Ministry for Primary Industries
Manatū Ahu Matua

Assessment of cooling practises applied during harvesting of New Zealand feral venison

Final report to
Ministry of Primary Industries

MPI Technical Paper No: 2015/11

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ISBN No: 978-0-908334-20-9 (online)
ISSN No: 2253-3923 (online)

March 2015

New Zealand Government

Growing and Protecting New Zealand

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This project was undertaken to evaluate the effect of current harvest, transportation, storage and processing on the efficiency of carcass cooling, and consequential microbiological quality of New Zealand feral venison. The report will inform decisions by risk managers of any need to revise the current MPI specifications for delivery of feral deer carcasses (wild, game estate or farmed animals that have become feral and then harvested) to the primary processor (Animal Products (Specifications for products intended for human consumption) Notice 2013 clause 60) (APA-HCS).

AgResearch examined current practices for cooling feral deer carcasses, compared the microbial loads on feral and farmed venison, and developed and validated a model in Food Product ModellerTM that could be used to determine microbial outcomes for different deer species and carcasses sizes held under different refrigeration scenarios.

In coming to their conclusions, AgResearch notes that the procedures for procuring feral deer in New Zealand, e.g. helicopter capture in the high country, and the higher ambient temperatures during harvesting than in other countries that traditionally harvest feral venison limit options for early and rapid cooling of carcasses. AgResearch also highlights the need to consider the balance between rapid cooling for optimizing microbiological quality and slow cooling for developing the game-flavours and tender meat expected of New Zealand feral venison.

The report concludes that application of the current APA-HCS will reduce the surface temperature of smaller weight carcasses to below 7°C within 24 hours of harvest (Australian standard AS4464:2007 for the cooling of feral carcasses), in all but the most poorly performing chillers. In contrast, it is unlikely that the exposed surface temperature of large carcasses will be reduced to below 7°C within 24 hours.

Whilst applying the Australian standard to initiate refrigeration within two hours of harvest (compared to 10 hours in the APA-HCS) would probably assist, AgResearch considers it unlikely that AMD or refrigerated transport facilities can be located or improved in terms of refrigeration capacity to the point that the Australian standard or IS-4 guidance target temperature/time parameters can be met.

Notwithstanding these observations, AgResearch notes that the meat ultimately sold for human consumption remains under the skin during harvest, transport and initial stages of chilling and is therefore effectively sterile until dressed at a processor. The level of bacterial contamination on the exposed surfaces of the carcass will be heavily influenced by the hygienic standards applied during dressing. The report therefore concludes that excellence in hygienic dressing is paramount for producing feral venison of the highest microbiological quality.

Most importantly, the report shows that premises that comply with the current APA-HCS time/temperature requirements and are using good hygienic practices have microbiological test results that meet the proposed EU microbiological standard for total counts and E. coli for feral venison. Revision of the current MPI specifications for delivery of feral deer to the primary processor appears unnecessary.

Food Product ModellerTM can, however, be used by industry to find practical solutions within industry constraints to facilitate optimisation of carcass cooling, and hence enhance the quality of New Zealand feral venison.

Lastly, the lack of data on pathogen prevalence within the NZ feral deer population prevents robust exposure assessment, hence attribution of foodborne risk of feral venison to humans. However, the use of indicator organisms such as Escherichia coli give regulators and industry some assurances in this regard. The AgResearch recommendation that feral venison be included in the National Microbiological Database (NMD) as a separate processing species to farmed venison will be considered by MPI.

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Client Report – FBP 12184

Assessment of cooling practises applied during harvesting of New Zealand feral venison – Final report

Ministry of Primary Industries

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March 2015

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Author's Note

Game meat is intended to have different flavours than farmed meat, which are brought about by the differences in harvesting and processing when compared to farmed deer. We therefore ask readers to consider carefully what constitutes "fitness-for-purpose" whilst reviewing the findings of this report.

For the purposes of this report, the term "feral venison" relates to meat that has been derived from wild, game estate and farmed gone feral, deer.

Summary

A project was undertaken to establish the efficacy of cooling practises currently applied to the harvesting of New Zealand feral venison, the microbiological consequences that might arise compared to processing farmed venison, and whether any revisions were required to the current MPI specification for cooling and delivery of carcasses to the primary processor contained within the Animal Products (Specifications for Products Intended for Human Consumption) Notice 2013, clauses 60 and 65.

Whilst observational data was obtained to determine the processes involved, much of the information regarding carcass cooling and microbiological growth rates were derived from the Food Product Modeller (FPM™) time/temperature integration model based on these processing parameters.

Validation of this model for use in determining feral venison cooling was originally proposed to be based on trials in the field. Investigations revealed however that both the ambient temperature and airflow around the carcass could not be accurately measured at all times during the critical death-to-Animal Material Depot phase of procurement. Observed cooling curves for this phase of processing were therefore obtained using a controlled experiment at a meat production facility.

From these experiments and models, we concluded that:

- FPM™ can be used to predict the microbiological outcomes of the chilling regimes applied to feral venison.
- Feral deer culling in New Zealand occurs primarily during the summer months, when helicopter harvesting is most effective. This is the opposite of normal practise elsewhere in the world, where feral venison is harvested during winter when animals are better fed and more water is available. Consequently, ambient temperatures in New Zealand during harvesting are considerably higher.
- For larger (40-50Kg dressed) carcasses, application of the current standard is unlikely to reduce the temperature at the exposed carcass surface to below 7°C

within 24 hours of harvest. However, as increases in chiller temperature are associated with significantly extended cooling rates, control over carcass refrigeration is still important.

- Microbiological analyses used to assess hygienic condition of feral carcasses will show higher results than for farmed venison due to differences in cooling of the carcass and hygienic practices in the field. Observational data and data published overseas suggest an increased Total Aerobic Count (TAC) in the order of 1 $\log_{10}$cfu/cm², with a wide variation across the results.
- Meat that is ultimately released for commerce remains under skin and therefore is effectively sterile until processed at the registered processing premise. Whilst the microbiological condition of the exposed carcass areas will have some impact on the bacterial transfer to the remainder during processing, this will be heavily influenced by the hygienic standards applied during dressing.
- A microbiological standard of TAC not < 6 $\log_{10}$cfu/cm², and *E. coli* < 2 $\log_{10}$cfu/cm², has been proposed for acceptance of feral venison meat in Europe. NMD results for feral venison observed during this study were found to comply with these criteria.
- Establishing the risk of transmission of pathogens to humans via feral venison is not possible without data on their prevalence within New Zealand feral deer populations. For example, the risk of transmission of Mycobacteria cannot be predicted using routine hygiene indicators such as TAC or *E. coli*.
- We therefore concluded it is unlikely that AMD or refrigerated transport facilities can be improved to the point that exposed surfaces can be chilled to <7°C for all types of feral deer harvested within 24 hours. As the site of microbiological concern (from which saleable meat is ultimately derived) remains under skin and is therefore sterile at this point, this initial period presents little food safety risk until final dressing. We note that the period of exposure prior to final dressing aids in the development of the “gamy” flavours particular to this product. We believe that the real food safety risk is from contamination of the newly exposed meat surfaces during final dressing, particularly from proximal surfaces, and that the Standard should reflect this. We also recommend that feral venison be considered a separate class under NMD, which would enable some degree of control, and the potential to improve the hygienic status over time.

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1. Objectives

- A review of current methods used in New Zealand for feral deer carcass recovery and processing into meat. The review to include available data regarding pathogenic and other bacteria likely to be present on carcasses that pose a risk to product safety and shelf-life.
- To determine what microbial and time/temperature data was available from the industry to use for modelling purposes, and gaps needed to be filled with field data.
- Identification of the likely worst-case carcass transport and storage scenario using historical industry data, if available.
- Validation of time/temperature models for predicting temperature and hygienic outcomes at the site(s) of microbiological concern[1] of feral species processed in New Zealand.
- To determine whether unacceptable levels of microbial contamination can occur under current regulatory requirements for the slaughter, partial dressing, transport, and final dressing of feral deer.
- To determine whether current refrigeration specifications for AMD's and transportation units in the Animal Products Notice are sufficient to prevent the growth of microbes to unacceptable levels.
- To determine whether the removal of pleural and peritoneal viscera and heavy trimming is sufficient to remove identified pathogens to acceptable levels.

2. Review of applicable standards

The Standard for the harvesting and processing of wild, game estate and farmed gone feral animals in New Zealand is documented in the Animal Products (Specifications for Products Intended for Human Consumption) Notice 2013 (HC Spec).

