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Spray chilling of deer carcasses -

Effects on carcass weight, meat moisture content, purge and microbiological quality

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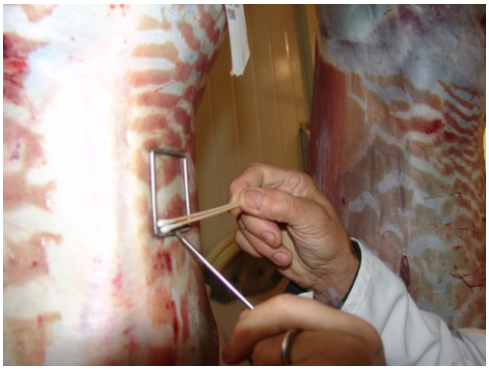

agresearch Client Report - CR 1309

Spray chilling of deer carcasses -
Effects on carcass weight, meat moisture content, purge and microbiological quality

Prepared for DEEResearch

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1 Background

An important meat quality attribute is the ability to hold water in the meat structure (Water-holding capacity; WHC). Loss of water in the form of exudation or drip affects the appearance of vacuum packaged chilled meat when it reaches the retail market and therefore consumer acceptability of meat at the point of purchase. Drip is also important in relation to the juiciness of cooked meat for table purposes, and the yield of processed meat products.

Venison is a high quality product with several attributes attractive to consumers – it is tender, has low fat content, a favourable fat composition and high levels of minerals (Hoffman & Wiklund, 2006). Chilled venison tenderises more rapidly compared to beef (Barnier *et al*., 1999; Farouk *et al*., 2007). Whilst this is a key quality attribute of venison; the advanced level of proteolysis (associated with this rapid tenderisation; Wiklund *et al*., 1997) makes it more susceptible to excessive drip loss. There is currently no agreement in the literature on the mechanisms causing and regulating drip loss in meat.

Over the last year (2007/2008) with financial support from AgResearch and DEEResearch we have been able to determine seasonal variation in drip loss, colour, calpain activity and tenderness in venison. The most important conclusion from this work in relation to WHC was; as tenderness improved over the storage period (up to 14 weeks of chilled storage at -1.5°C) it was accompanied by a significant increase in purge (averaging 2.5%) in the venison samples. This effect was not seasonal but found in venison samples from all slaughter time-points included (December, March, July and September) (Wiklund *et al*., 2009).

In the current project we have studied spray chilling of deer carcasses as an example of processing techniques applied to reduce carcass weight/water loss during the cooling cycle. Spray chilling involves intermittent water sprays during carcass cooling and can reduce weight loss by approximately 2%, but has also been demonstrated to have a negative impact on important quality attributes (Brown *et al*., 1993; Greer & Jones, 1997). This study has for the first time collected data on weight loss distribution/water uptake in deer carcasses and evaluated impact of spray chilling on meat moisture content, drip loss, tenderness and microbiological quality of venison.

2 Material and methods

2.1 Main study

Animals

A total of 20 red deer carcasses (average weight 51.2 kg) were included in the study. Carcasses were selected at the carcass grading station and randomly allotted to either a control treatment (no spray chilling) or a spray chilling treatment. Meat samples for moisture determination (approximately 5 g) were collected immediately after grading at four different carcass sites: *M. triceps brachii* (shoulder), *M. longissimus dorsi* (loin, at the last rib), *M. obliquus abdominis externus* (flap) and *M. biceps femoris* (silverside). Meat samples were sealed in plastic zip-lock bags and kept in a cooled chilly bin during transport back to AgResearch Hamilton. After meat sampling, the carcasses were hung in the two experimental silos with temperature probes inserted to measure surface (rib cage area) and deep leg (measured in the *M. semimembranosus* close to the pelvic bone) temperatures. The silos were closed, fans and spray chilling were then turned on.

The following day, fans were turned off, temperature probes removed and the weight and temperature data down loaded from the data logger to a laptop computer. Meat samples for moisture determination were collected again at the same four sites of the carcass but in an undamaged part of the same muscles. Carcasses were then transferred to the boning room and a part of the left hand side *M. longissimus dorsi* (shortloin) was collected from each carcass. The shortloins were transported cooled in a chilly bin to AgResearch Hamilton, where they were cut in two pieces, weighed, vacuum packaged and randomly allotted to either 3 weeks or 9 weeks storage at -1.5°C.

Spray chilling silos

AgResearch MIRINZ had 2 galvanised steel cylindrical silos that had previously been used for spray chilling trials. After some modifications were made for this project, the silos were transported to Rotorua where they were installed at the Silver Fern Farms deer slaughter premises. Each silo consists of a cylindrical section, supported on 4 legs fitted with wheels, and the silo in turn supports a fan. The total height is 2.6 m and they are about 1 m in diameter (Figure 1).

Figure 1. Spray chilling silos in place in the chiller at Silver Fern Farms deer slaughter premises in Rotorua.

Each silo was fitted with a 0 to 100 kg load cell which was mounted on a bracket reasonably central to the axis of the silo and at a height that could easily handle a deer carcass up to about 60 kg. The load cells were fitted with a hook designed to take a standard mutton gambrel which was too small for the deer carcasses, so some new gambrels were made for this project. Since the AgResearch silos were not fitted with a pump or spray provision, at Rotorua the silos were connected to the plant's spray system using basic Nylex 70 mm garden hose and snap connect fittings (where Figure 2 indicates a ¾" BSP fitting, these ends were in fact blanked off). Two spray bars were fitted across each silo so that the spray nozzle height and spacing from the carcass matched pretty well the system that was already in place at the Rotorua plant.

