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The effect of aging time before freezing on water-holding capacity, tenderness, colour and eating quality of venison and beef

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The effect of ageing time before freezing on water-holding capacity, tenderness, colour and eating quality of venison and beef

Prepared for DEEResearch

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1 Background

Colour, tenderness and juiciness are the most important attributes affecting both the consumer decision in the purchase of meat on retail display and the acceptability of the meat once cooked and consumed (Risvik, 1994). Chilled-never-frozen (CNF) meat currently attracts a premium price over accelerated conditioned and aged (AC&A) meat which is fully frozen within 48 h of slaughter (Hagyard, 1979). The price differential between CNF and frozen AC&A meat is due to CNF meat having more reliable tenderness, less drip loss and longer retail colour display life compared to AC&A meat. There is no clear evidence that the eating quality of CNF meat is superior to frozen and thawed meat when the meat has been aged prior to freezing.

Meat is composed of about 75% water; the bulk of the water is held either within the myofibrils, between the myofibrils, between the myofibrils and the cell membrane (sarcolemma), between muscle cells or between muscle bundles (Huff-Lonergan & Lonergan, 2005). The retention of this water in the meat structure throughout the supply chain is a measure of the eating and processing quality of meat. The ability of chilled meat to hold water (usually called water-holding capacity) is one reason it currently attracts a premium price over frozen meat. The superiority of CNF meat over AC&A meat in terms of water-holding ability could be due to the latter having a more intact muscle structure and thus more defined channels for moisture loss relative to the former (Huff-Lonergan & Lonergan, 2005).

Colour is an important attribute affecting the decision by the consumer at the point of purchase whether to buy meat on retail display or not (Bekhit & Faustman, 2005). Meat colour is affected by a number of factors including freezing and frozen storage. The superior colour of chilled meat over frozen meat could be due to the latter losing more colour pigments in thaw exudates (Huffman, 1980) or as a result of the destruction of the mitochondrial enzyme system during freezing and subsequent storage.

Venison is generally more tender than beef, and for some deer species ageing of the meat is not necessary at all (Barnier *et al*., 1999; Wiklund *et al*., 1997). This phenomenon has been explained by high activity of tenderising enzymes in venison (Barnier *et al*., 1999; Farouk *et al*., 2007a) compared with beef. The present experiment is part of a wider study designed to test the hypothesis that ageing of meat prior to freezing will narrow or eliminate the difference in the quality, including eating quality, moisture loss and colour, between CNF meat and frozen AC&A meat. Beef and venison were included as examples of slow (beef) and fast (venison) tenderising meats in testing the hypothesis.

To our knowledge this is the first study reporting data on the effects of long term chilling, freezing and ageing for beef and venison quality attributes such as water-holing capacity, colour and eating quality.

2 Material and methods

Animals
Eight young bulls (age 2-3 years) and eight red deer (*Cervus elaphus*) stags (< 2 years) were included in the study. The bulls were slaughtered according to standard procedure at Silver Fern Farms beef export processing plant in Te Aroha. All carcasses at this plant are hot-boned within 1 h *post mortem* (Farouk & Swan, 1998). The deer were slaughtered according to standard procedure at Duncan & Co deer slaughter premises in Rotorua. The deer carcasses were kept at 10°C for approximately 6 hrs *post mortem* and then chilled down to 1°C according to normal practices at the plant. Carcasses were boned out 1 day *post mortem*.

The beef samples (both *M. longissimus dorsi*; (LDs) striploins) were collected at hot-boning and transported chilled to AgResearch MIRINZ, stored at 10°C until in *rigor* and then transferred to 2°C. Deer samples (both LDs) were collected at boning 1 day *post mortem* and transported chilled to AgResearch MIRINZ.

At 2 days *post mortem*, all LDs (beef and deer) were cut into four pieces and the resulting 8 sub-samples from each animal were weighed and then randomly assigned to one of eight treatments:

1 = chilled storage at -1.5°C for nine weeks
2 = frozen storage at -18°C for nine weeks
3 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for eight weeks
4 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for six weeks
5 = chilled storage at -1.5°C for fourteen weeks
6 = frozen storage at -18°C for fourteen weeks
7 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for thirteen weeks
8 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for eleven weeks

After the storage periods (9 and 14 weeks) were completed, the frozen meat samples were removed from the freezer and left to thaw at 4ºC. Meat quality measurements and consumer evaluations were then carried out on two consecutive days. In this report, data from the 9 weeks storage period is presented for both venison and beef to illustrate the differences in these two types of meat. The 14 weeks storage data included in the report is for venison only.

pH measurements
Meat pH was measured in all samples stored for 9 and 14 weeks (for different storage treatments, please see Material and Methods; Animals) 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).