- *The carcass must be subjected to chilling within 10 hours of harvest, and either:*
  - *Arrive at the processing premises within 24 hours; OR,*
  - *Be refrigerated[2] at an Animal Material Depot (AMD) within 10 hours of killing, and to arrive at the processing premises within 96 hours.*

[1] A recent EFSA Scientific Opinion (EFSA, 2014) has determined that surface temperatures only can be used to indicate microbial growth. See text later in this section and footnote 5.
[2] The original AP Notice (2004) specified that the AMD must operate at 3°C or colder, but this was removed in the 2007 Amendment.

A number of other documents make reference to the harvesting of feral deer, including:

- Guidance document: certified suppliers and certified game estate suppliers of wild and game estate animals (2014) (http://www.foodsafety.govt.nz/elibrary/industry/administrative-manual-supplier-amdt-3/index.htm).
- Industry Standard 4: Procurement of Animals for Food. Amendment1, November 2002
- Industry Standard 6: Processing of Edible Product. Amendment 5, May 2004 (http://www.foodsafety.govt.nz/industry/sectors/meat-ostrich-emu-game/meatman/is6/is6.pdf)
- Draft Meat Code of Practice: Presentation for post-mortem examination. Part 2, Chapter 6 (not publicly available).

AgResearch considers the refrigeration and time requirements to have been harmonised across these documents.

Industry Standard 4 (IS 4) also provides additional guidance suggesting that the *internal* temperature of killed game should be reduced to less than 7 °C[3] within 24 hours of killing. MPI has advised that as this is guidance only, processors are not required to record such data nor does MPI verify against guidance.

Export premises must also comply with Overseas Market Access Requirements (OMAR). The EU OMAR[4] requires that wild game from an AMD must be received at the processing premise within 72 hours of killing. Export premises consulted during this project noted that the majority of the export trade is with the EU, and that these premises routinely apply the more stringent 72 hour (EU-OMAR) standard rather than operating using different market-dependent processes.

International Standards

The Australian Standard AS4464:2007 specifies that a wild game animal carcass be placed under refrigeration within *two hours* of being harvested (unless between the hours of sunset and sunrise, in which case refrigeration must be within two hours of sunrise). The temperature at the "site of microbiological concern"[5] must be reduced to 7 °C as soon as possible, but not later than 24 hours after being *placed under refrigeration*, unless delivered to the processing premise within this time period. The temperature of the carcass must be below 7°C on arrival at the processing premise. Currently, the Australian Standard does not specify a maximum time specified for

[3] 7°C is considered a critical temperature as the growth of most mesophilic pathogens ceases below this point.
[4] European Union (EU); Animal Products: Overseas Market Access Requirements (OMAR) Amendment 20, December 2010
[5] The site on the meat where micro-organisms of concern are likely to be located, or if unknown, the thermal centre of the meat.

holding carcasses at the AMD, which could result in carcasses being held at AMD longer than is necessary so that the temperature of 7° C can be achieved before transportation.

Current EC regulation 853/2004 (s4, ch2.5) requires that “chilling begin within a reasonable period of time after killing, and achieve a temperature throughout the meat of not more than 7°C” (where climatic conditions permit, active chilling is not necessary). A review by Paulsen et al. (2012) noted that in Europe, the Codex Alimentarius Commission Guide to Good Hygienic Practice (CAC, 2005) is also applied to wild game processing. This article also indicated that evisceration should be performed between ½ to 3 hours after killing, and the carcass attain temperatures of ≤7°C within 12 to 24 hours after killing, although a careful examination of CAC/RCP 58/2005 by the authors did not reveal this exact specification. Further, EC regulation 854/2004 (sIV,chVIII,A,e,x & sIV,chVIII,B) requires that a carcass showing putrefactive changes be *declared unfit for human consumption*.

A scientific opinion on public health risks related to storage and transport of meat of domestic ungulates has recently been released by the European Food safety Authority (EFSA, 2014). This opinion was directed to slaughterhouses to determine whether or not it was possible to apply alternative carcass core temperatures (higher than the current requirement of 7 °C in Regulation 853/2004) in combination with specific transport durations for carcasses of domestic ungulates after slaughter without increasing the risk associated with the growth of pathogenic microorganisms. Similar issues occur for storage and transportation of feral animals.
EFSA concluded that:

- Bacterial contamination of red meat occurs primarily at the surface. *Salmonella* spp. and *Yersinia enterocolitica* are also found in lymph nodes, but it is unknown whether they can proliferate in these tissues during chilling.
- Carcass surface temperature is a more relevant indicator of the effect of chilling on bacterial growth than core temperature.
- Based on source, human disease potential, and ability to grow under chill conditions, the most relevant pathogens to consider during red meat carcass chilling are *Salmonella* spp., enterohaemorrhagic *E. coli*, *Listeria monocytogenes* and *Yersinia enterocolitica*.
- If there is equivalent or less bacterial growth there is no additional risk to the consumer. Total bacterial growth is affected by the continuum of chilling in the slaughter plant, during transport, deboning, storage, retail and catering/domestic refrigeration.
- It is possible to have different combinations of slaughterhouse-transportation time-temperature chilling scenarios that result in equivalent or less bacterial growth than

that obtained using the currently mandated chilling requirements (chill to a core temperature of 7°C in the slaughterhouse chillers before transportation for a maximum of 24 hours).

In Britain, considerable variation has been reported in the time between animals being killed and their arrival at a processing premise. In general, animals are shot 24 hours before being transported for processing, or may be held refrigerated for several days at the hunting ground before transportation (Radakovic & Fletcher, 2011). On arrival at the processing plant, the carcasses are chilled to less than 7°C "within a reasonable period of time".

The Meat Safety Act No. 40 of the Republic of South Africa (2000) part V, section 11.(1)(h), par 67, requires partially dressed carcasses and offal to be chilled within 12 hours of culling to a temperature not exceeding 7°C, *however*, when the ambient temperature is >15°C, it must be chilled *within four hours* (van Schalkwyk, Hoffman, & Laubscher, 2011). van Schalkwyk et al. (2011) also noted that carcasses should endure a process of maturation at a temperature of between 7°C and 2°C for at least 24 hours prior to boning, to achieve optimum meat quality and to deactivate the Foot and Mouth virus.

3. Microorganisms of Sanitary Significance

A review of the available literature suggested that the microorganisms of primary concern in the processing of feral venison are *Mycobacterium bovis*, *Mycobacterium avium*, *Salmonella* spp., *Campylobacter* spp., *Escherichia coli* O157:H7, and other enterohaemorrhagic *E. coli* (EHEC) serotypes. As previously noted, EFSA also consider *L. monocytogenes* and *Y. enterocolitica* to be important when considering the chilling regimes applied to slaughtered ungulates.

A comprehensive qualitative risk assessment was commissioned by the UK Food Standards Agency (FSA) on the hazards and risks associated with wild game (Coburn, Snary, Kelly, & Woolridge, 2005). This study concluded that the risk to human health from the consumption of wild deer meat in the UK was low for *E. coli* O157:H7 and *M. bovis*, and very low for *Salmonella*, *Campylobacter jejuni* and *M. avium*. The risk from handling carcasses was low for *M. bovis*, and very low for *E. coli* O157:H7, *Salmonella*, *C. jejuni* and *M. avium*.

Furthermore, a comprehensive study into the prevalence of EHEC in game meat samples was conducted by the German Federal Institute of Risk Assessment between 2002 and 2006. Whilst the prevalence of EHEC in 2002 was only 3%, reported data for

2005 revealed a prevalence of 14.8%. This was notably higher than the prevalence reported for beef, and included serotypes O26:H11, O103:H2 and O128:H2, all of which had been associated with human disease in that area (Bandick & Hensel, 2011; Bartels & Bülte, 2011).

Whilst tuberculosis is an important zoonotic disease that is known to infect Red, Sika and Fallow deer in New Zealand (Coleman & Cooke, 2001; Gavier-Widén, Cooke, Gallagher, Chambers, & Gortázar, 2009), its intracellular nature and slow growth rate preclude the potential for changes in prevalence to arise from poor time/temperature control during transportation. Control of this class of organism is through management of endemic areas and veterinary inspection; we have, therefore not included *Mycobacterium* spp. in our analysis.

A number of studies into the prevalence of *Salmonella* in wild large game have been conducted across Europe, and were summarised by Paulsen et al. (2012). The majority of studies were completely negative for *Salmonella*, although one outbreak was recorded on high alpine pasture in Austria, attributed to close proximity to domestic cattle and chamois.