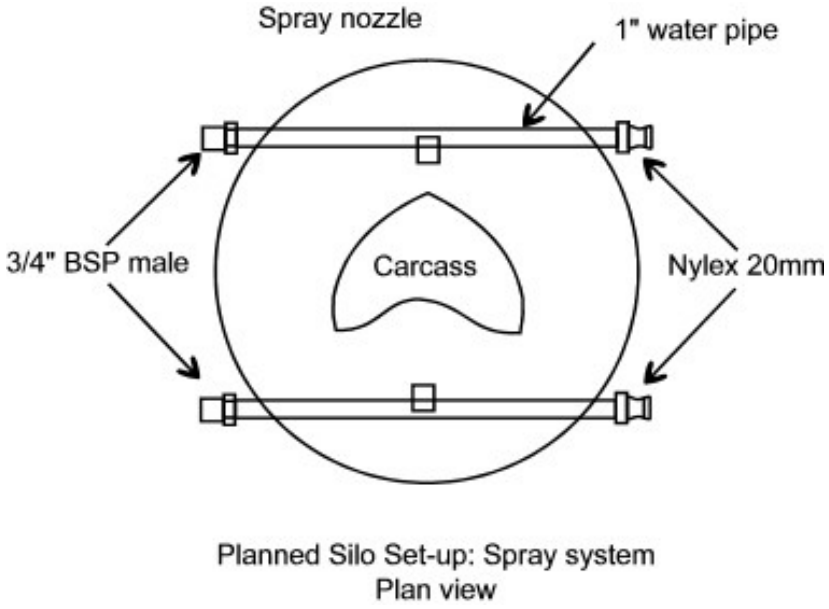

Figure 2. Diagram illustrating the plan view of the silo set up showing carcass position in relation to the spray nozzles.

A fan speed control was provided using a single PDL motor speed controller. Unfortunately, when the air velocity profile was measured using a Dantec hot-wire anemometer in each silo, they were found to be different, so a simple adjustable aperture device was constructed and fitted to the top of the higher velocity silo (above the fan) so the air velocity could be manually adjusted to match the slower unit which was adjusted to provide an air velocity very similar to what was measured in the normal operating slaughter plant chiller.

Temperature probes were installed in each silo to measure deep leg, surface as well as air temperatures in the room. Temperatures and carcass weights were continuously recorded using a Grant Squirrel data logger, which was placed along with other electrical connections in a splash protected case.

The final chilling parameters used in this study were: airflow of 0.8 m/s in both experimental silos. In one of the silos spray chilling was applied for 6 h of the chilling cycle as intermittent sprays then the spray was turned off and carcasses chilled only by air. Each pair of spray nozzles used in the silos (one on each side of the carcass) would normally spray 3 carcasses on a rail according to the system set up in the plant chiller and we calculated that each carcass would receive an equal 1/3 share of the total volume sprayed. This would result in 15 l/carcass over the spray period and as the silos were plumbed into the plant system we assumed the same volume would be applied to the test carcasses. The second silo was used as the control treatment with only air chilling applied to the carcasses.

Moisture content

Meat samples were removed from the zip-lock bags, cut up finely (none of the meat samples had any fat coverage, so the whole sample was used) and then divided in two sub–samples for duplicate analysis. Approximately 1.5 – 2 g of meat was put in pre-weighed aluminium dishes, dried in an oven at 101°C for 18 h, cooled down for 30 min and then re-weighed (AOAC 950.41B, 2005).

Microbiological quality
In 10 of the 20 deer carcasses included in the main study, microbiological status (total aerobic count) was assessed on swabs taken at the lumbar end of the left hand side *M. longissimus dorsi* before meat samples for moisture determination were collected, *i.e.* immediately after grading and before the chilling treatments and then again after the chilling treatments were completed at 1 day post slaughter. Further, micro swabs were also collected on the shortloin samples after 3 weeks and 9 weeks of chilled storage at -1.5°C immediately upon opening the vacuum bags.

A non-destructive swabbing method was used (NZFSA, 2008). The sampling area (25 cm^2) was marked with a sterile template and sampled with 2 cotton wool swab sticks moistened with Maximum Recovery Diluent (MRD; Difco, Detroit, USA). The swabs were rubbed vertically, horizontally, and diagonally across the entire sampling surfaces. After sampling the cotton swabs were placed in the test vial containing 15 ml of MRD. The sampling was repeated with another 2 dry swabs which was placed into the same test vial. The test vials were transferred in a cooled chilly bin to AgResearch Hamilton for microbiological analysis within 2-4 hours of sampling.

The test vials with the samples were shaken vigorously so that the cotton was evenly distributed in the diluents. Aerobic plate counts (APC) were determined using standard spread plate method. Briefly, 0.1 ml of the appropriate dilutions was spread over the surface of duplicate dried plate count agar (PCA; Difco, Detroit, USA) plates. All the spread plates were incubated aerobically at 30^oC for 48 hours. All the colonies present were counted and expressed as the number of colony forming units (CFU) per cm^2 of carcass surface. The lower limit of detection (LLD) was 3 CFU cm^{-2} of carcass surface for one colony on one of the two duplicate plates.

pH measurements

Meat pH was measured in all samples stored for 3 and 9 weeks at -1.5°C using a portable automatic temperature compensation pH meter (Testo® 230, Germany) fitted with pH penetration probe type 13 and NTC food penetration temperature probe. The pH meter was calibrated at pH 7.0 and 4.0 with buffers (Mallinckrodt Chemicals, USA) stored at room temperature (20°C).

Purge loss, cooking loss, total loss and tenderness

Purge loss, cooking loss and tenderness were measured in all samples stored for 3 and 9 weeks at -1.5°C. Purge loss was calculated as the difference in the weight of the loins before and after storage expressed as a percentage of the original weight of the loins. A thermocouple was inserted in each sample to measure the temperature at the centre of the sample during cooking. Loins were cooked in bags submerged in boiling water until the internal temperature of the sample reached 75°C. After cooking the samples were immediately cooled on ice. Ten 1 cm x 1 cm cross-section x 2.5 cm long samples were prepared from the cooked sample with the muscle fibres running longitudinally along the

sample. Each sample was then sheared with the long axis of the fibres running perpendicular to the blade, using a MIRINZ tenderometer. The results were expressed as shear force (kgF).

Cooking loss was measured after each of the two storage times. Loin samples were weighed before cooking and after cooking the meat samples for tenderness measurements, were blotted dry and re-weighed. The cooking loss was calculated as amount of weight lost and expressed as a percentage of the original sample weight. Total loss was calculated as purge + cooking loss.