Drip loss, purge loss, cooking loss, total loss and tenderness
Drip loss, purge loss, cooking loss and tenderness were measured in all samples stored for 9 and 14 weeks (for different storage treatments, please see Material and Methods; Animals).

The Honikel method (Honikel, 1998) was used to gravimetrically measure drip loss as an indication of water-holding capacity of meat. Samples of approximately 50-100g were cut, weighed, suspended in a netting and hung inside a plastic jars which were stored at 4°C for 48 h, removed from the netting, dabbed dry with a paper towel, and then re-weighed. Drip loss was calculated as the difference in the weight of the samples before and after storage expressed as a percentage of the original weight of the samples before storage.

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.

Loins were cooked in bags submerged in boiling water until the internal temperature of the sample reached 75°C. A thermocouple was inserted in each sample to measure the temperature at the centre of the sample during cooking. After cooking the samples were immediately cooled on ice. 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/thaw loss + cooking loss.

Ten 2.5 cm long and 1 cm x 1 cm cross-section slices (bites) were prepared from the cooked sample with the muscle fibres running longitudinally along the slice. 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).

Colour measurements

Meat colour was measured in all samples stored for 9 and 14 weeks (for different storage treatments, please see Material and Methods; Animals). One steak (2 cm thick) was cut from each sample upon opening of the vacuum bags, put on a tray overwrapped with an oxygen permeable plastic film and allowed to bloom for 3 h at 1-2ºC before colour was measured using a Minolta Colour Meter (CR-300, Minolta Colourimeter (Minolta Camera Co., Ltd, Japan).

CIE L* (lightness), a* (redness) and b* (yellowness) values were measured (D65, 10º) through the package film at three random locations and in triplicate on each steak, averaged, and Hue angle (Hue°) (arctan b/a) and saturation $(a^2+b^2)/0.5$ were calculated (Hunter & Harold, 1987). Colour measurements were taken on each sample on days 0, 1, 3 and 7 after opening the vacuum bags and between measurements the samples were stored in darkness at 2ºC as previously reported for venison (Wiklund *et al*., 2006).

Consumer evaluation

Three consumer evaluations, carried out on three separate days were included in the study; one using the beef LD and one using the deer LD after 9 weeks storage and one using the venison LD after 14 weeks storage (for different storage treatments, please see Material and Methods; Animals). At each of the three evaluations 48 consumers assessed the meat samples. Every consumer assessed all four treatments of the meat (Treatments 1-4 for meat stored 9 weeks and treatments 5-8 for meat stored for 14 weeks). The group of consumers could be regarded as an in-house consumer panel at AgResearch MIRINZ, Ruakura Research Centre, recruited through the campus by email. The meat samples were roasted in a conventional oven at 175°C to an end

temperature of 72°C (measured with thermocouples). The preparation of the meat samples took place on the day of the individual evaluation immediately prior to the sensory sessions which were carried out in a sensory laboratory with separate booths and under normal white light.

At each of the sensory sessions the consumers were presented with four warm meat samples placed in plastic cups with lids, and coded with a random three-digit number. Together with the meat samples, a questionnaire was presented. The consumers were asked to evaluate the samples for three different attributes; tenderness, juiciness and overall liking using an unstructured continuous line scale from 0 (low intensity) to 15 (high intensity). The consumers were also asked to record any other comments they had about the samples.

Statistical analysis
In the comparison of beef and venison LD one animal (beef) was excluded from the analysis due to high pH. Data was analysed using the REML directive of GenStat (Payne *et al*., 2008) with both species included in the same analysis. Venison data was analysed using the ANOVA directive of GenStat (Payne *et al*., 2008).