Whilst *Y. enterocolitica* has been isolated from farmed deer, the prevalence of virulent strains (as determined by presence of the *ail* virulence gene) was reported to be low (French, Rodriguez-Palacios, & Lejeune, 2010). In addition, virulent strains of *Y. enterocolitica* are known to compete poorly in the presence of other Enterobacteriaceae (ICMSF, 1996). Consequently, we view *Y. enterocolitica* to present only a low risk in feral venison.

Clostridium difficile was reported with high prevalence in the French *et al*. (2010) study, however this was attributed to farming practice as the organism has not been reported in feral deer. Where investigated, *Listeria monocytogenes* was found to have a very low prevalence (Membré, Laroche, & Magras, 2011). Few other studies have examined venison specifically for *Cl. difficile* or *L. monocytogenes*, so the true prevalence of these organisms remains unknown.

Gill (2007) observed that, as the initial microbiological condition of each carcass is affected by multiple, highly variable factors, followed by equally inconsistent changes during skinning and dressing, the microbiological condition of both the wild (feral) deer carcasses overall, and the meat obtained from them would vary greatly. This observation is supported by articles reporting total bacterial numbers from feral venison carcasses (Paulsen & Winkelmeyer, 2004; Sumner, Perry, & Reay, 1977). Gill also noted that unskinned feral venison carcasses may be held for several weeks at near freezing temperatures to allow the development of “gamy” flavours, which could allow the growth of aerobic psychotropic bacteria (e.g. *Pseudomonas* spp.), depending on the airflow in the chiller and subsequent desiccation/water activity (a_w) of the

exposed surfaces of the carcass. Whilst feral venison is not stored for these periods in New Zealand, the authors have noted that the development of “gamy flavours” would be considered “fit for purpose” by discerning (e.g. German) markets.

Whilst the presence and concentration of *Escherichia coli* has been shown to be unreliable as an index organism for the presence of other enteric pathogens in foods (Kornacki & Johnson, 2001), it remains valuable in the assessment of overall food quality and the hygienic conditions present during food processing. *E. coli* is also the organism used to model aerobic and anaerobic growth using the process hygiene index (PHI) where it has been deemed indicative for the enteric pathogens found in raw meat (Lovatt, Bell, & LeRoux, 2006).

4. Hunting and recovery methods used in the procurement of feral deer

The New Zealand export premises surveyed for this report all report their source of feral venison carcasses to be from helicopter hunters. This method has been shown to be the most cost-effective for commercial harvesting in areas with high densities of feral deer (Nugent & Choquenot, 2004). A small domestic trade exists in ground hunted game, but numbers are comparatively minimal.

It was noted that in New Zealand, feral venison harvesting occurs mainly over summer, when animals are more often located on open land and therefore more readily targeted by helicopter hunters; this is the opposite to Europe, where most wild game is harvested over winter (van Schalkwyk et al., 2011). Consequently, cooling criteria that are applied to wild game harvesting in Europe may not translate to hygienic practice in New Zealand.

Helicopter hunting requires three personnel – the pilot, the shooter, and the ‘gutter’. The animals are preferentially head-shot using a shotgun loaded with buckshot and the GPS waypoint where the animal was shot and/or came to rest recorded. Deer are ferried immediately after shooting to a convenient location where the gutter removes the intestines and skirt leaving the kidneys, genitals and pluck (liver, heart lungs, trachea etc.). The full head (including ears) and hooves are left on the carcass at this stage. A plastic bar-coded tag is attached to the flap of the carcass, denoting the date, time and waypoint, which is cross-referenced to a kill sheet. Carcasses are then either taken directly to the meat processor or hung in the animal materials depot (AMD) (where the pluck is removed from the body cavity and hung over the brisket to enhance ventilation and cooling – see Figure 1) before refrigerated transfer to the processing plant (Sumner et al., 1977).

While carcasses hanging from a helicopter may be exposed to cooling airflow, transport of several carcasses and stacking while awaiting further on-location processing is likely to slow cooling of the carcass perhaps to a similar rate as carcasses hunted and transported by land. It is impractical to attempt to measure the rate of cooling from the time of death to delivery to the processing premises. Therefore, it is assumed in this report that the initial cooling curve for the carcass surfaces of microbiological concern on both helicopter and land transported animals is similar.

It has been noted that helicopter hunting has been organised around the 10 hour harvest to chill requirement to achieve the most cost-effective use of very expensive equipment. Consequently, reducing this time is only possible with the introduction of mobile AMD's for domestic operations (as permitted by the 2007 amendment). It has still to be determined whether such mobile units can be used effectively throughout New Zealand.

5. Intermediate storage and transport

Following slaughter, the gutted carcasses are either transported directly to the processing premises and placed in a receivals chiller within 10 hours, or are loaded into a chiller-truck or mobile-AMD and delivered to the processor within 24 hours, or to an AMD (or mobile AMD) with subsequent delivery to the processor by chilled transportation within 96 hours of slaughter.

MPI does not specify refrigeration operating temperatures for AMDs and mobile-AMDs, although they must be hygienically designed and operated. They must have calibrated temperature gauges to enable monitoring of the operating temperature of the facility at the hottest point. Those in mobile-AMDs must be automated and the temperature profile of each load provided to the processing premises on arrival.

The authors have not visited AMDs to ascertain carcass handling procedures (load-in numbers, chiller loading patterns, holding times, etc) and cooling curves but have modelled the worst case scenario using available industry data, albeit limited. .

6. Findings from processing premise visited[6]

On arrival of a batch of carcasses from an AMD at the processing plant the deep muscle temperature of a carcass was verified by plant personnel and found to be 2°C. Records revealed that carcass muscle temperatures on arrival varied from 1-4°C[7]. The carcasses were stored in a separate chiller operating at 1°C, where they could remain for up to 6 days before processing.

A pre-process work up was performed during this period (Figure 2) where the fore-tendons were removed, hocks cut (but left hanging), cheek and jaw-line opened with tongue exposed through the lower jaw, and head severed at the atlas joint leaving it to hang on the remaining muscles and hide strip.

On the production day, the carcasses were moved into the inspection room where the Meat Inspector removed and inspected the vital organs and head for completeness, any lesions, abnormalities, and the healthiness of the glands around the base of the tongue and back of the skull. The check includes the condition of the ears (verifying the animal is feral) and the overall condition of the carcass.

Figure 1 – "pluck" exposed prior to inspection

Figure 2 - initial work-up in pre-inspection chiller

[6] Following discussions with other companies, the authors consider the operations described in this section of the report to be typical of the majority of New Zealand feral venison premises.
[7] Other facilities investigated indicated receiving temperatures of between 2 and 7°C

The deer processed during our visit were in passable condition (all were processed), although the Meat Inspector noted that the workmanship of the gutter was a little below par, particularly around cutting of the skirt. Putrefactive changes were also observed inside the thoracic cavity (Figure 3), with the presence of maggots inside two carcasses (Figure 4). Faecal pellets and other visible contamination were observed in the cavities of many of the carcasses inspected. This has been attributed to the gutting process.

Following inspection, the carcass was moved to the hide removal and trim area. The pizzle was removed (from stags), the hide cleared from the hind-quarters, and the hind tendons were removed. The hide was then cleared from around the cavity.

The carcass was then railed to the hide puller, where the hide was carefully drawn down off the carcass. Trimming then continued with the neck and surrounding area excised to expose clean meat, followed by the flap and anal areas to remove exposed or damaged tissue.

The rib-section cannot go for boning due to internal contamination; therefore this was slab-boned to recover the rib-cover meat, shoulders and backstraps.

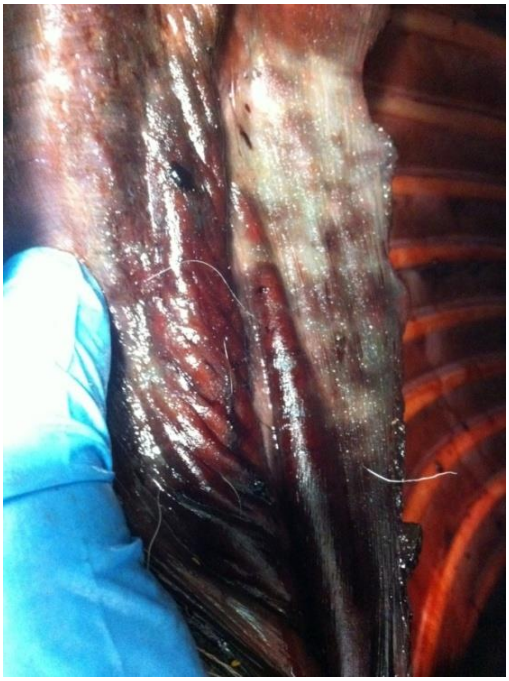

Figure 3 – putrefactive changes inside thoracic cavity.