2.2 Friday effect

Ten extra carcasses were used for this part of the study. They were selected at the carcass grading station and randomly allotted to either a control treatment (no spray chilling) or a spray chilling treatment. Using the same technique as described earlier, swabs were taken for determination of microbiological status (total aerobic count) at the lumbar end of the left hand side *M. longissimus dorsi* immediately after carcass grading, the carcasses were then hung in the two experimental silos with temperature probes inserted to measure surface (rib cage area) and deep leg (measured in the *M. semimembranosus* close to the pelvic bone) temperatures. The silos were closed, fans and spray chilling were then turned on. Carcasses were left in the silos as they would have been in a practical situation where animals are slaughtered on a Friday and carcasses boned out on the following Monday (3 days later). After the chilling cycle was completed, fans were turned off, temperature probes removed, micro swabs were again collected at the lumbar end of the left hand side *M. longissimus dors* and the weight and temperature data down loaded from the data logger to a laptop computer.

Statistical analysis

The data captured at the end of the experiment were analysed using the ANOVA directive of GenStat 11th Edition (2008). The splines with their half Least Significant Differences (if the shaded areas don't overlap the splines are significantly different at 5%) were fitted to the data collected over time using a Bayesian smoothing technique Flexi (Upsdell, 1994).

3 Results

Carcass weight and temperature changes during chilling

Weight changes for air chilled and spray chilled carcasses are shown in Figure 3. It is clearly demonstrated that during the first 6 hours of chilling (when water was sprayed) there was a weight increase in the spray chilled carcasses. After the water was turned off, the weights immediately started to decline. Initial weight of the carcasses from the two treatment groups were not significantly different (p=0.70; Table 1).The average weight change over the chilling period for the air chilled and spray chilled carcasses differed significantly (p<0.001), with the air chilled carcasses losing about 1 kg and the spray chilled carcasses losing less than 0.1 kg.

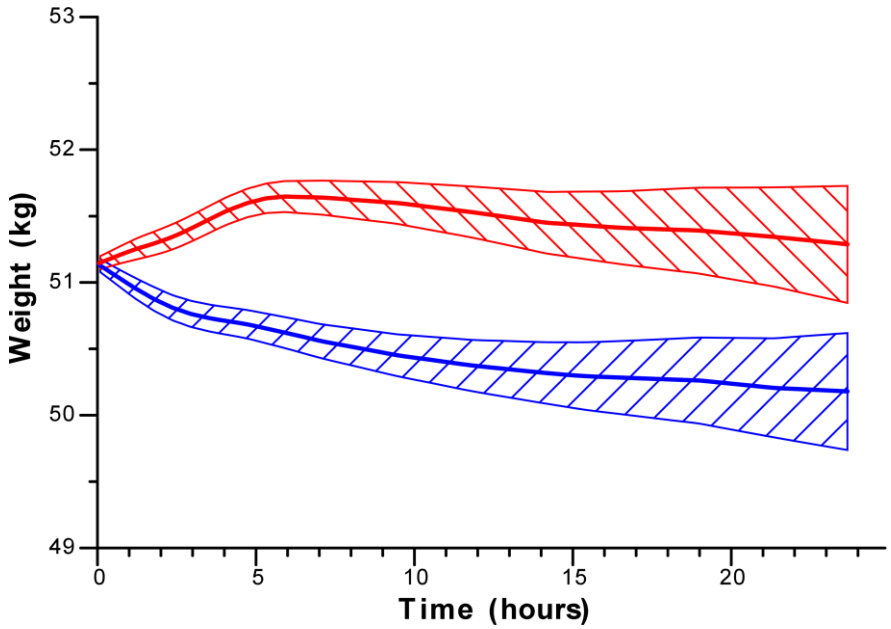

Figure 3. Weight change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, *n*=10) or control treatment (air chilling only, blue line, *n*=10).

Table 1. Carcass and meat quality characteristics for meat samples (*M. longissimus dorsi,* shortloin) stored at 3 or 9 weeks at -1.5°C from red deer included in the study.

Trait	Treat 1 (No spray chilling, n=10)	Treat 2 (Spray chilling, n=10)	SED
Carcass weight, kg	51.3	51.1	0.49
pH in loin			
3 w	5.51	5.54	0.02
9 w	5.56	5.57	0.03
Purge, %			
3 w	2.60	2.25	0.36
9 w	4.31	4.72	0.34
Cooking loss, %			
3 w	27.75	28.73	1.14
9 w	27.55	27.06	0.99
Total loss, %			
3w	30.50	31.23	1.23
9w	31.86	31.73	1.06
Shear force, kgF			
3 w	4.28	4.07	0.38
9 w	3.55	3.69	0.25

Means in the same row with different letters are significantly different ($p \leq 0.05$).

Surface and deep leg temperature declines for the two chilling treatments are shown in Figures 4 and 5. The final deep leg temperatures did not differ between air chilled and spray chilled carcasses (mean values of 2.0°C and 1.9°C, respectively), however the final surface temperature was significantly lower (p=0.01) in spray chilled (1.3°C) carcasses compared with air chilled (1.5°C).

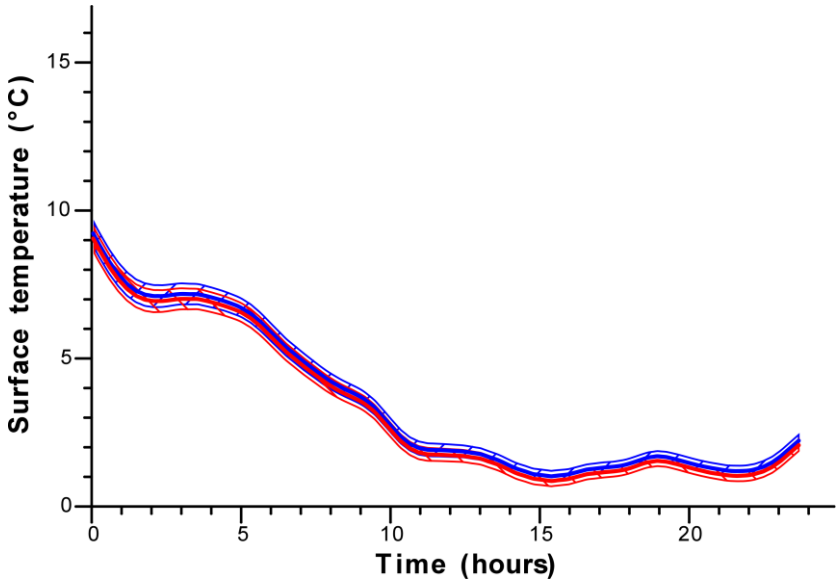

Figure 4. Surface temperature change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, n=10) or control treatment (air chilling only, blue line, n=10).