3 Results

3.1 Moisture loss, pH and tenderness

Beef had higher (p=0.004) pH at all the ageing periods compared to venison (Table 1). Ageing prior to freezing had no effect on the pH of beef and venison LD (Table 1). Thus, any difference observed in the water-holding capacity of the meat with ageing time could not be pH related. Purge/thaw loss was lower (p=0.03) while drip loss (p<0.001) and cook loss were higher (p=0.04) in beef relative to venison. The higher pH in beef relative to venison did not, overall, translate into a higher water-holding capacity. There were interactions between meat type and ageing time for the moisture losses determined in this study (p=0.01). Purge loss decreased in beef with ageing time while it decreased in the first three periods and then significantly increased in the fourth period in CNF venison (Table 1, Fig.1). Drip loss decreased with ageing time in meat from both species but the decrease was more pronounced in beef relative to venison (Table 1, Fig. 1). Ageing time did not affect the cook loss or total moisture loss in meat from any of the two species (Table 1). For venison samples stored for 14 weeks, purge and drip loss showed a similar pattern to that of venison stored for 9 weeks, although the levels of both purge and drip loss were higher (Table 1, Fig. 2). Meat pH, cooking loss and total moisture loss in the venison samples stored for 14 weeks all showed comparable values to those measured after 9 weeks of storage (Table 1).

There was a highly significant (p<0.001) difference in shear force values at all ageing times between beef and venison samples stored for 9 weeks (Table 1). Venison samples after 48 h ageing already had shear force values of 4.2 kgF compared to 18.5 for beef. This tenderisation profile was also true for the venison samples at 14 weeks of storage (Table 1). The much tougher beef samples did improve in tenderness with ageing, however the shear force values measured in CNF meat after 9 weeks of storage (mean value of 9.1 kgF) were much higher than in venison (Table 1).

TABLE 1. Meat quality characteristics (mean values and standard error of difference, SED) for venison and beef samples (*M. longissimus dorsi*) stored 9 and 14 weeks using the following treatments; 1) frozen 9w or 14w, 2) chilled at -1.5ºC for 1w then frozen for 8w or 13w, 3) chilled at -1.5 ºC for 3w then frozen for 6w and 11w and 4) chilled at -1.5 ºC for 9w or 14w.

Trait	Frozen 9w	Chilled 1w/frozen	Chilled 3w/frozen	Chilled 9w	SED
pH in LD					
Venison 9w	5.49	5.52	5.48	5.51	0.05
Beef 9w	5.74	5.77	5.79	5.76	0.05
Venison 14w	5.51	5.50	5.51	5.49	0.02
Drip, %					
Venison 9w	3.6	3.1	1.7	0.8	0.71
Beef 9w	6.8	6.6	4.7	1.4	0.71
Venison 14w	5.7	4.8	3.1	1.3	0.50
Purge, %					
Venison 9w	3.9	3.2	2.9	4.0	0.63
Beef 9w	3.5	3.1	3.1	1.2	0.63
Venison 14w	5.2	4.1	3.9	4.6	0.52
Cooking loss, %					
Venison 9w	27.1	27.9	28.3	26.7	1.4
Beef 9w	30.1	29.8	28.0	31.2	1.4
Venison 14w	25.5	25.3	25.8	26.3	1.4
Total loss, %					
Venison 9w	31.0	31.1	31.2	30.7	1.3
Beef 9w	32.2	31.4	29.9	31.4	1.7
Venison 14w	30.6	30.9	29.7	30.9	1.3
Shear force, kgF					
Venison 9w	4.2	3.6	3.1	3.2	0.34
Beef 9w	18.5	15.2	11.7	9.1	1.36
Venison 14w	6.0	3.7	3.7	2.9	0.61