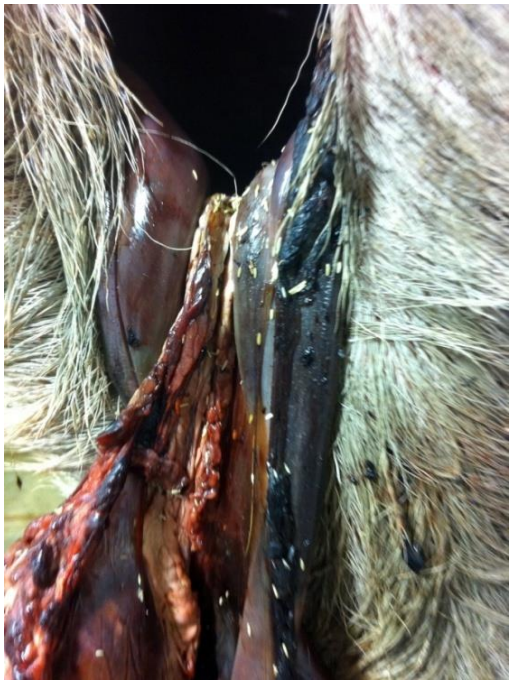

Figure 4 - maggots and putrefactive changes.

We noted that the udders had been removed from the hinds as part of field dressing by the gutter. This practice results in a portion of the hind-leg being exposed, which would require further trimming during dressing (Figure 5). Enquiries of the staff involved showed an awareness of this issue and an ability to detect the affected area.

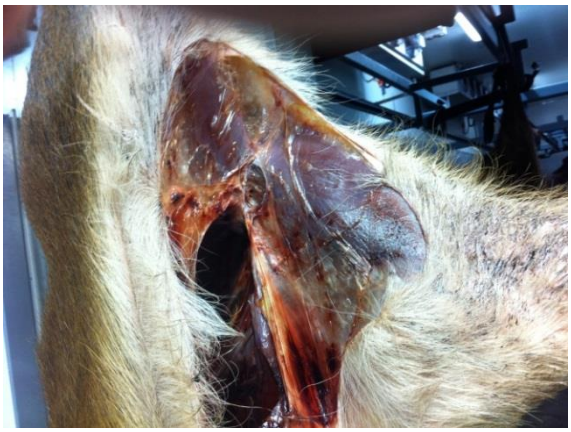

Figure 5 – Hind-leg tissue exposed due to udder removal

At the premise visited, we were impressed by the skill level displayed by the Meat Inspector and dressers. The processing was conducted on a one-at-a-time basis, which allowed for greater care to be taken.

7. Modelling of carcass cooling

Mathematical models were used to estimate the surface and deep muscle carcass temperatures that would be achieved 24 hours post kill, and to calculate the potential number of generations of growth of *E. coli* and the PHI[8] at the carcass surface, for a number of "worst-case" time/temperature scenarios allowable within current standards and guidelines. Modelling was the preferred method to determine these parameters as it was not possible to control a worst-case experiment in the field, particularly with regard to ambient temperature and maintaining carcass surface loggers during aerial transport. The modelling software utilised was Food Product Modeller™ (FPM™), which can be purchased from AgResearch Ltd. by operators if required.

The models were developed using carcass weight ranges described by premises. A distribution of dressed carcass weights for red deer hinds and stags are presented in Figure 6. Anecdotally, the carcass weights for fallow deer are on average ~13kg lighter for both does and bucks (reds average dressed carcass 38kg and 42kg, and fallow 24 and 29kg, respectively).

[8] The final *E. coli* numbers determined by the FPM™ model are different to the PHI, as the calculated probability distributions for *E. coli* take into account the variability in both the initial microbial loading and the potential growth during cooling for a given meat product. (Lovatt et al., 2006).

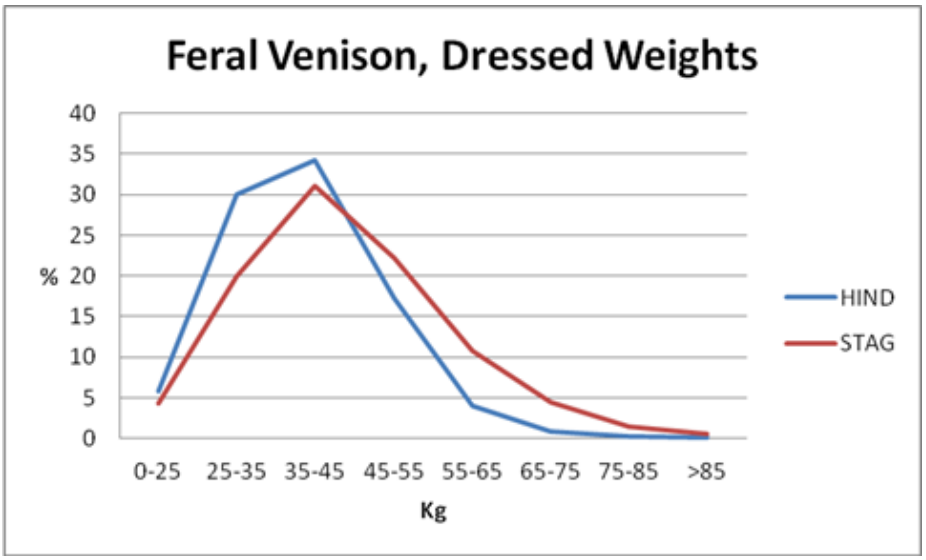

Figure 6 – Weight range of dressed (hide removed) feral red deer carcasses.

The cooling models were based around the following, "worst-case" assumptions:

a) Carcasses stored in an AMD prior to processing

- 20-50Kg[9] dressed (i.e. hide off) carcass weight. This represents the range from the smaller fallow/Sika hinds, to the larger red stags, based on premise data.
- An initial body temperature of 38°C[10]
- A 10 hour time period from killing to arrival at the AMD (the maximum allowable), with models constructed to reflect ambient temperatures of 25, 15, 10 and 5 °C.
- The model used was based on an AMD that was predicted to operate similarly to usual practices in processing premises and chilled transportation with 0.1m/s[11] airflow and achieving an equilibration temperature of 1°C.
- Further models were constructed to demonstrate the effect of running an AMD at 2, 4, and 6°C based on the larger 40-50Kg stag carcasses.
- Time at the AMD was inputted at the maximum allowed 86 hours (96 hours from harvest, less the 10 hours maximum allowed between harvest and arrival at the AMD), plus 4 hours maximum for transport from AMD to processor.

[9] This range was based on the carcass yields at the processing premises visited in (5) over a three month period

[10] Based on measured rumen temperature of red deer of 38-39°C, depending on season (Turbill, Ruf, Mang, & Arnold, 2011)

[11] At this point, bacterial proliferation occurs only on areas not enclosed by skin following field dressing, i.e. the visceral cavity. Airflows in this cavity have been measured to be minimal under all conditions – see 9.1.

- Transport from the AMD to the production premise was estimated to be 4 hours at 1°C with airflow of 0.1m/s (i.e. negligible – allowing for reasonably dense loading of carcasses, with animals touching, as the worst-case scenario).
- Storage at the premise prior to final dressing for 6 days in a chiller held at 1°C with 0.1 m/s airflow

b) Carcasses delivered directly to the processing premise

- 40-50Kg[12] dressed (hide off)
- An initial body temperature of 38°C
- A 10 hour period from harvest to refrigerated transport.
- A 24 hour time period from harvest to arrival at the premise (the maximum allowable)
- The models were constructed to reflect ambient temperatures of 25, 15, 10 and 5 °C, and transport temperatures of 1, 2, 4, and 6 °C with an airflow of 0.1m/s.
- Storage at the premise prior to final dressing for 6 days in a chiller held at 1°C with 0.1 m/s airflow

The results from the model were assessed against the following criteria:

- A surface temperature of below 7°C, 24 hours post-harvest (the authors considered this to be an acceptable application of the IS4 standard). The modelled time taken for the surface temperature to reach 7°C was also recorded.
- An aerobic PHI of less than 14 (maximum allowable for farmed deer? by NZ Industry Standard IS-6).
- Less than 16 generations of *E. coli*[13].

7.1 Validation of the model

AgResearch normally promotes the generic FPM™ model on the basis that we are confident it is accurate to ±10% using the standard dataset. The model can however be refined for a specific application by comparing against real measured data and adjusting accordingly.