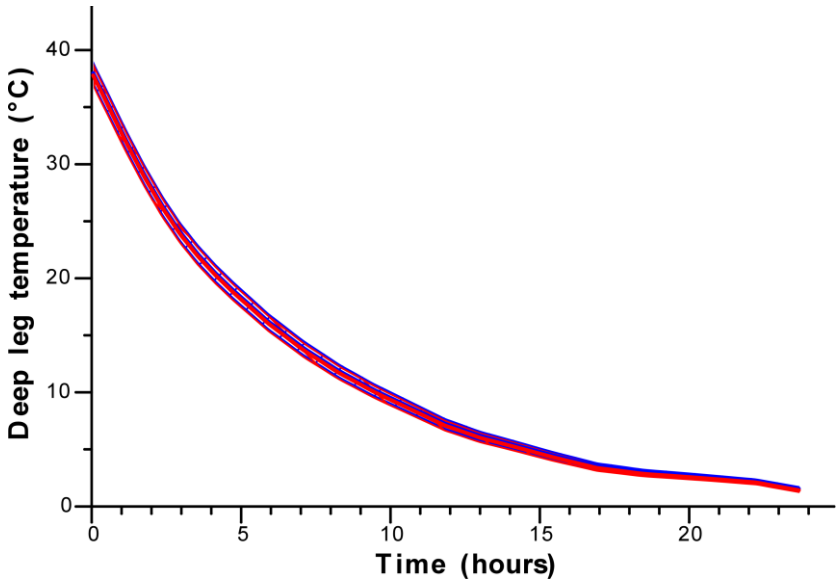

Figure 5. Deep leg temperature change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, n=10) or control treatment (air chilling only, blue line, n=10).

Moisture content

For the control treatment (no spray chilling), moisture content decreased significantly (p<0.001) during the chilling cycle at all four measured carcass sites (shoulder, loin, flap and leg) (Fig. 6). In contrast, after the spray chilling treatment moisture content increased significantly (p<0.001) in the flap and decreased significantly (p<0.001) in the shoulder. In the loin and leg areas there were no differences in moisture content before and after spray chilling treatment (Fig. 7).

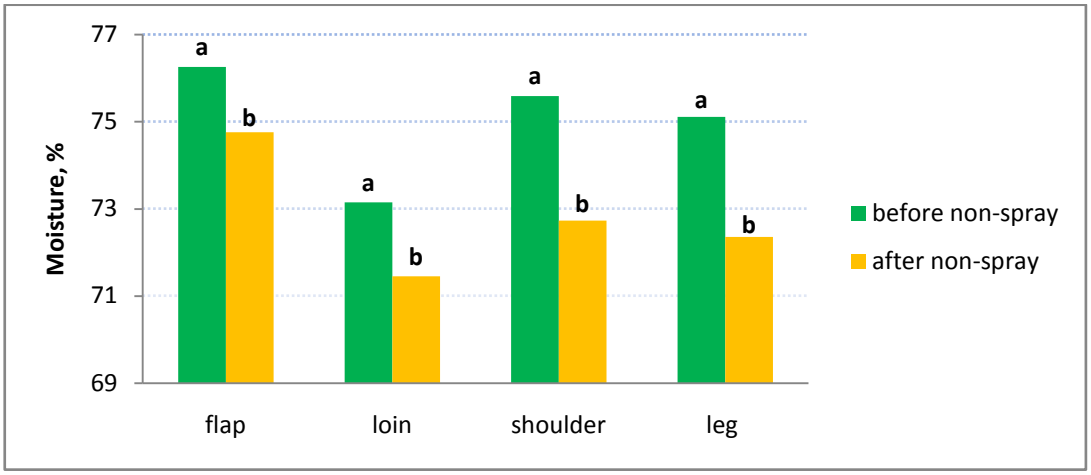

Figure 6. Moisture content at four different carcass sites: *M. triceps brachii* (shoulder), *M. longissimus dorsi* (loin, at the last rib), *M. obliquus abdominis externus* (flap) and *M. biceps femoris* (leg) before and after control treatment (air chilling) of deer carcasses (n=10). Means **within** the same muscle with different letters are significantly different (p≤0.05).

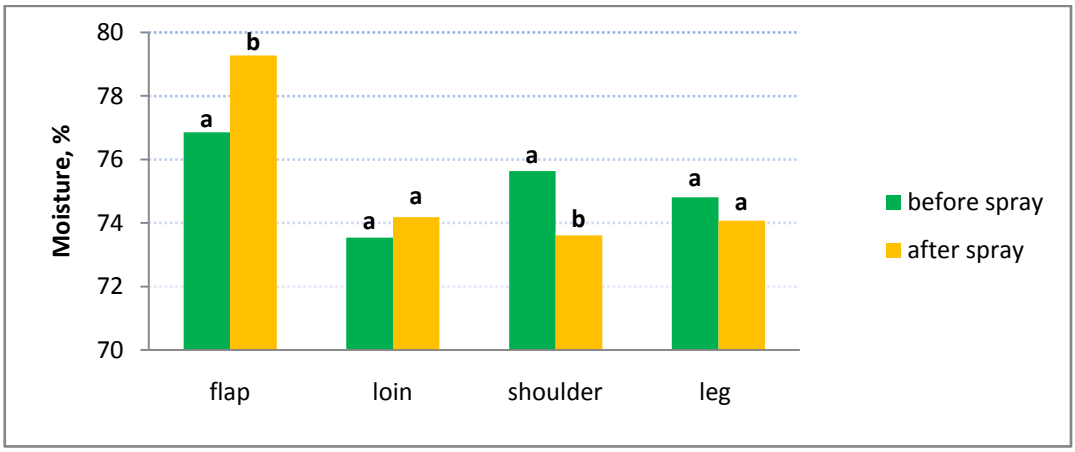

Figure 7. Moisture content at four different carcass sites: *M. triceps brachii* (shoulder), *M. longissimus dorsi* (loin, at the last rib), *M. obliquus abdominis externus* (flap) and *M. biceps femoris* (leg) before and after spray chilling of deer carcasses (n=10). Means **within** the same muscle with different letters are significantly different (p≤0.05).

Purge, cook loss, total loss, pH and tenderness

No difference between the two chilling treatments after storage at -1.5°C for 3 and 9 wks were found in any of the measured attributes purge, cook loss, total loss, pH or tenderness (Table 1).