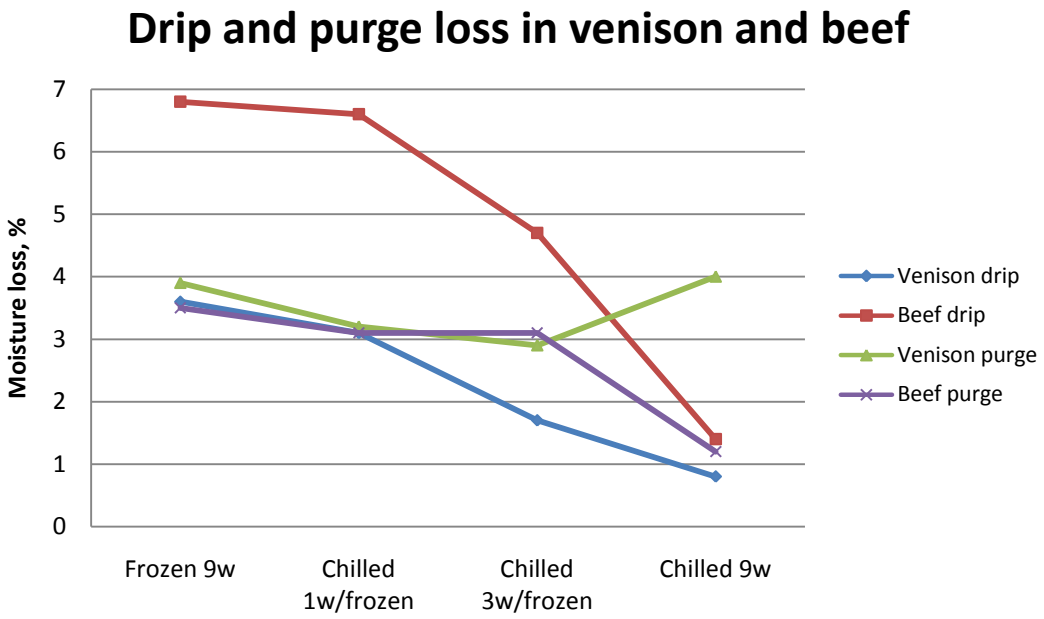

FIGURE 1. Drip and purge loss (%) in venison and beef samples (*M. longissimus dorsi*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w.

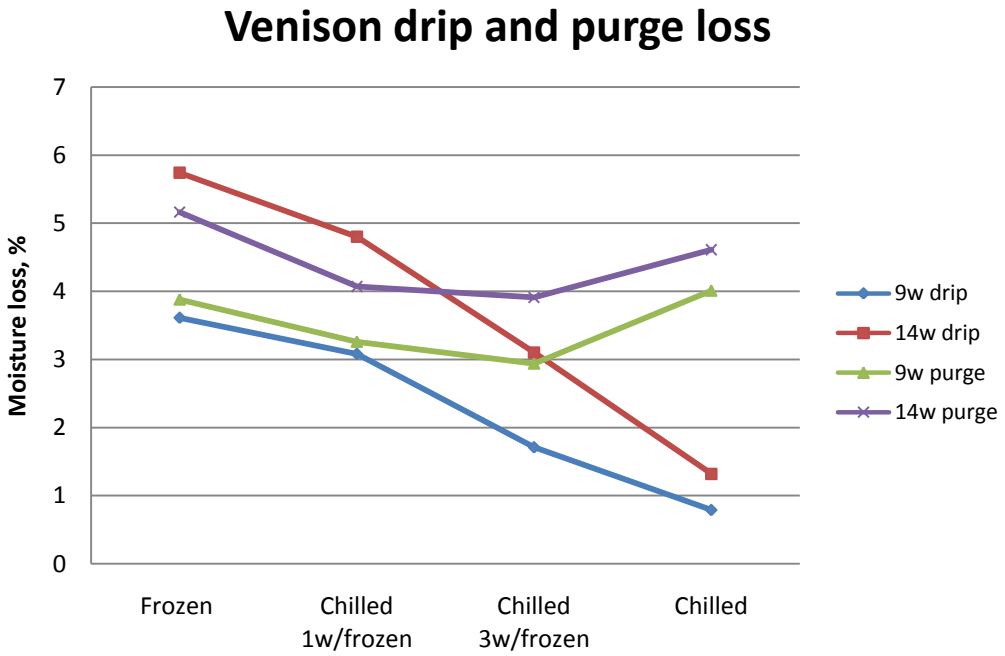

FIGURE 2. Drip and purge loss (%) in venison samples (*M. longissimus dorsi*) stored 9 and 14 weeks using the following treatments; 1) frozen 9w or 14w, 2) chilled at -1.5ºC for 1w then frozen for 8w or 13w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 11w and 4) chilled at -1.5ºC for 9w or 14w.

3.2 Colour measurements

Venison was brighter red (higher Minolta a* values) than beef (p=0.05) on the first day of simulated retail display and then became less red at longer display times, especially after 3 and 7 days of display (Fig. 3). Venison was browner (higher hue angle) relative to beef (p=0.02) throughout display (Fig. 4).