It was originally intended that validation of the model for use in determining feral venison cooling would be based on field trials. Subsequent investigation revealed

[12] The range for red deer at the processing premises
[13] Assuming an initial inoculum of 2000 cfu/cm², 16 generations are required to achieve 10^8 cfu/cm², being the number of organisms required for onset of putrefaction (Gill, 1996).

however that both the ambient temperature and airflow around the carcass could not be accurately measured at all times during the critical death-to-AMD phase of procurement. Consequently, the appropriate cooling curves were obtained using a controlled experiment at a meat production facility:

- Farmed deer were selected post-slaughter, eviscerated and transferred to a separate (feral) chiller area. Carcass spacing was consistent with normal loading of the chiller to ensure typical air movement around the carcass during these measurements.
- The “hide-on” carcass weight was measured (including head).
- A series of temperature data-loggers (TinyTag, Chichester, UK) were attached to each carcass, with tapered Teflon probes located at shoulder & hind leg points, mounted on the surface (stainless steel disk and plastic staple method) , & deep within the tissues (8 probes per carcass in total). Other loggers were placed in close proximity to the carcasses to measure chiller temperature. Measurements were made every 5 minutes for the duration of the study.
- The chiller air velocity was measured using a hot wire anemometer (Dantec, Skovlunde, Denmark) at hindquarter and shoulder levels.
- The chiller was closed and the carcasses allowed to equilibrate for 3 days. Operating conditions were 0.4 m/s airflow and a mean temperature of -0.3 °C.
- The temperature probes were then removed, and the carcasses skinned. A final carcass weight was determined “hide-off”.
- The temperature profiles were then compared to the profiles predicted by FPM™, and the model was corrected as required.

7.2 Verification of the model

The corrected model was verified in the field by measuring the cooling curves in the deep muscle tissues of hunted deer carcasses:

- Temperature data loggers were attached to the carcasses of helicopter-culled venison on arrival at the AMD. The probes were inserted into the deep tissues of the leg or shoulder muscle of five carcasses.
- The date and time shot, and approximate location, was recorded for each carcass evaluated.
- The carcasses were held at the AMD at a mean recorded temperature of 1.8 °C (range +5.0 to -1.2 °C), transported and processed at the meat premise as per

normal practice. Loggers were removed immediately prior to skinning and dressing and the temperature profiles compared to the model profile.

- The model profile used for verification assumed the AMD chiller was operating at 1°C[14] and the airflow around the area of microbiological concern was 0.1m/s (see footnote 11).

8. Microbiological analysis

Carcass microbiology results from fully dressed, trimmed feral carcasses were obtained as described in the NMD technical specifications for six sample events from the premise visited above. These were summarised to provide means, maximum, minimum and standard deviation values. For comparison, results for farmed venison processed at the same facility during the same time period (nine events) were analysed in the same manner. The NMD "all data to date" results for these parameters were also evaluated.

9. Results

9.1 Validation of FPM™ for estimating feral venison cooling

The data from the controlled experiment described in 7.1 using farmed deer was copied into FPM™ to create a baseline model, which was then "tuned" until the surface and centre temperatures matched the measured temperatures with acceptable precision. It was determined that the carcass mass needed to be measured "hide on", and that the air velocity would have the greatest impact on the surfaces inside the carcass body cavity, where it could be expected that the air velocity would be very low or zero compared to the air velocity over the exterior of the carcass. This resulted in the use of 0.1 m/s as the figure that provided the best fit of the model against measured data.

Alternative methods were compared, including changing the heat transfer coefficient (such as had previously been used to model carcasses wrapped in plastic or stockinet) but the use of 0.1 m/s air velocity was found to provide the best match.

The temperature/time cooling curves of the actual farmed carcasses[15] tested, compared to the values predicted by the model after "tuning", are reproduced

[14] Data obtained from industry for 7 facilities revealed a mean AMD set-point of 1.3°C, with a minimum of 0°C and maximum of 3°C.

graphically in Figure 7. Although the actual shoulder surface temperature cooled more rapidly than this model, it was nevertheless considered the best validation of the cooling rate for the whole carcass.

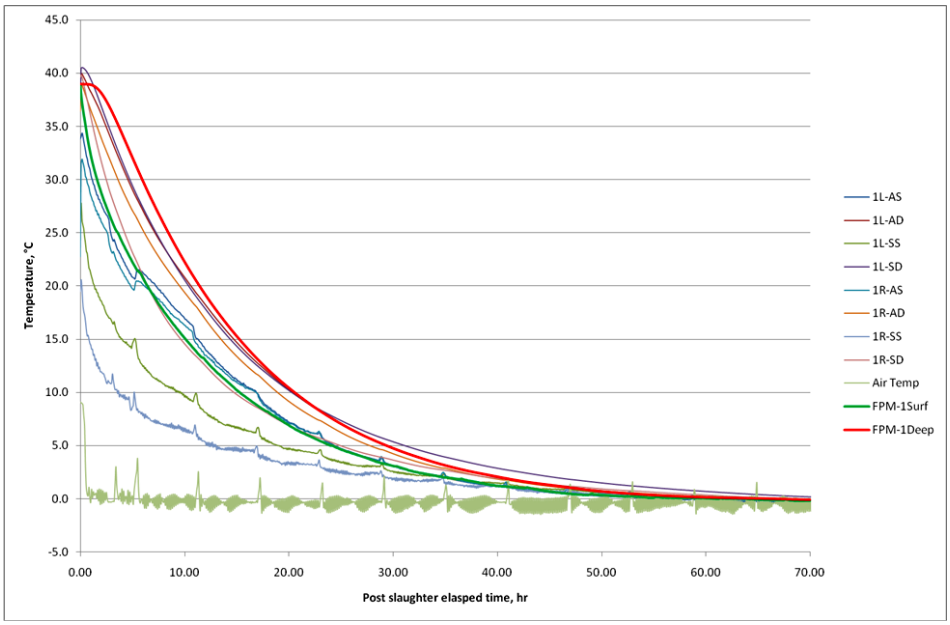

Figure 7 – Comparison of farmed venison carcass cooling curves versus predicted cooling rates from FPM™ for a 60Kg dressed, 72 Kg hide-on carcass.

L = left, R = right, A*x* = aich bone, S*x* = shoulder, *x*S = surface, *x*D = deep tissue, FPM = modeled curve.

9.2 Verification of FPM™ Model

Based on the "hide-on" carcass weight, the model was then verified against cooling curves measured from feral venison harvested in the Taupo area. The results are presented in Figure 8.

[15] Farmed venison carcasses are larger than feral carcasses. As the FPM model takes the mass into account when calculating the thermodynamic properties of each carcass, this is not considered to be a confounding variable.

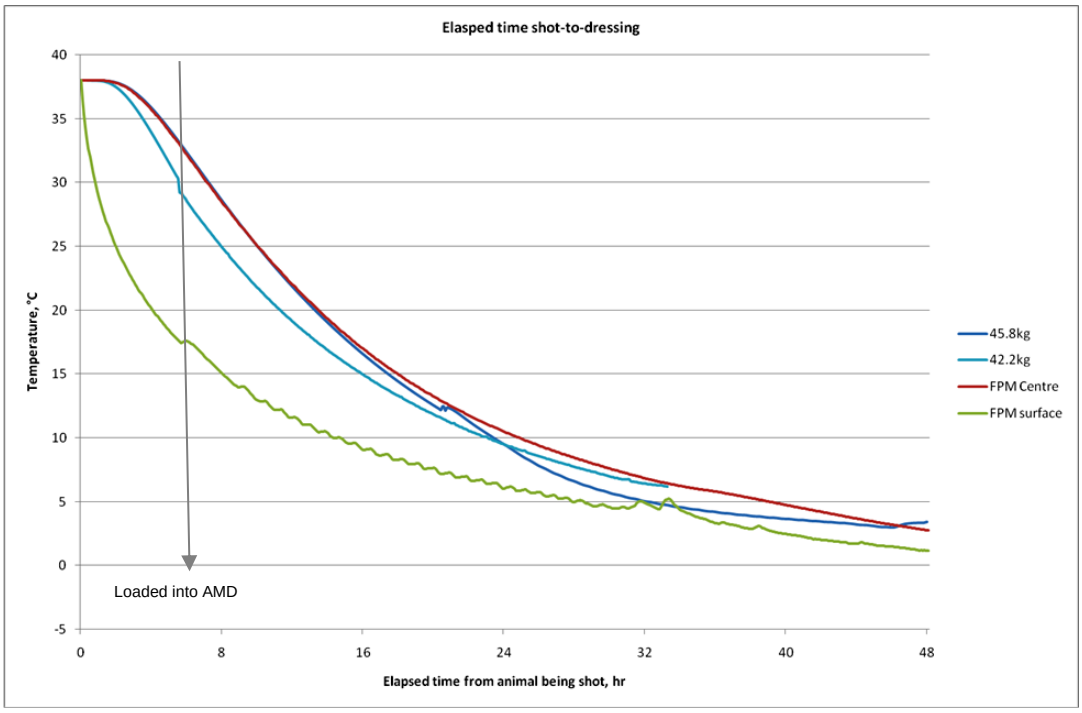

Figure 8 – Actual cooling curves for 42.2Kg and 45.8Kg feral carcasses (eviscerated/hide on weight, deep tissue probes) compared to the validated modeled curves. Ambient temperature for the region during harvesting was 5°C (NIWA, 2011). Note the harvest-to-AMD portions are estimated.

