun pellets in slaughter sheep and lambs are unlikely.

6 Effects of Presentation Status and Key Process Steps on Microbiological Hazards

6.1 Presentation Status of Livestock for Slaughter

The two most important factors affecting the presentation quality of lambs for slaughter in New Zealand are the length and the degree of contamination of the fleece. Fleece length usually ranges from a minimum of approximately 1 cm on freshly shorn animals to a maximum of approximately 15 cm on lambs that have never been shorn (Biss and Hathaway, 1995a). The cleanliness of the fleece varies largely in relation to the prevailing environmental conditions around the time of slaughter and conditions during transport of the animals from the farm to the slaughterhouse.

New Zealand studies clearly show that the presentation status of lambs, including preslaughter washing, has a significant effect on the microbiological contamination of the carcass (Biss and Hathaway, 1995b; 1996a; 1996b). Increased wool length, dirtiness, and the use of preslaughter washing are significantly associated with increased levels of microbiological contamination of the carcass. Biss and Hathaway (1995b) found that the initial microbiological contamination on carcasses derived from clean, shorn (≤2 cm), unwashed lambs was five times lower than that from dirty, woolly (≥6 cm), washed lambs, which were the worst presented animals.

Biss and Hathaway (1995b) also observed that carcasses from unwashed lambs had lower microbiological contamination, but had markedly higher rates of visible contamination than those from washed lambs. Subsequent studies have confirmed this finding (Biss and Hathaway, 1996a; Lee *et al*., 1997). Industry needs to identify procedures that offer an acceptable balance between decreasing the presence of potential enteric pathogens, while limiting rates of visible contamination to levels acceptable to industry, their clients and regulators.

HACCP validation trials to compare microbiological contamination levels on carcasses pre-HACCP (i.e. GMP-based controls) and post-HACCP (i.e. HACCP-based controls) were recently undertaken at three premises. Results show that carcasses from lambs presented for slaughter with short (3-5 cm), clean, and dry wool and processed under a HACCP plan

based on the generic model, have significantly lower prevalence and levels of *E. coli* (Lee *et al*., 1997).

It is clear that presenting sheep and lambs for slaughter with short, clean and dry wool is ideal. However, for most premises it would be unrealistic to expect that stock with these ideal characteristics would be available at all times of the year. Premises therefore have to develop their own criteria and procedures that deliver a balance between an acceptable microbiological outcome and what is commercially practical.

6.2 Forequarter Workup and Removal of the Pelt

The major food safety hazard associated with the dressing of lamb carcasses is the contamination of meat with enteric pathogens (e.g. *Salmonella* spp., *E. coli* O157:H7) originating from faecal material (Gill *et al*., 1995). Faecal contamination of dressed carcasses can occur as a consequence of either direct contact with faecal material or contact with surfaces that have themselves been in contact with faecal material, e.g. fleece and operators' hands (Bell and Hathaway, 1996). Even brief contact with faecal material can produce contamination of up to 106 bacteria /cm2, enough to cross-contaminate 10 or more successive carcasses at significant levels (Roberts, 1980). The attachment of bacteria is both instantaneous (within 1 min) and resistant to rinsing (Kriaa *et al*., 1985).

The microbiological profile of operators' hands after dressing procedures that necessitate direct contact with the fleece is similar to that carried by the fleece in that region (Bell and Hathaway, 1996). Therefore, contact between carcass and unrinsed operators' hands may introduce comparable contamination to contact between carcass and fleece, for those operations in which fleece/hand contact is unavoidable.

Studies of inverted dressing systems for sheep and lambs in New Zealand indicate that forequarter workup and pelting have a significant impact on the microbiological contamination of the lamb carcass (Bell *et al*., 1993; Biss and Hathaway, 1995a), even when appropriate livestock presentation is practised. Contamination during pelting is the single most important contributor to the microbiological contamination of ovine carcasses, compared with evisceration and inspection. In addition, while there is a gradual "smoothing" of the initial effects as dressing proceeds, the effects obtained at pelting are, in general, maintained through to cutting and boning of the product (Biss and Hathaway, 1995a). These findings are supported by a recent national microbiological survey of lamb carcasses in New Zealand export premises (MAFRA, unpublished data).