Microbiological quality

For the 10 carcasses included in the main study, there were no significant differences in total aerobic counts (CFU/cm^2) between the two chilling treatments at any of the measured time-points (before chilling, after chilling and after 3 or 9 weeks of storage in vacuum packages at -1.5°C). However, comparisons within each chilling treatment showed a significant (p<0.05) increase in CFU/cm^2 after 9 weeks of storage in vacuum packages at -1.5°C for the spray chilled carcasses (Figure 8).

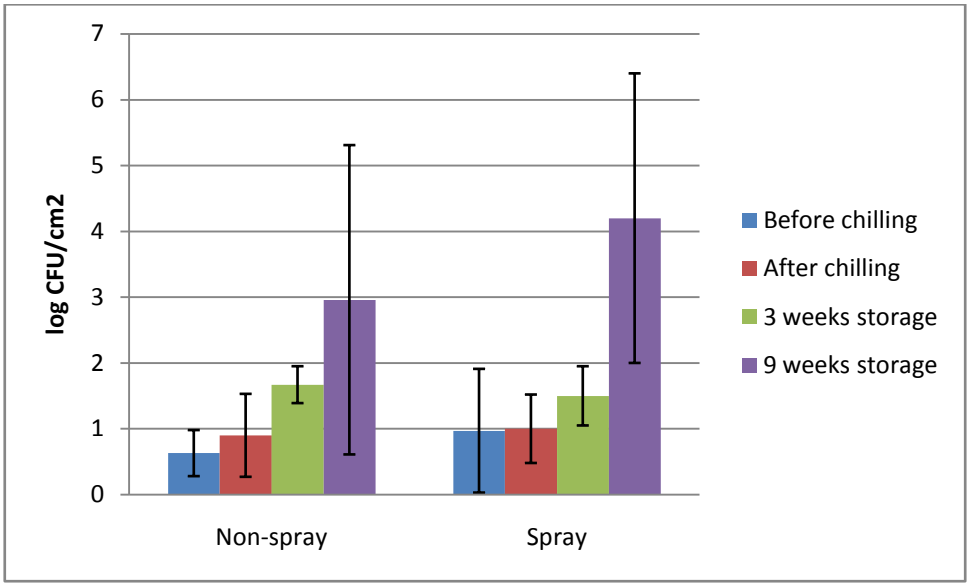

Figure 8. Microbiological quality (log CFU/cm^2) in venison samples (*M. longissimus dorsi, n*=5 for each treatment) from carcasses exposed to spray chilling and air chilling (control treatment). Swabs were taken before chilling, after chilling and after 3 and 9 weeks of storage in vacuum bags at -1.5°C. Mean values and bars indicating SD.

"Friday effect": Carcass weight and temperature changes during chilling

The weight and temperature changes in air chilled and spray chilled carcasses left in the chillers for 3 days are shown in Figures 9, 10 and 11. As previously shown in Figure 3, during the first 6 hours of chilling (when water was sprayed) there was a weight increase in the spray chilled carcasses. The average weight change over the 3-day chilling period for the air chilled and spray chilled carcasses differed significantly (p<0.001), with the air chilled carcasses losing about 1.5 kg and the spray chilled carcasses losing 0.1 kg (Fig. 9).

Surface and deep leg temperature declines for the two chilling treatments are shown in Figures 10 and 11.The final deep leg temperature of the air chilled carcasses was significantly higher (p=0.04) compared with the spray chilled carcasses (mean values of 1.6°C and 1.4°C, respectively). Surface temperature showed the same difference; significantly higher (p=0.001) value for air chilled carcasses compared with spray chilled (mean values of 1.4°C and 1.2°C, respectively).

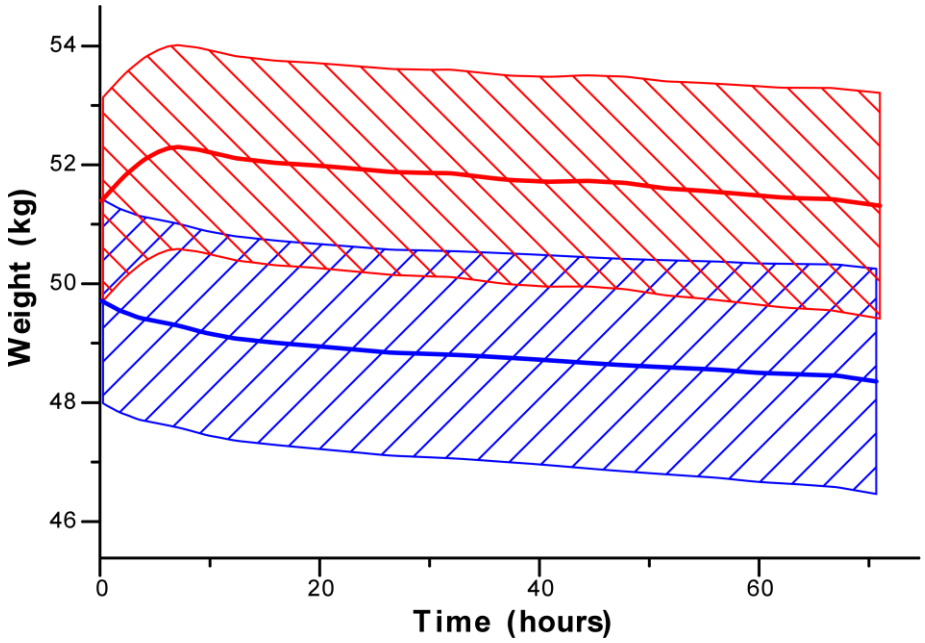

Figure 9. Weight change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, *n*=5 or control treatment (air chilling only, blue line, *n*=5) for 3 days ("Friday effect").