Beef and venison samples linearly (p<0.001) became brighter red with prolonged ageing time prior to freezing (Fig. 3). This increase in Minolta a* value was more evident and more linear in beef than in venison, as by the third day of display there was virtually no effect of ageing on the redness of venison while significant differences were observed in beef (Fig. 3). The colour display life of venison and beef loin samples decreased (meat became browner; the hue angle increased) with an extended period of ageing prior to freezing (p<0.001) (Fig. 4). Looking at the venison results only, both storage times (9 and 14 weeks) showed a clear decrease in colour display life after 3 and 7 days of display , *i.e.* lower a* values (Fig. 5) and increased hue angles (Fig. 6). The reduction of colour display life was more obvious in venison relative to beef. No difference was observed in hue angle in beef samples with ageing longer than a week prior to freezing while a linear difference was observed in venison (Fig. 4). Based on the observation in previous studies (Farouk *et al*., 2007b; Wiklund *et al*., 2001) that indicate a* values of 12 and Minolta hue angle of 19-25° as the cut off points for the acceptability of venison and beef respectively, the display life for meat samples stored in the dark was only 3 days for venison while beef remained acceptable for a week.

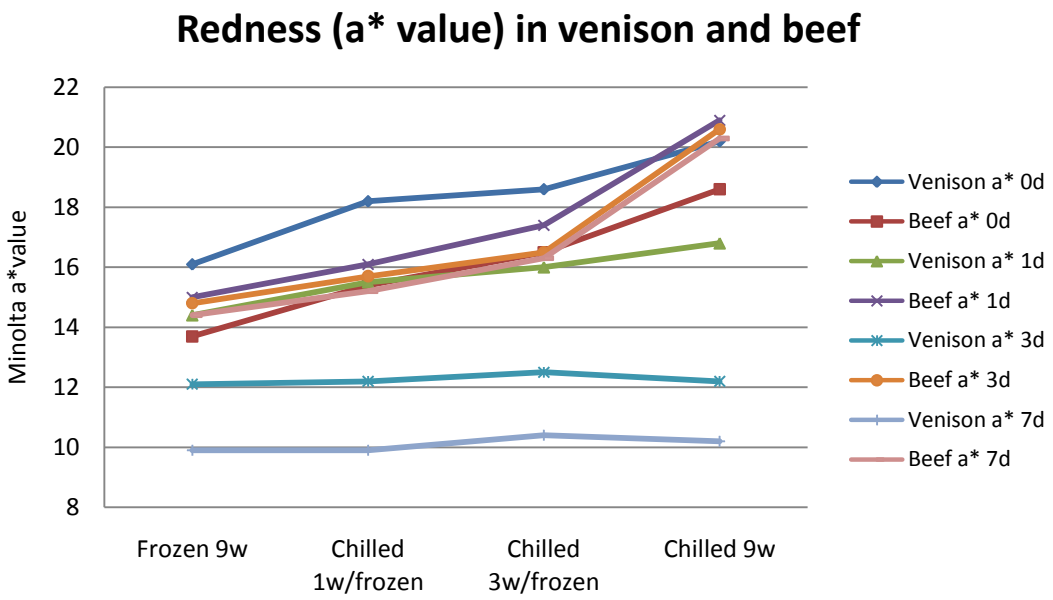

FIGURE 3. Redness (Minolta a* values) in venison and beef samples (*M. longissimus dorsi*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5 ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w. Colour measurements were taken on days 0, 1, 3 and 7 of refrigerated storage at 2ºC.