Bell *et al*. (1993) observed that with inverted dressing of lamb, high levels of bacterial contamination were associated with opening cuts in the forequarter region, e.g. the Y-cut brisket region. The aerobic plate count (APC) recorded for the brisket sites were consistent with fleece/carcass contact which occur primarily due to fleece rollback (Bell and Hathaway, 1996). Carcasses also showed very high contamination at the flap site, which was suspected to be associated with the manual punching process used to clear the flank region to reduce pelt strain. This procedure provides a good opportunity for the manual transfer of microbial contamination from the fleece to the flap region of the carcass. Poor livestock presentation has been shown to increase contamination at these forequarter sites and also impact on other less affected sites such as the hindquarter.

Considerable effort is applied to the control of direct carcass-pelt contact (rollback) in New Zealand premises because of the assumption that this one of the most important mechanisms by which the bacteria are transferred from the pelt to the carcass. The study of Biss and Hathaway (1995a) confirmed the validity of this assumption. They observed that the mean APC on the neck of each of three groups tested were significantly reduced if rollback was controlled. APC counts were reduced from 11,200 to 360 CFU/cm^2 for shorn, unwashed lambs; from 7,400 to 2,600 CFU/cm^2 for woolly, unwashed lambs; and from 39,800 to 5000 CFU/cm^2 for woolly, washed lambs. Mean *E. coli* counts obtained were very low, and an analysis of the incidence of detectable counts revealed a significantly lower incidence if rollback was controlled in the two unwashed groups. Visible contamination, comprising of wool with occasional deposits of dust, was also significantly reduced in the unwashed groups by controlling rollback.

Under GMP, premises should be able to control the occurrence of rollback to ≤5% for short wool, dry, clean sheep and lambs (Biss, pers. com.).

6.3 Pre-Evisceration Washing

Pre-evisceration washing has long been used as an integral part of the production of ovine carcasses to remove visible contamination. A New Zealand study showed that pre-evisceration washing applied to the forequarters of ovine carcasses in an inverted dressing system resulted in the reduction of high levels of visible contamination by 62.8 to 70.5%, primarily through the removal of wool (Biss and Hathaway, 1994). Although the benefits of pre-evisceration washing in terms of visible contamination are clear, there have been concerns that such washing results in the redistribution of microbiological contaminants from localised sites of high contamination to a much greater surface area of the carcass.

Biss and Hathaway (1996c) investigated the effect of pre-evisceration washing on visible contaminants and associated microbiological contamination on ovine carcasses. Their study showed that pre-evisceration washing of carcasses had very little effect on the uncontaminated areas of the carcasses, but markedly reduced the mean APC and *E. coli* counts at the site of visible contaminants. However, the residual levels of both APC and *E. coli* counts directly at sites of faecal contamination after washing were still significantly higher than at visually clean sites. There was very little evidence of redistribution of bacteria to immediately adjacent but visually clean sites. These findings are in general agreement with those reported by Hardin *et al*. (1995) who observed minimal redistribution of pathogens from areas of faecal contamination to immediately adjacent sites following trimming, cold water washing and acid washing of beef carcass surfaces.

In contrast, other studies have reported (Bell *et al*., 1996; Gill *et al*., 1996) that carcass washing of beef carcasses brought about posterior to anterior redistribution of microbial contamination, resulting in increased counts at forequarter sites. Biss and Hathaway (1996c) suggests that the likelihood of such redistribution to dependent sites may be greater for beef carcasses than lamb carcasses because lamb carcasses have smaller surface areas to be covered by the wash, and the integrity of their subcutaneous tissues is generally intact after pelting.

6.4 Evisceration

In modern processing, the respiratory and intestinal tracts are not considered major sources of contamination (Bell and Hathaway, 1996). Evisceration can be carried out with minimal contamination of the carcass provided no leakage from the gastrointestinal tract occurs and the intestinal tract is not ruptured or punctured during evisceration. The preventive measures for reducing hazards during evisceration include: tying of the oesophagus to prevent escape of ingesta, enclosing of the bung to prevent escape of faeces, and the intact removal of viscera (Bell *et al*., 1996).

A New Zealand study on the hygienic efficiency of conventional and inverted lamb dressing systems showed that very little contamination, measured by APC_{37} and *E. coli* counts, occurred after pelt removal except at the peri-anal site following the ringing operation (Bell and Hathaway, 1996). This indicates that current hygiene practices used after pelt removal, including those used during evisceration, are effectively containing contamination of the skinned carcasses.

6.5 Trimming

Microbiological contamination is significantly increased in areas of ovine carcasses directly affected by wool and faecal material. The study of Biss and Hathaway (1996c) showed that the microbiological effect of faecal material or wool was restricted to the area that was directly affected, and the presence of these contaminants were not associated with increased microbiological loads on visually clean areas of the carcass. Residual levels of both APC and *E. coli* counts directly at sites of faecal contamination after pre-evisceration washing were still significantly higher than at visually clean sites.