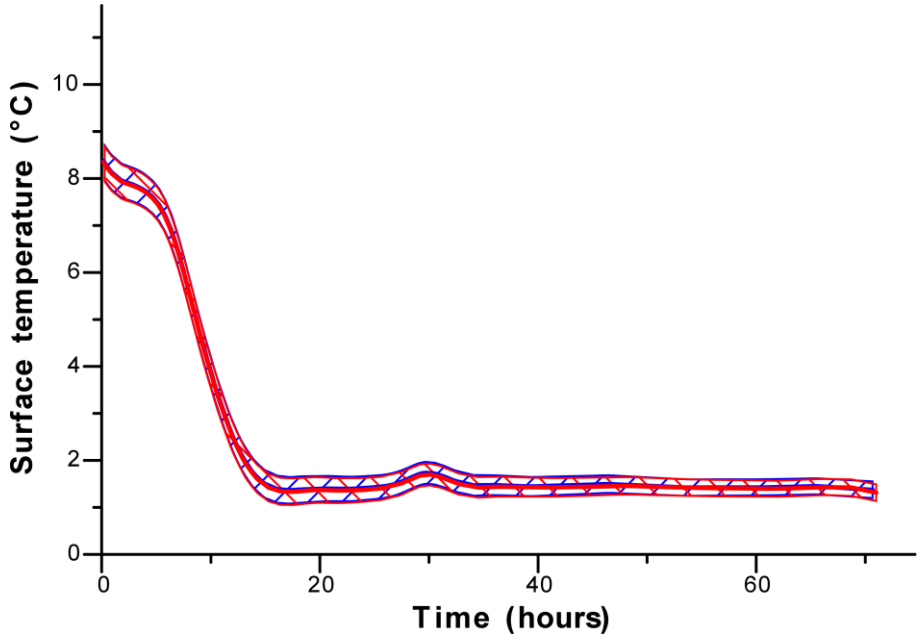

Figure 10. Surface temperature change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, *n*=5) or control treatment (air chilling only, blue line, *n*=5) for 3 days ("Friday effect").

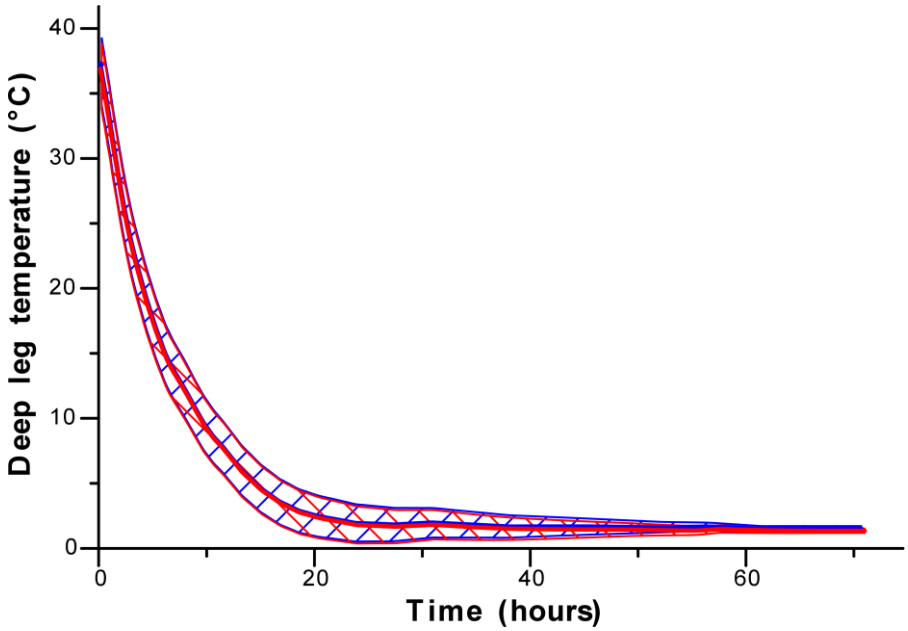

Figure 11. Deep leg temperature change (splines with their half Least Significant Differences - if the shaded areas don't overlap the splines are significantly different at 5%) during the chilling cycle in deer carcasses exposed to spray chilling (red line, *n*=5) or control treatment (air chilling only, blue line, *n*=5) for 3 days ("Friday effect").

"Friday effect": Microbiological quality

In the "Friday effect" part of the study, no significant differences were found in total aerobic counts (CFU/cm^2) between the two treatments at the time-points before or after the chilling cycle (Figure 12). When comparing the changes in micro status within treatments there were also not any significant differences (Fig. 12)

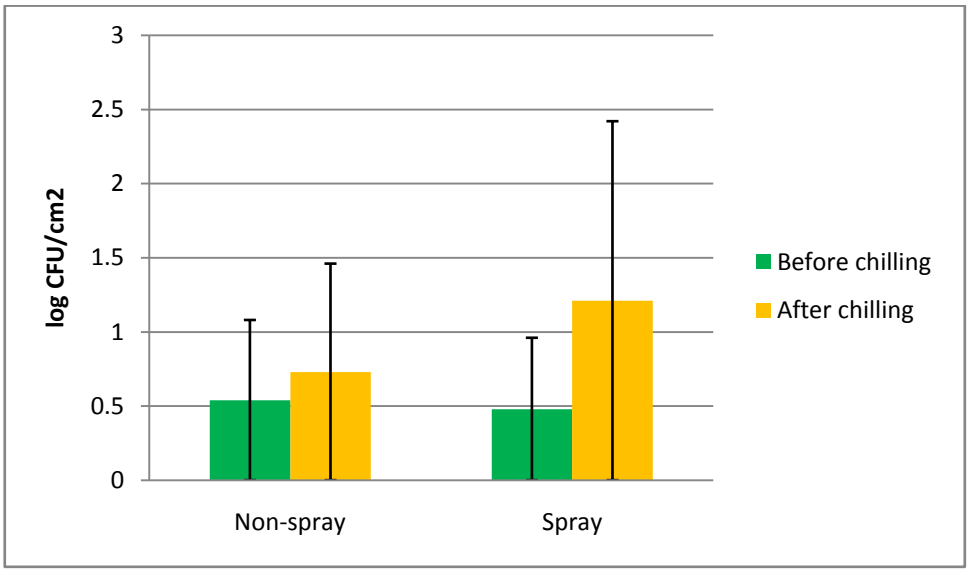

Figure 12. The "Friday effect" on microbiological status (log CFU/cm^2) of venison samples (*M. longissimus dorsi, n*=5 for each treatment) from carcasses exposed to spray chilling and air chilling (control treatment) to illustrate the practical scenario of slaughtering on Friday, chilling the carcasses over the weekend and boning the following Monday. Mean values and bars indicating SD.