9.3 Modelled cooling curves

Using the validated model, calculations were undertaken using a range of carcass weights, ambient temperatures and time to determine the time taken for the surface temperature to reach 7°C and predict the impact this would have on the bacterial growth i.e. the number of generations achieved.

Table 1 – Modelled temperature and bacterial generations on the exposed carcass surfaces, based on a harvest to AMD time delay of 10 hours (the maximum allowed) and transfer to the processing premise within 96 hours of harvesting with variable ambient temperatures.

Mass, Kg		Cooling conditions					24h post-slaughter			Time to surface temp of 7°C (h)
Field dressed	Final dressed	Ambient °C	AMD °C	AMD airflow m/s	Premise chiller °C	Premise airflow m/s	Carcass surface °C	*E. coli* (gen)	Aerobic PHI (gen)	
60	50	25	1	0.1	1	0.1	11.4	27	28	36
60	50	15	1	0.1	1	0.1	10.2	20.7	21.1	34
60	50	10	1	0.1	1	0.1	9.6	17.5	17.7	32
60	50	5	1	0.1	1	0.1	9.1	14.5	14.7	31
50	40	25	1	0.1	1	0.1	9.5	25.3	26.4	30
50	40	15	1	0.1	1	0.1	8.2	18.7	19.1	27
50	40	10	1	0.1	1	0.1	7.6	15.5	15.7	26
50	40	5	1	0.1	1	0.1	7.0	12.5	12.7	24
40	30	25	1	0.1	1	0.1	6.6	23.0	24.1	23
40	30	15	1	0.1	1	0.1	5.5	16.0	16.3	21
40	30	10	1	0.1	1	0.1	4.9	12.8	12.9	19
40	30	5	1	0.1	1	0.1	4.3	9.9	10	18
30	20	25	1	0.1	1	0.1	3.1	20.0	21.0	18
30	20	15	1	0.1	1	0.1	2.5	12.5	12.8	18
30	20	10	1	0.1	1	0.1	2.2	9.4	9.6	14
30	20	5	1	0.1	1	0.1	1.9	7.0	7.1	12

"gen"= generations of growth; PHI = Process hygiene Index

Modelled results that did not meet the criteria (<7°C 24 hours post-slaughter, <16 generations for *E. coli*, PHI <14, achieving 7°C within 24 hours), are highlighted in red; results meeting the criteria are highlighted in green.

Table 2 - Modelled temperature and bacterial generations on the exposed carcass surfaces, for AMD's operating under less than optimum temperatures. Harvest to AMD time delay remains 10 hours with transfer to the processing premise within 96 hours with varying AMD temperatures.

Mass, Kg		Cooling conditions					24h post-slaughter			Time to surface temp of 7°C (h)
Field dressed	Final dressed	Ambient °C	AMD °C	AMD airflow m/s	Premise chiller °C	Premise airflow m/s	Carcass surface °C	*E. coli* (gen)	Aerobic PHI (gen)	
60	50	15	1	0.1	1	0.1	10.2	20.7	21.1	34
60	50	15	2	0.1	1	0.1	10.9	21.1	21.5	37
60	50	15	4	0.1	1	0.1	12.2	21.9	22.3	47
60	50	15	6	0.1	1	0.1	13.6	22.8	23.2	70
50	40	15	1	0.1	1	0.1	8.2	18.7	19.1	27
50	40	15	2	0.1	1	0.1	8.9	19.1	19.4	30
50	40	15	4	0.1	1	0.1	10.4	19.8	20.2	36
50	40	15	6	0.1	1	0.1	11.8	20.7	21.0	54
40	30	15	1	0.1	1	0.1	5.5	16.0	16.3	21
40	30	15	2	0.1	1	0.1	6.3	16.3	16.6	22
40	30	15	4	0.1	1	0.1	7.9	17.0	17.3	27
40	30	15	6	0.1	1	0.1	9.5	17.7	18.0	37
30	20	15	1	0.1	1	0.1	2.5	12.5	12.8	18
30	20	15	2	0.1	1	0.1	3.4	12.7	12.9	16
30	20	15	4	0.1	1	0.1	5.3	13.0	13.3	19
30	20	15	6	0.1	1	0.1	7.1	13.7	13.9	25

Table 3 - Modelled temperature and bacterial generations on the exposed carcass surfaces, for carcasses placed into refrigerated transport 10 hours post harvest, received and placed into processing premise chiller 24 hours post-harvest.

Mass, Kg		Cooling conditions					24h post-slaughter			Time to surface temp of 7°C (h)
Field dressed	Final dressed	Ambient °C	Transport °C	Transport airflow m/s	Premise chiller °C	Premise airflow m/s	Carcass surface °C	*E. coli* (gen)	Aerobic PHI (gen)	
40	30	15	1	0.1	1	0.1	5.5	16.0	16.3	21
50	40	15	1	0.1	1	0.1	8.2	18.7	19.1	27
40	30	15	3	0.1	1	0.1	7.1	16.7	16.9	24
50	40	15	3	0.1	1	0.1	9.7	19.4	19.8	29
40	30	15	6	0.1	1	0.1	9.5	17.7	18	26
50	40	15	6	0.1	1	0.1	11.8	20.7	21.0	31

9.4 Microbiological results

Tables 4 – 6 summarises the microbiological data (APC and *E. coli*) obtained from NMD sampling events from both feral and farmed venison processed at the same premises.

Table 4 –Feral venison carcass microbiology results.

	Aerobic Plate Count Log_{10} cfu/cm²				*Escherichia coli* Log_{10} cfu/cm²			
	hind leg	sternum	foreleg	All	hind leg	sternum	foreleg	All
Mean	2.45	2.68	1.63	2.25	-0.09[16]	0.32	0.18	0.14
Minimum	0.71	-0.53	-0.53	-0.53	-0.53	-0.53	-0.53	-0.53
Maximum	5.03	5.69	5.65	5.69	3.36	2.32	3.46	3.46
Standard deviation	1.31	1.98	2.01	1.81	1.10	1.09	1.39	1.18
n=	14	14	14	42	14	14	14	42

Table 5 – Farmed_Venison carcass microbiology results.

	Aerobic Plate Count Log_{10} cfu/cm²				*Escherichia coli* Log_{10} cfu/cm²			
	hind leg	sternum	foreleg	All	hind leg	sternum	foreleg	All
Mean	1.69	1.70	0.44	1.28	-0.48	-0.44	-.053	-0.48
Minimum	0.38	0.62	-0.53	-0.53	-0.53	-0.53	-0.53	-0.53
Maximum	3.42	2.71	2.46	1.73	0.30	0.30	-0.53	0.30
Standard deviation	0.63	0.53	0.81	0.30	0.18	0.22	0.00	0.09
n=	30	30	30	90	30	30	30	90

Table 6 – NMD “all data to date” for farmed venison*.

	Aerobic Plate Count Log_{10} cfu/cm²				*Escherichia coli* Log_{10} cfu/cm²			
	hind leg	sternum	foreleg	Whole cc	hind leg	sternum	foreleg	Whole cc
Mean	1.39	1.34	0.85	1.63	-0.46	-0.44	-0.48	-0.88
Minimum	-0.53	-0.53	-0.53	-1.10	-0.53	-0.53	-0.53	-1.10
Maximum	5.79	5.38	5.77	5.60	2.88	3.03	3.08	2.68
Standard deviation	1.06	0.95	1.01	0.77	0.29	0.32	0.24	0.49
n=	19432	19430	19439	19440	19466	19460	19459	19467

* Note that this includes both traditional and inverted dressed carcasses.

[16] Negative Log_{10} values relate to decimal values of <1 cfu/cm², that are derived from reporting a 25cm² sample as per cm².