Application of HACCP food safety principles to ovine slaughter and dressing suggests that visible faecal contamination (predominantly occurring on the hindquarters when present) and major wool contamination should be removed by trimming (Biss and Hathaway, 1996c). Although trimming results in the removal of visible contaminants, it has negligible effect on the overall microbiological condition of carcasses (Gill *et al*., 1966). New Zealand studies suggest that visible defects are not reliable indicators of overall microbial contamination and therefore should be used with caution when used as monitoring tools for overall carcass hygiene (Biss and Hathaway, 1995b; 1996a).

6.6 Cooling

6.6.1 Growth of mesophilic pathogens

Immediately after slaughter, the animal's body temperature rises slightly from the normal 37°C to about 40°C, then falls at a rate which depends on the characteristic of the animal (e.g. size and fat cover) and the chilling parameters (e.g. air temperature, air velocity, carcass loading pattern) (MIRINZ Bulletin, 1973). All pathogenic bacteria associated with meat are capable of growth at these temperatures. The minimum growth temperature for *E. coli* and/or *Salmonella* on meat has been determined to be ≥7°C (Shaw *et al*., 1971; Mackey *et al*., 1980; Smith, 1985). Thus, 7°C is the endpoint generally accepted by the Commission of the European Communities (E.C.) as an appropriate temperature for minimal mesophilic pathogen growth. In the studies that reported *Salmonella* growth at temperatures below 7°C (i.e. at 5.3°C), either the growth was not associated with meat or a normal meat microflora, or the organism was not a meat-related strain (Mitchener and Elliot, 1964; Palumbo, 1986).

The temperature range from 7°C to around 40°C is referred to as the "mesophile window" or the temperature range where there is an opportunity for mesophiles, in particular enteric organisms such as *E. coli* and *Salmonella*, to grow to unacceptable numbers. A rapid and

controlled reduction in carcass and product temperature to 7°C is required to prevent or at least maintain pathogen proliferation within acceptable limits.

6.6.2 Boning during cooling

Some ovine carcasses processed in New Zealand are boned during cooling (i.e. warm and hot boning). It is important for the New Zealand meat industry to ensure that warm and hot boned meat are processed under conditions that will produce microbiologically safe products.

Studies at the Meat Industry Research Institute of New Zealand (MIRINZ) (Gilbert and Davey, 1976; Gilbert *et al*., 1976) showed that electrical stimulation and hot boning were not detrimental to the microbiological integrity of beef, as long as correct chilling and effective sanitation techniques were practised. This conclusion is supported in the reviews of Kotula (1981) and Oblinger (1983), and confirmed in later studies by Lee *et al*. (1985) and Kotula *et al*. (1987).

Oblinger (1983) suggests that it is the temperature profile or history of products that is of primary importance to producing a microbiologically acceptable product rather than the boning method (i.e. cold boning v. hot boning). Adequate and prompt chilling of hot boned meat is considered to be a critical point in the overall process. The initial chilling rate is a major factor in determining the bacteriological condition of hot boned beef (Fung *et al*., 1981; Lee *et al*., 1985) and significantly affects the number and kinds of organisms that develop on the meat surface.

6.6.3 Refrigeration criteria

The New Zealand meat industry has consistently placed a high priority on management of the physical environment of carcasses and meat during the period that they are within the "mesophile window". To ensure that meat processors adequately control bacterial growth during meat processing, the NZFSA has imposed requirements for specific operations such as carcass and product cooling. Current regulations require that refrigeration systems achieve standard time/temperature regimes for the different post-slaughter processes (IS 6: Sections 3.5-3.7), or that they achieve the Process Hygiene Index (PHI) criteria (IS 6: Section 3.5.2, TD 00/65).

The standard time/temperature regimes were derived from traditional Good Manufacturing Practice (GMP), which have been shown to result in microbiologically safe products. During

the mid-1980s, MIRINZ developed a practical method for determining the potential of *E. coli* proliferation that might occur during the cooling of meat, by integrating the temperature history with the growth characteristics of the bacteria (Gill *et al*., 1985). The method, Temperature Function Integration (TFI), was used in 1988 by MAF, MIRINZ and industry to develop a set criterion for the hot boning of carcasses (Armitage, 1997a). To serve as reference points, MIRINZ determined the hygienic quality of beef cold boned under processes operating to GMP standards. Based on this, a commercially workable hot boning process was developed that was at least equivalent in microbiological outcome to the cold boned standard. Studies have shown that compliance with the standard hot boning time/temperature regime (i.e. meat reduced to ≤7°C within 24 hours) should be able to limit *E. coli* growth at the slowest cooling sites on a carcass to about 10 generations or an increase of 3 logs (Reichel *et al*., 1991). This microbiological outcome is also consistent with what can be achieved under time/temperature regimes set by the E.C. for cold boned beef.