4 Discussion

Most post-mortem chilling processes of livestock carcasses are primarily employed to ensure food safety, maximize shelf life and reduce shrinkage with less focus on maintaining tenderness and colour of the finished product (Savell *et al*., 2005). The principal purpose of spray chilling is to reduce carcass weight loss during chilling, especially during the first 24 hours *post mortem* (Allen *et al*., 1987). Spray chilling systems are currently in use in North America, Europe and elsewhere in the world for beef, lamb, poultry (Brown *et al*., 1993), pork (Gigiel *et al*., 1989) and in New Zealand also for venison (Merts *et al*., 1998). The process of spray chilling involves the intermittent spraying of cold water onto carcasses during the first 3-8 h *post mortem* (Hippe *et al*., 1991) to replace moisture lost by evaporation (Gigiel *et al*., 1989). The present results confirmed the positive effect of spray chilling in minimising weight loss of deer carcasses from 1 kg in conventional (air) chilled carcasses down to less than 0.1 kg weight loss in spray chilled carcasses. These savings were maintained over a three day storage period so that in spray chilled carcasses versus conventionally chilled carcasses left in the chiller from Friday to Monday ("Friday effect") the weight losses were 0.1 kg and 1.5 kg, respectively.

The phenomenon of increased meat pH values during long term chilled storage of venison samples have previously been reported (Wiklund *et al*., 2001), but was not found in this study. The measured pH values in the present study varied between 5.42 - 5.71 which are values in the optimal range to safeguard meat quality and shelf life. Shear force values similar to those found in the present venison loin samples, which all represents very tender meat, have been reported previously (Wiklund *et al*., 2001, 2009; Farouk *et al*., 2007). The conclusion from the present study that spray chilling did not affect meat tenderness in venison has earlier been reported for beef (Hippe *et al*., 1991) and venison (Merts *et al*., 1998).

From the literature, purge loss during vacuum storage has been reported to increase after spray chilling of beef (Allen *et al*., 1987) and venison (Merts *et al*., 1998) carcasses. In contrast, spray chilled lamb (Brown *et al*., 1993) and beef (Hippe *et al*., 1991) have also been found to have the same levels of purge compared with commercially chilled carcasses. Purge in vacuum bags during long-term chilled storage has been reported previously for venison, showing both lower (Wiklund *et al*., 2001) and similar (Wiklund *et al*., 2006) levels of purge loss compared with the present study. The increasing amount of purge loss over the storage period observed in this study agrees well with earlier published venison studies (Wiklund *et al.,* 2009; Farouk *et al*, 2009). However, the present results were in agreement with the mentioned lamb and beef studies (Brown *et al*., 1993; Hippe *et al*., 1991) when concluding that spray chilling of the deer carcasses did not increase the amount of purge in vacuum packed loin (*M. longissimus dorsi*) samples after 3 or 9 week of storage at -1.5°C. Further, the additional attributes measured relating to WHC (cooking loss and total loss) also indicated that spray chilling did not cause an increased fluid loss from the venison after 3 or 9 week of storage at -1.5°C.

One theory to consider is that the mechanism behind these results is due to the effect of spray chilling allowing the carcass to retain the natural/original moisture content. We hypothesize that in air chilling, as the air removes moisture from the surface by evaporation, internal moisture replaces it. With spray chilling, the wet surface allows for evaporation to take place without affecting the moisture content of the deep

muscle/meat (particularly in the loin and leg regions in the present study). This would mean that the natural moisture content of the deep muscle/meat is retained rather than migrating to the meat surface. Furthermore, the water sprayed onto the carcass is never absorbed by the meat. Therefore, it is likely that the 'natural' moisture content in the meat is more stable in the structure and would therefore be less easily lost as purge or cooking loss.

In the present study, the overall mean bacterial counts recovered from the 20 samples collected prior to the treatments (air chilling or spray chilling) were 0.65 ± 0.50 $\log_{10}$CFU $cm^{-2.}$ These levels of bacterial counts are comparable to those reported in The National Microbiological Database for primal cuts from deer carcasses (0.32±0.99 $\log_{10}$CFU cm^{-2}; NZFSA, 2009). Compared to other sampling sites on the deer carcass, the loin area is normally cleaner. However, the relatively high standard deviations for the mean values for bacterial counts in the present study suggest that carcass contamination is highly variable even at a carcass site that is not usually heavily contaminated. In addition, variation in individual samplers' technique could also cause high variability in the results.

Various results are reported for the effect of spray chilling on the microbiological quality of meat. An increase in bacterial counts after spray chilling has been found for beef (Hippe *et al.*, 1991), but there has also been data published showing no difference in microbial status between spray chilled and commercially chilled beef (Greer & Jones, 1997) or even better microbiological quality after spray chilling of pork (Greer & Dilts, 1988). It has been suggested that these contrary results may be due to variation in the time allowed for carcasses to dry between when the spray chilling is turned off and the chilling cycle is completed (Strydom & Buys, 1995). If the surface of the spray chilled carcasses is allowed enough time to dry, bacterial loads may be reduced due to dehydration. On the contrary, if the carcass surface is still wet at the end of the chilling cycle it may promote bacterial growth, although such growth is minimised by the rapid reduction in carcass surface temperature characteristic for normal commercial chilling procedures.

Spray chilling applied in this study did not affect the microbiological quality on deer carcasses or vacuum-packed loins. Similar findings were reported previously for beef and pork under various spray chilling conditions (Hamby *et al.,* 1987; Strydom & Buys, 1995; Greer & Jones, 1997; Furtado- Drehmer 2005; Kinsella *et al.*, 2006). In agreement with our present deer study, the earlier reports demonstrated that spray chilling reduced the carcass shrinkage without increasing the microbiological surface populations compared to conventional air chilling. The microbial counts on deer loins after 9 weeks of vacuum-packed chilled storage were still relatively low and indicative of the low initial bacterial levels and/or slow growth rates. Extended shelf life can be expected even for the spray chilled carcasses which showed higher counts at this stage. This difference cannot be easily explained and could be due to the high variability in carcass contamination mentioned above.

5 Conclusions

- Spray chilling reduced carcass weight loss significantly. The over-night weight loss of air chilled and spray chilled carcasses were 1 kg and less than 0.1 kg, respectively. Even after the "Friday effect" (3 days in the chiller) the positive effect of spray chilling in reducing carcass weight loss was demonstrated; air chilled carcasses lost 1.5 kg and spray chilled carcasses 0.1 kg.