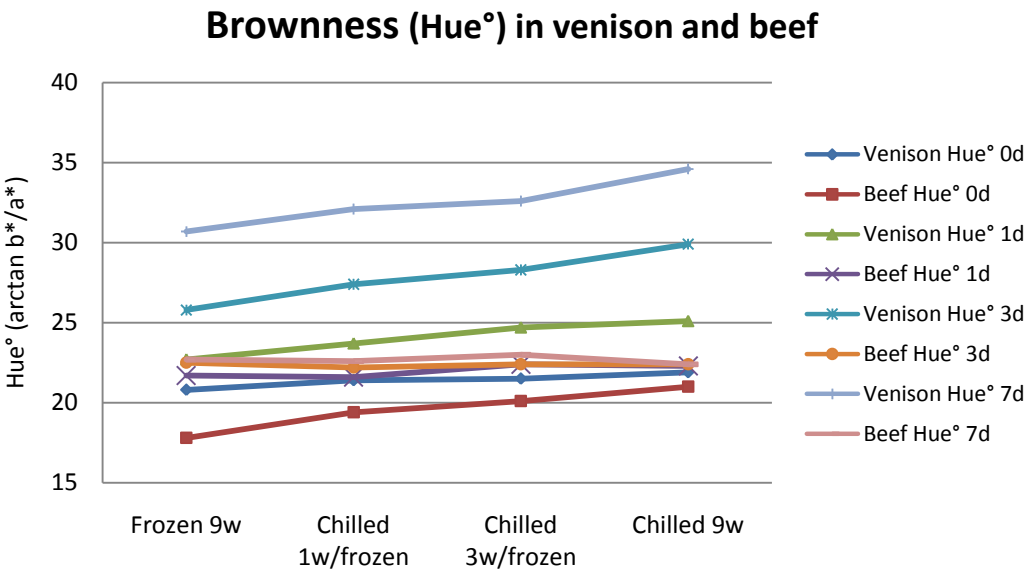

FIGURE 4. Brownness (hue angle) in venison and beef samples (*M. longissimus dorsi*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w. Colour measurements were taken on days 0, 1, 3 and 7 of refrigerated storage at 2ºC.

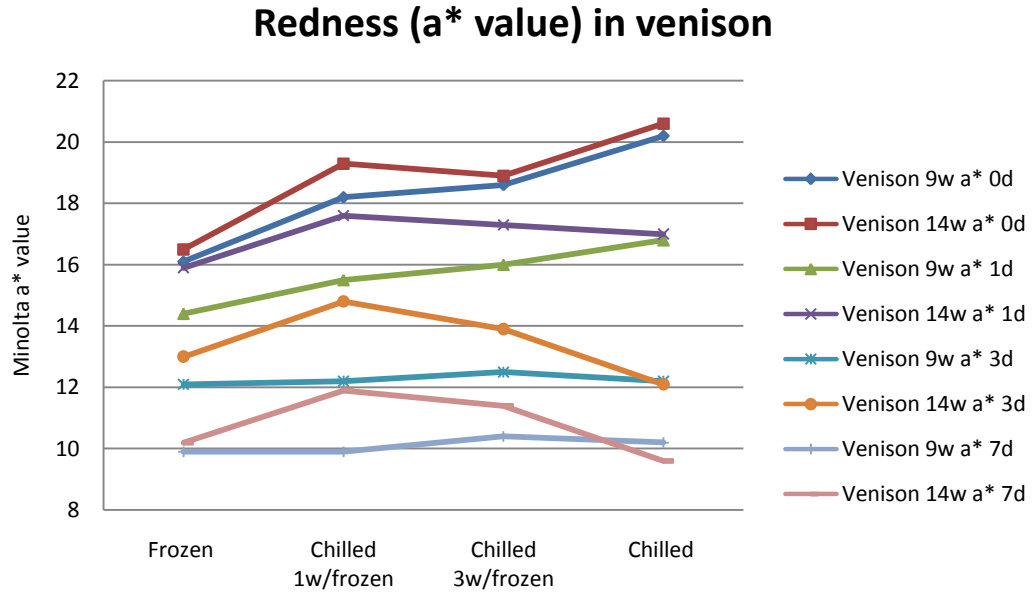

FIGURE 5. Redness (Minolta a* values) in venison samples (*M. longissimus dorsi*) stored 9 and 14 weeks using the following treatments; 1) frozen 9w or 14w, 2) chilled at -1.5 ºC for 1w then frozen for 8w or 13w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 11w and 4) chilled at -1.5ºC for 9w or 14w. Colour measurements were taken on days 0, 1, 3 and 7 of refrigerated storage at 2ºC.