The MIRINZ method was used again later to develop criteria for the warm boning of beef (Armitage, 1997a). The E.C. cooling standard for cold boned meat (i.e. 7°C deep meat temperature within 48 hours of slaughter) was used as the accepted GMP reference when developing the criteria.

The PHI criteria are discussed in more detail in the next section.

6.6.4 The assessment of cooling processes and the Process Hygiene Index (PHI)

Temperature function integration is a technique for calculating bacterial growth from product histories and data relating bacterial growth rate to the temperature. The method of assessment involves the collection of temperature histories that show the worst possible temperature conditions for product moving through a process, identification of the type of bacterial growth that will occur at each stage of the process, and calculation of the extent to which an indicator organism could, in the worst possible case, grow during the process (Gill *et al*., 1985).

E. coli has been proposed as the process hygiene indicator for the meat industry in New Zealand because of its specific association with intestinal environments, its inevitable presence in high numbers in faeces, and its similarity in growth characteristics to *Salmonella* (Bell and Armitage, 1995). *Salmonella* spp. are not recommended as an indicator because of their relatively low prevalence in healthy slaughter stock and, hence, in faeces.

The temperature-related growth kinetics of *E. coli* and *Salmonella* spp. have been shown to be sufficiently similar (Herbert and Smith, 1980; Smith, 1985) to permit the hygienic adequacy of cooling processes to be reliably assessed or monitored using *E. coli* indicator systems. In addition, where *E. coli* and/or *Salmonella* have been studied in conjunction with either staphylococci or *Clostridium perfringens*, results have indicated that the former organisms have the greater ability for growth in meat (Angelotti *et al*., 1961; Goepfert and Kim, 1975; Farrell and Upton, 1978). Thus, action taken to control the growth of *E. coli* and/or *Salmonella* using 7°C as an endpoint appears to be sufficient to also control staphylococci and strains of Clostridia relevant to meat (Jones, 1995).

Temperature function integration has been used to effectively characterise the hygienic adequacy of cooling processes for beef and lamb carcasses (Gill *et al*., 1991a; 1991b, Jones, 1993, 1996; Armitage, 1997a), hot boned beef (Reichel *et al*., 1991) and beef offals (Gill and Jones, 1992). The method is discussed in more detail by Gill (1993) and Armitage (1997a).

New Zealand has used the method to determine the criteria for the different cooling processes after slaughter that would give equivalent outcomes in terms of microbial proliferation (Armitage, 1997a). The objective standard for the cooling of carcasses or product is expressed as a dimensionless PHI. One index unit represents a potential for the microbial growth equivalent to one generation of *E. coli*.

Measurement of the cumulative PHI commences immediately after slaughter and dressing and includes all activities during cooling until the surfaces of concern have been reduced to 7°C or less. The standard (TD 00/65) states that based on 20 samples, cooling processes are not to exceed the following cumulative PHI criteria at the surfaces of microbiological concern (Reichel *et al*., 1991; Gill and Jones, 1992; Gill, 1993):

- 80% of values 10
- maximum 14

Processing according to these criteria is expected to give equivalent results to those achieved under well controlled GMP.

It should be noted that **it is the cooling process that is being assessed, not the absolute hygienic status of individual products leaving the process** (Gill, 1993). The assessment of hygienic adequacy will ensure that the time and temperature conditions that the product experiences during cooling do not cause unacceptable proliferation of mesophilic pathogens. Such assessment does not assure that product entering the process is hygienically

adequate, or that a source of extraneous contamination does not exist in the process. It is, therefore, important that carcasses entering the cooling process have been slaughtered and dressed under a HACCP plan that achieves specified microbiological targets.

6.6.5 Cases of process failure in New Zealand

Armitage (1997b) studied six cases of process failure in New Zealand premises over a 2-year period. The study showed that non-compliance with standard time/temperature requirements could potentially compromise the microbiological safety of products.

In all cases, process failure was caused by inadequate refrigeration or refrigeration malfunction. Process failure for three of the cases occurred during post-boning cooling of cartons of hot boned meat, and for one case it occurred during post-slaughter cooling of lamb carcasses. These case studies showed that when failure to maintain adequate control occurred during the initial cooling of products down to 7°C, significant increases in both aerobic plate counts and mesophile growth (as measured by *E. coli*) were observed.