- No negative effects on meat quality (tenderness, purge and cooking loss) of spray chilling were found.
- The retained moisture levels in the loin after spray chilling did not result in higher amount of purge or cooking loss after 3 or 9 weeks of storage. This suggests that the positive effect of reduced carcass weight loss will be valid also for a cut typically destined for the high value chilled market.
- Bacterial levels were low in general. An expected increase resulted over the storage period, but final values on log scale of 3 and 4 CFU after 9 weeks of vacuum-packed chilled storage are very acceptable levels.

6 Technology transfer

The project has to date produced the following outputs:

Presentations

- Wiklund. E. 2009. Venison quality research update. Venison Processor's Technical Committee, 18 March, Wellington New Zealand.
- Wiklund, E. 2009. Venison and water-holding. DEEReseach Board meeting, 15 July, Christchurch.

Publications

- Wiklund, E. (2009). How venison holds water – Animal and processing aspects investigated. The Deer Farmer, Country-Wide Publications Ltd, June/July 2009.

Scientific publications

- The results from the project will be prepared for publication in the international journal Meat Science.

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8 References

Allen, D. M., Hunt, M. C., Luchiari Filho, A., Danler, R. J & Goll, S. J. 1987. Effects of spray chilling and carcass spacing on beef carcass cooler shrink and grade factors. Journal of Animal Science 64, 165-170.

AOAC, Method 950.41B.2005. Official Methods of Analysis, 15th ed. – *Association of Official Analytical Chemists*, Arlington, VA, USA.

Barnier, V. M. H., Wiklund, E., van Dijk, A., Smulders, F. J. M. & Malmfors, G. 1999. Proteolytic enzyme and inhibitor levels in reindeer (*Rangifer tarandus tarandus* L) vs. bovine longissimus muscle, as they relate to ageing rate and response. Rangifer, 19, 13-18.

Brown, T., Chourouzidis, K.N. and Gigiel. 1993. Spray chilling of lamb carcasses. *Meat Science,* 34, 311-325.

Farouk, M. M., Beggan, M., Hurst, S., Stuart, A., Dobbie, P. & Bekhit, A. E. D. 2007. Meat quality attributes of chilled venison and beef. Journal of Food Quality 30, 1023-1039.

Farouk, M., Wiklund, E., Stuart, A. & Dobbie, P. 2009. Ageing prior to freezing improves waterholding capacity in beef and venison. Proceedings: 55th International Congress of Meat Science and Technology, 16-21 August, Copenhagen, Denmark.

Furtado-Drehmer, A-M. 2005. Carcass weight loss and study of pork meat shelf-life. MSc Thesis, Santa Maria, RS, Brazil.

GenStat. 2008. GenStat for Windows 11th Edition, version 11.1.0.1575. VSN International, Oxford.

Gigiel, A., Butler, F. & Hudson, B. 1989. Alternative methods of pig chilling. Meat Science 26, 67-83.

Greer, G. C. & Dilts, B. D. 1988.Bacteriology and retail case life of spray chilled pork. Canadian Institute of Food Science and Technology Journal 21, 295-299.

Greer, G.G. & Jones, S.D.M. 1997. Quality and bacteriological consequences of beef carcass spray-chilling: Effects of spray duration and boxed beef storage temperature. *Meat Science* 45: 61-73.

Hamby, P.L., Savell, J.W., Acuff, G.R., Vanderzant, C. & Cross, H.R. 1987. Spray-chilling and carcass decontamination systems using lactic and acetic acid. Meat Science 21, 1–14.

Hippe, C. L., Field, R. A., Ray, B. & Russell, W. C. 1991. Effect of spray chilling on quality of beef from lean and fatter carcasses. Journal of Animal Science 69, 178-183.

Hoffman, L. C. & Wiklund, E. 2006. Game and venison – meat for the modern consumer. Meat Science, 74, 197-208.

Kinsella, K.J., Sheridan, J.J., Rowe, T.A., Butler, F., Delgado, A., Quispe-Ramirez, A., Blair, I.S. & McDowell, D.A. 2006. Impact of a novel spray-chilling system on surface microflora, water activity and weight loss during beef carcass chilling. Food Microbiology 23, 483–490.

Merts, I., Hill, H. K. & Chadderton, T. 1998. Chilling regimes to minimize moisture loss from venison. MIRINZ Confidential Report CR 687. Prepared for the New Zealand Game Industry Board.

NZFSA. 2008. Sampling. In: DRAFT Schedule 1 Technical Procedures for the National Microbiological Database. Pp. 50-56. http://www.nzfsa.govt.nz/animalproducts/publications/manualsguides/nmd/nmd-tech-proced/checksheets/nmdchecklistguidelines.pdf

NZFSA. 2009 NMD demographic forms. www.nzfsa.govt.nz/animalproducts/publications/forms/nmd-demographics/

Savell, J. W., Mueller, S. L. & Baird, B. E. 2005. The chilling of carcasses. Meat Science 70, 449-459.

Strydom, P.E. & Buys, E.M. 1995. The effects of spray-chilling on carcass mass loss and surface associated bacteriology. Meat Science 39, 265-276.

Upsdell, M. P. 1994. Bayesian smoothers as an extension of non-linear regression. The New Zealand Statistician, vol 29, no.2, pp66-81.

Wiklund, E., Barnier, V. M. H., Smulders, F. J. M., Lundström, K. & Malmfors, G. 1997. Proteolysis and tenderisation in reindeer (*Rangifer tarandus tarandus L*) bull longissimus thoracis muscle of various ultimate pH. Meat Science, 46, 33-43.

Wiklund, E., Dobbie, P., Stuart, A. & Littlejohn, R. P. 2009. Seasonal variation in venison drip loss, calpain activity, colour and tenderness. AgResearch Client report prepared for DEEResearch, CR 1288, Hamilton, New Zealand.

Wiklund, E., Sampels, S., Manley, T. R., Pickova, J & Littlejohn, R. P. 2006. Effects of feeding regimen and chilled storage on water holding capacity, colour stability, pigment content and oxidation in red deer (*Cervus elaphus*) meat. Journal of the Science of Food and Agriculture, 86, 98-106.

Wiklund, E., Stevenson-Barry, J. M., Duncan, S. J. & Littlejohn, R. P. 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.