10. Discussion

10.1 Impact of modelled cooling curves

The output from FPM™ indicates that, for larger (40-50Kg dressed) carcasses, the AMD chillers are unlikely to be able to reduce the surface temperature field dressed (hide-on) carcasses to below 7°C within 24 hours during the summer months. If the AMD is operating at less than optimum efficiency (e.g. an equilibration temperature of 4°C) this could take almost 2 days to achieve. For smaller carcasses (<30Kg fully dressed) a surface temperature of 7°C is achievable within 24 hours in all but the most poorly performing AMD or premises chillers.

As a consequence, particularly on the larger carcasses, bacteria would be able to reproduce to large numbers under these conditions, although mesophilic pathogens would be rapidly out-competed by psychrotrophic spoilage organisms, particularly Pseudomadaceae (Gill, 2004), which would continue to proliferate even when the carcass temperature was reduced below 7°C, unless limited by desiccation.

An additional series of models were investigated using FPM™ to estimate whether reducing the kill-to-AMD time or improving AMD efficiency might result in successful temperature control of larger carcasses (Tables 7 and 8):

Table 7 – Predicted exposed carcass surface temperatures at 24 hours based on 10, 5 and 2 hour time delays between kill and arrival at AMD at an ambient (summer at altitude) temperature of 15°C with the AMD operating at ***1°C with an air velocity of 0.1m/s around the carcass.***

Field dressed mass Kg	Final dressed mass Kg	Ambient Temp °C	Time from harvest to AMD (h)	24 hrs post slaughter		
				Surface temp °C	*E.Coli* generations	Aerobic PHI (gen)
60	50	15	10	10.2	20.7	21.1
60	50	15	5	9.3	16.7	17.1
60	50	15	2	8.8	14.1	14.3

This model suggested that it is not practicable for the larger red deer carcasses to be chilled such that surface temperatures fall to below 7°C at 24 hours post slaughter using the equipment currently available.

Table 8 - Predicted exposed carcass surface temperatures at 24 hours based on 10, 5 and 2 hour time delays between kill and arrival at AMD at an ambient (summer) temperature of 15°C with the AMD operating at ***-1°C with an air velocity of 0.25m/s around the carcass.***

Field dressed mass Kg	Final dressed mass Kg	Ambient Temp °C	Time from Harvest to AMD (h)	24 hrs post slaughter		
				Surface temp °C	*E. Coli* generations	Aerobic PHI (gen)
60	50	15	10	8.2	19.6	20
60	50	15	5	7.2	15	15.5
60	50	15	2	6.7	12	12.2

This model indicates that carcass surface temperatures can potentially be reduced to below 7°C in larger carcasses if the AS 4464:2007 harvest-to-AMD criteria of 2 hours are used in conjunction with a more efficient chiller.

As the 2 hour window is however only likely to be possible using a mobile chiller facility, which places constraints on the effectiveness of the refrigeration system, it therefore remains questionable whether such a standard is practicable for chilling larger carcasses. Further, in the absence of electrical stimulation, more rapid chilling could reduce the internal temperature of smaller carcasses below 15°C before rigor mortis is complete, risking cold-shortening (Wiklund, Stevenson-Barry, Duncan, & Littlejohn, 2001).

10.2 Visual inspection

Putrefactive changes inside the thoracic cavity are a consequence of proliferation by spoilage bacteria, particularly Pseudomonadaceae and Moraxellaceae. Unlike the majority of pathogenic bacteria, these organisms continue to proliferate aerobically under chilled conditions (e.g. *Pseudomonas spp.*, 2 generations/day at 2°C; 1.75 generations/day at 0°C), until desiccation of the meat surface reduces water activity (a_w) to < 0.95 (Gill, 2004), which will only occur when the relative humidity (Rh) in the holding chiller falls below 95%. Consequently, the onset of putrefaction on the carcass cannot be regarded a reliable indicator or abuse.

A similar question arose around the presence of maggots on some carcasses. Could this be considered an indicator of abuse? The authors contacted Dr Allen Heath, Entomologist at AgResearch Wallaceville, and Dr. Dallas Bishop, Forensic Entomologist at AsureQuality, who kindly offered the following opinions:

- The acquisition of blowfly larvae or eggs occurs very rapidly in the field (with blowflies appearing within seconds of the death of an animal) unless the temperature was below 0°C or the wind speed was >3m/sec.

- Initial exploration of the carcass by females could result in eggs / encapsulated larvae / larvae being deposited within the first few hours (some references report this happening almost immediately).
- Development of most eggs to first instar larvae can occur in 18 - 24 hours. The warmer the temperature the quicker the development and emergence. For insects that deposit encapsulated larvae (e.g. *Calliphora hilli* & *Xenocalliphora sp.*), these will emerge on contact with a feeding surface.
- Chilling has little preventive effect, even at a very early stage post mortem, although it will slow larval development. The bigger the mass of larvae the less likely you would notice any slowing of development.
- Larvae may not be seen on the external surfaces but may be present within the body cavity & thus insulated from immediate effects of refrigeration. These are likely to appear again on warming or removal from a chiller.
- Therefore one would expect, especially during summer months, the chances of eggs & larvae being present on carcasses to be high.

Consequently, the onset of insect infiltration on the carcass cannot be regarded a reliable indicator of abuse.

10.3 Microbiological results

It is particularly important to note that sampling sites required by the NMD technical specifications remain under skin, and therefore effectively sterile (Gill, Penney, & Nottingham, 1978) until, final dressing and trimming takes place at the meat plant[17]. Further, discussions with the meat premises have elucidated that, by their observation, the microbiological quality of the meat harvested is more dependent on the skill and time pressure on the workers than on the microbiological condition of the feral carcass on arrival at the plant. Based on the visual condition of the carcasses, this is a minimum of 10^9 /cm² on the exposed surfaces (Gill, 2004). The authors postulate however, that the site of microbiological concern is in fact the area covered by skin which ultimately yields the saleable meat, which is effectively sterile until final dressing.

We therefore conclude that control of microbiological contamination on the meat for consumption is heavily dependent on good hygienic practise.

As predicted by Gill (2007), there was considerable variation between individual samplings and across the different sample sites when evaluating the Aerobic Plate Counts and *E. coli* counts between feral and farmed sourced deer. Nevertheless, mean APC counts are approximately 1 $\log_{10}$ higher for feral venison as compared with

[17] Even if this is not the case, e.g. through trimming of the udder close to the leg site, the exposed area will still be trimmed, and the site relocated to the closest adjacent under-skin surface.

farmed venison for the same premise and time period. These counts are comparable with wild venison results overseas and results reported previously in New Zealand (Paulsen & Winkelmeyer, 2004; Sumner et al., 1977).

The published literature is often equivocal on what might constitute criteria for acceptance based on microbiological data. Most often, articles that do consider acceptance criteria recommend application of the EC meat standard 2073/2005 (APC daily mean m = 3.5 $\log_{10}$cfu/cm², M = 5.0 $\log_{10}$cfu/cm²; Enterobacteriaceae 1.5 $\log_{10}$cfu/cm², M = 2.5 $\log_{10}$cfu/cm²; by destructive sampling method). More recently, Paulsen (2011; 2012) collated all of the microbiological limits published to date, and considered all the factors that might bring about the wide range of microbiological results reported. These reviews concluded that with good hygienic practise, it was "entirely possible" to produce skin-on large game carcasses with microbiological criteria of: Total Aerobic Count (TAC) not to exceed 6 $\log_{10}$cfu/cm², and *E. coli* not to exceed 2 $\log_{10}$cfu/cm², on exposed muscle surfaces arriving at game handling establishments, resulting in a similar level per gram for meat cuts at retail. Whilst the sampling methods, timing and location differ for the NMD data presented in section 8.4, the majority of samples tested *comply with this standard of acceptability and would therefore be regarded as microbiologically equivalent to European product*, at least for indicator bacteria.

As stated previously, the presence and concentration of *Escherichia coli* has been shown to be unreliable as an index organism for the presence of other enteric pathogens in foods. In order for *E. coli* to be a good indicator or index organism, the following assumptions would need to be met (Mills, Barea, & Bell, 2004):

- The sources of contamination *E. coli* and other pathogens are the same.
- While there may be differences in distribution between individual skins (and hence carcasses), over a larger number of carcasses the distribution of enteric pathogens (when present) is similar to that of *E. coli*.
- The numerical ratio between *E. coli* and other pathogens (when present) is relatively constant.
- The adhesive properties of *E. coli* and other pathogens are comparable.
- The transfer of pathogens (when present) during dressing is comparable to *E. coli*.