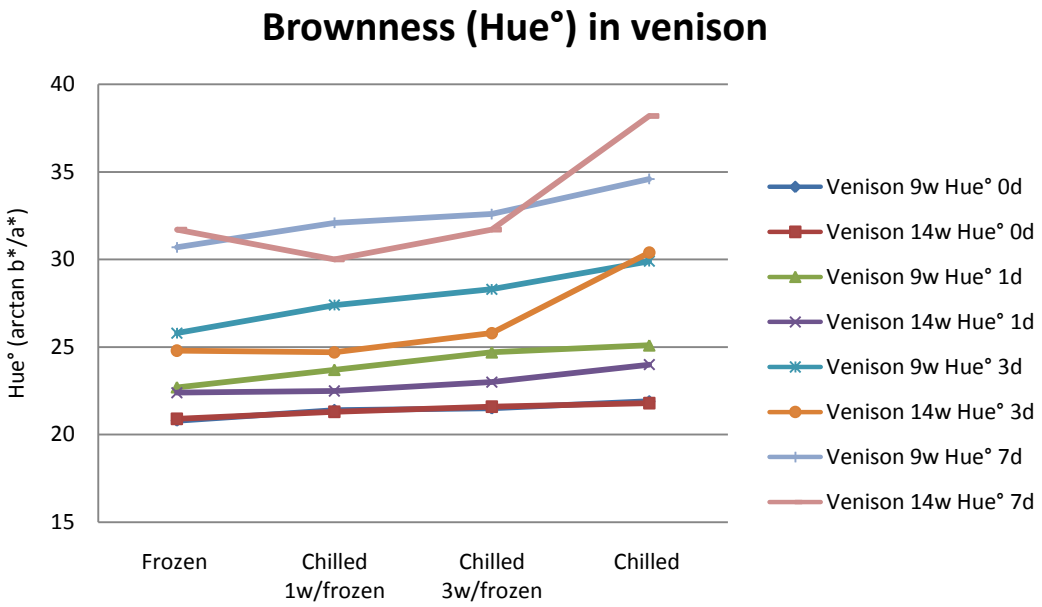

FIGURE 6. Brownness (hue angle) in venison samples (*M. longissimus dorsi*) stored 9 and 14 weeks using the following treatments; 1) frozen 9w or 14w, 2) chilled at -1.5ºC for 1w then frozen for 8w or 13w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 11w and 4) chilled at -1.5 ºC for 9w or 14w. Colour measurements were taken on days 0, 1, 3 and 7 of refrigerated storage at 2ºC.

3.3 Consumer evaluation

Figures 7, 8 and 9 show the consumer scores for the three sensory attributes of venison and beef samples stored for 9 weeks. For beef, ageing prior to freezing significantly affected consumer scores for tenderness (p=0.004), juiciness (p=0.014) and overall liking (p=0.005). For tenderness, the significant effect of treatment was mainly related to the CNF meat receiving the highest (average SED=0.65) consumer scores (6.1) relative to the other treatments that did not differ (Fig. 7). Scores for juiciness reflected that of tenderness with CNF meat receiving the highest (average SED=0.59) consumer scores (7.8) while all the other samples had lower and similar consumer scores (Fig. 8). CNF and meat aged for 3 weeks before freezing did not differ significantly (average SED=0.57) in consumer scores (7.8 and 7.1, respectively) for overall acceptability. Meat samples frozen at 48 h *post mortem* and the ones aged for one week before freezing had the lowest overall liking scores (6.0 and 5.9, respectively) (Fig. 9).

Venison samples frozen at 48 h *post mortem* had the lowest (average SED=0.65) consumer scores (7.8) for tenderness, though not significantly different (p=0.95) relative to the other samples (Fig. 7). For juiciness (average SED=0.59) and overall liking (average SED=0.57) the consumer scores were similar for all treatments (Figs. 8 and 9).

As previously stated in the Material and Methods section, the statistical analysis for beef and venison samples was carried out with both species included in the same analysis, which made it possible to make a comparison of the consumer scores for the different loin samples. For all the sensory attributes assessed, there were highly significant ($p \leq 0.001$ for all three attributes) differences between beef and venison samples. Venison samples were given the highest consumer scores (Figs. 7, 8 and 9). This difference was most obvious in the consumer scores for tenderness where the average

scores ranged between 7.8 and 9.9 for venison samples and between 4.2 and 6.6 for beef LD samples (Fig. 7).

The venison samples stored for 14 weeks showed a similar trend in consumer scores compared to the 9 weeks venison samples mentioned above. The samples frozen at 48 h *post mortem* had the lowest scores (8.8) for tenderness (average SED=0.52), although this difference was not significant (p=0.95) compared to the other ageing times (Fig. 10). For juiciness (average SED=0.55) and overall liking (average SED=0.48) the consumer scores were similar for samples from all ageing times (Fig. 10).