For the other two cases, loss of temperature control occurred during secondary cooling of chilled lamb and bobby veal. The chilled lamb products (6.5-6.9°C) were transferred to a cold-store for freezing. The refrigeration failed to activate and the air temperature in the blast freezer remained at ≥10.7°C for 16 hours before the non-conformance was identified and the freezer activated. The aerobic plate counts for the chilled lamb samples increased without any significant change in *E. coli* counts. This suggested that microbial proliferation in this instance was most probably due to psychrotrophic spoilage organisms. In the bobby veal case, carcasses were cold boned after slaughter, with meat temperatures at about 3°C. The refrigeration failed soon after the cartons were placed in the freezer allowing the product temperature to rise to 25°C over 70 hours. Microbiological tests showed that mesophile growth to unacceptable levels had occurred.

6.6.6 Cutting, boning, and trimming

The biological hazard associated with cutting and boning relates to the redistribution of pathogenic bacteria that are present on the incoming carcasses and the transfer of microorganisms from the work environment.

Cutting boards, boning tables, conveyors, knives, hands and clothing of personnel have all been implicated as vehicles for the transfer of bacteria (West *et al*., 1972; Newton *et al*., 1975; 1978; Widders *et al*., 1995).

Sheridan *et al*. (1992) reported that the level of contamination on beef cuts as a result of boning was related to the amount of trimming and work-up the cuts received. Those cuts that were handled and trimmed most had the highest levels of contamination (i.e. the fillet and striploin). The method of boning has also been shown to have a significant influence on the level of microbial contamination on beef cuts. Table boning resulted in a significantly higher microbial contamination than rail boning for cold boned (Moorhead *et al*.1997) and hot boned beef (Smulders and Eikelenboom, 1987). Moorhead *et al*. (1997) also observed that contamination introduced by trimming and conveying unwrapped and bagged primals is similar and of minor importance, compared to that introduced during the boning operation.

Transfer and redistribution of bacteria during the cutting and boning operations are expected to be adequately controlled by prerequisite programmes (i.e. effective cleaning procedures for equipment, good boning techniques and personnel hygiene).

6.6.7 Chill storage of vacuum packed cuts

After primary cooling, some vacuum packed primal cuts are further cooled and held at lower temperatures (-1.5 to 1°C). Vacuum packaging and low temperature storage results in a longer storage life due to a change in the microflora on the meat. None of the organisms pathogenic to humans will grow at -1.5 to 1°C, but *Yersinia enterolitica* can proliferate at a slightly higher temperature of 2.5°C (Petersen *et al*., 1991).

No special hazards are associated with vacuum packaging. The lactic acid bacteria that normally develop are harmless, and the conditions of relatively low pH and low temperature are unfavourable to recognised pathogens (ICMSF, 1980).

6.6.8 Freezing

The extensive research carried out by MIRINZ on microbial growth at sub-freezing temperatures clearly indicates that meat or meat products stored at product temperatures below -8°C will not support any microbial growth (Winger, 1984). However, if present, some pathogens will survive freezing temperatures.

The different pathogens that could be present on meat and meat products prior to freezing show different sensitivities to freeze damage. Freezing causes damage to *Salmonella*, but it does not guarantee its destruction in food. *Salmonella* have been detected in products that have been stored frozen for years (ICMSF, 1996b). Staphylococci are relatively resistant to freezing temperatures. Vegetative cells of *C. perfringens* are very sensitive to freezing, but

its spores are highly resistant to cold. *E. coli* survives well in frozen food. Little change was observed in number of *E. coli* O157:H7 in beef patties during 9 months storage at -20°C (Doyle and Schoeni, 1984). It is, therefore, important that meat and meat products are within acceptable microbiological levels prior to freezing.

A recent MIRINZ study was undertaken to determine the effect of simulated commercial freezing regimes and frozen storage on *E. coli* 0157:H7 on beef trimmings (Dykes *et al*., 1999). Their findings indicated the occurrence of sub-lethal injury, but not cell death under the simulated commercial freezing regimes (-18°C or -35°C) and frozen storage conditions (-18°C for 12 weeks) examined. The study showed that freezing and frozen storage are unreliable methods to assure the safety of beef trimmings with respect to *E. coli* 0157:H7. The consistent sub-lethal injury observed, however, makes freezing ideal for use in combination with newer intervention strategies to improve product safety.

7 References

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