At present, very little data has been published regarding prevalence of pathogenic bacteria on feral deer carcasses in New Zealand; the only reference found (Sumner et al., 1977) reported *Salmonella* were not isolated from 67 carcasses sampled. It is therefore not possible to establish the actual risk associated with consumption of NZ venison obtained from feral sources (i.e. from *Salmonella*, EHEC and *Campylobacter*).

11. Conclusions

- FPM™ has been validated for use to predict the microbiological outcomes of the chilling regimes applied to feral venison.
- Feral venison procurement in New Zealand occurs primarily during the summer months, when helicopter harvesting is most effective. This is the opposite of normal practise elsewhere, where venison is normally harvested during winter. Consequently, ambient temperatures during harvesting in NZ are considerably higher.
- For larger (40-50Kg dressed) carcasses, the temperature at the exposed carcass surface is unlikely to reduce to below 7°C within 24 hours of harvest using current operational practice. Increases in chiller temperature are however associated with significantly extended cooling rates; therefore some control over refrigeration remains important.
- Consequently, microbiological analyses used to assess hygienic condition of the carcass will show higher counts for feral than for farmed venison. Observational data and data published overseas suggested an increase in the order of 1 $\log_{10}$cfu/cm², with a wide variation across the results.
- Meat that is ultimately released for commerce remains under skin until final dressing and therefore effectively sterile until processed at the registered processing premises. Whilst the microbiological condition of the exposed areas carcass will have some impact on the transfer to the remainder during processing, this will be ***heavily influenced by the hygienic standards applied during dressing***.
- A microbiological standard of Total Aerobic Count (TAC) not <6 $\log_{10}$cfu/cm², and *E. coli* < 2 $\log_{10}$cfu/cm², has been proposed for acceptance of feral venison meat in Europe. For premises observing good hygienic practise, NMD results for feral venison observed during this study complied with these criteria.
- Establishing the risk of transmission of pathogens to humans via feral venison is not possible without data on their prevalence.

12. Recommendation

It is unlikely that AMD or refrigerated transport facilities can be improved to the point that exposed surfaces can be chilled to <7°C within 24 hours for all types and weights of feral deer harvested. As the site of microbiological concern (from which saleable meat is ultimately derived) remains under skin and is therefore sterile at this point, this presents little food safety risk until final dressing, and aids in the development of the

"gamy" flavours particular to the product. We believe the real food safety risk is from contamination of the newly exposed meat surfaces during final dressing, particularly from proximal surfaces, and that the Standard should reflect this. We also recommend that feral venison should be considered a separate class under NMD, which would enable some degree of control, and the potential to improve the hygienic status with time.

13. References

Bandick, N., & Hensel, A. (2011). Zoonotic diseases and direct marketing of game meat: aspects of consumer safety in Germany. In P. Paulsen, A. Bauer, N. Vodnansky, R. Winkelmeyer & F. Smulders (Eds.), *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance* (pp. 93-100). Wageningen: Wageningen Academic Publishers.

Bartels, A., & Bülte, M. (2011). Verotoxigenic *Escherichia coli* (VTEC) in wild ruminants in Germany. In P. Paulsen, A. Bauer, N. Vodnansky, R. Winkelmeyer & F. Smulders (Eds.), *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance* (pp. 107-111). Wageningen: Wageningen Academic Publishers.

CAC. (2005). Code of hygienic practise for meat (Vol. CAC/RCP 58-2005): Codex Alimentarius Commission.

Coburn, H., Snary, E., Kelly, L., & Woolridge, M. (2005). Qualitative Risk Assessment of the Hazards and Risks of Wild Game. *The Veterinary Record, 157*, 321-322.

Coleman, J., & Cooke, M. (2001). *Mycobacterium bovis* infection in wildlife in New Zealand. *Tuberculosis, 81*(3), 191-202.

EFSA. (2014). Scientific opinion on the public health risks related to the maintenance of the cold chain during storage and transport of meat. Part 1 (meat of domestic ungulates). [Scientific Opinion]. *EFSA Journal, 12*(3), 3601.

French, E., Rodriguez-Palacios, A., & Lejeune, J. (2010). Enteric bacterial pathogens with zoonotic potential isolated from farm-raised deer. *Foodborne Pathogens and Disease, 7*(9), 1031-1037.

Gavier-Widén, D., Cooke, M., Gallagher, J., Chambers, M., & Gortázar, C. (2009). A review of infection of wildlife hosts with *Mycobacterium bovis* and the diagnostic difficulties of the 'no visible lesion' presentation. *New Zealand Veterinary Journal, 57*(3), 122-131.

Gill, C. (1996). Extending the storage life of raw chilled meats. *Meat Science, 43*(S), S99-S110.

Gill, C. (2004). Spoilage, Factors Effecting, Microbiological. In W. Jensen (Ed.), *Encyclopedia of Meat Sciences* (Vol. 3, pp. 1234-1330). Oxford: Elsevier.

Gill, C. (2007). Microbiological conditions of meats from large game animals and birds. *Meat Science, 77*, 149-160.

Gill, C., Penney, N., & Nottingham, P. (1978). Tissue sterility in uneviscerated carcasses. *Applied and Environmental Microbiology, 36*(2), 356-359.

ICMSF. (1996). *Yersinia enterocolitica*. In T. Roberts, A. Baird-Parker & R. Tompkin (Eds.), *Micro-organisms in foods: Characteristics of microbial pathogens* (Vol. 5). London: Blackie.

Kornacki, J., & Johnson, J. (2001). *Enterobacteriaceae*, Coliforms and *Escherichia coli* as quality and safety indicators. In F. Pouch Downes & K. Ito (Eds.), *Compendium of Methods for the Microbiological Examination of Foods* (pp. 69-82). Washington, DC: American Public Health Association.

Lovatt, S., Bell, R., & LeRoux, G. (2006). Establishment of critical hygiene indices for meat cooling processes evaluated by a temperature function integration method. *Journal of Food Protection, 69*(9), 2084-2090.

Membré, J.-M., Laroche, M., & Magras, C. (2011). Assessment of levels of bacterial contamination of large wild game meat in Europe. *Food Microbiology, 28*(5), 1072-1079.

Mills, J., Barea, H., & Bell, R. G. (2004). Carcass Mapping Study. Hamilton: AgResearch MIRINZ.

NIWA. (2011, 22/5/12). The National Climate Database Retrieved 8/7/11, 2011, from http://www.cliflo.niwa.co.nz/

Nugent, G., & Choquenot, D. (2004). Comparing cost-effectiveness of commercial harvesting, state-funded culling, and recreational deer hunting in New Zealand. *Wildlife Society Bulletin, 32*(2), 481-492.

Paulsen, P. (2011). Hygiene and microbiology of meat from wild game: an Austrian view. In P. Paulsen, A. Bauer, N. Vodnansky, R. Winkelmeyer & F. Smulders (Eds.), *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance* (pp. 19-37). Wageningen: Wageningen Academic Publishers.

Paulsen, P., Smulders, F., & Hilbert, F. (2012). *Salmonella* in meat from hunted game: A central European perspective. *Food Research International, 45*(2), 609-616.

Paulsen, P., & Winkelmeyer, R. (2004). Seasonal variation in the microbial contamination of game carcasses in an Austrian hunting area. *European Journal of Wildlife Research, 50*, 151-159.

Radakovic, M., & Fletcher, J. (2011). Risk management of game: from theory to practice. In P. Paulsen, A. Bauer, N. Vodnansky, R. Winkelmeyer & F. Smulders (Eds.), *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance* (pp. 209-221). Wageningen: Wageningen Academic Publishers.

Sumner, J., Perry, I., & Reay, C. (1977). Microbiology of New Zealand feral venison. *Journal of the Science of Food and Agriculture, 28*, 829-832.

Turbill, C., Ruf, T., Mang, T., & Arnold, W. (2011). Regulation of heart rate and rumen temperature in red deer: effects of season and food intake. *Journal of Experimental Biology, 214*(6), 963-970.

van Schalkwyk, D., Hoffman, L., & Laubscher, L. (2011). Game harvesting procedures and their effect of meat quality: the Africa experience. In P. Paulsen, A. Bauer, N. Vodnansky, R. Winkelmeyer & F. Smulders (Eds.), *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance* (pp. 67-92). Wageningen: Wageningen Academic Publishers.

Wiklund, E., Stevenson-Barry, J., Duncan, S., & Littlejohn, R. (2001). Electrical stimulation of red deer (*Cervus elaphus*) carcasses - effects on rate of pH decline, meat tenderness, colour stability and water-holding capacity. *Meat Science, 59*, 211-220.