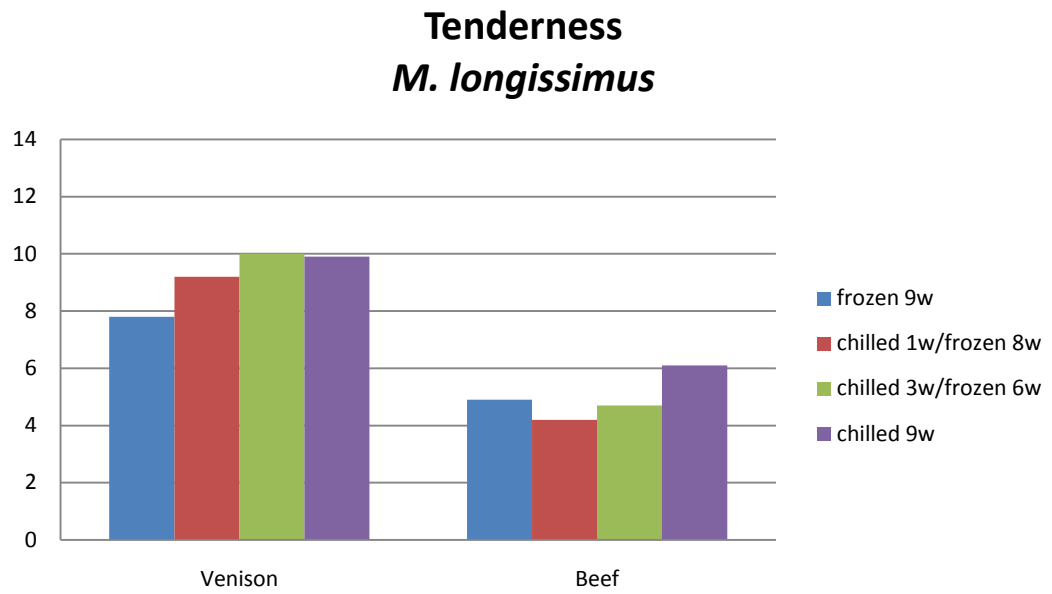

FIGURE 7. Consumer scores for tenderness in oven roasted beef and venison LD (*M. longissimus*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w.

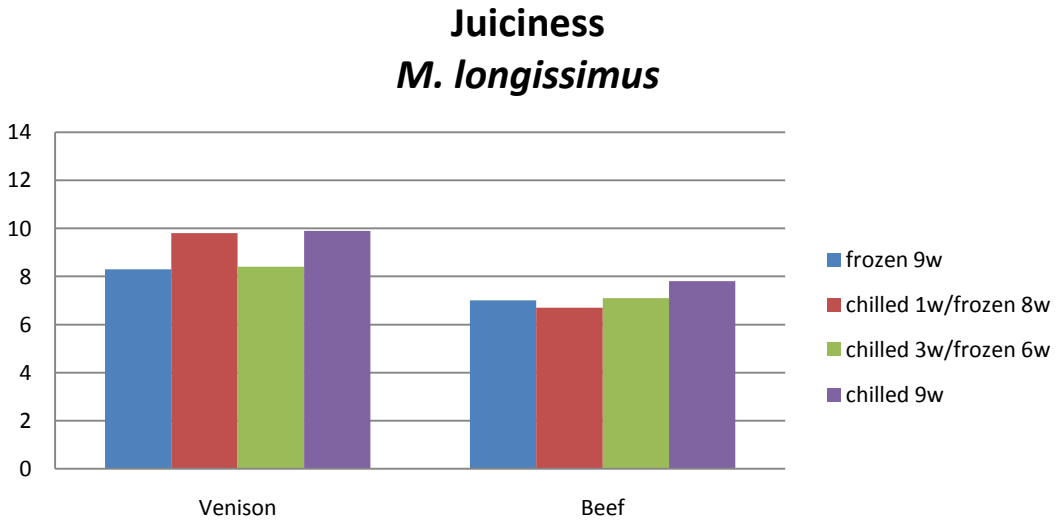

FIGURE 8. Consumer scores for juiciness in oven roasted beef and venison LD (*M. longissimus*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w.

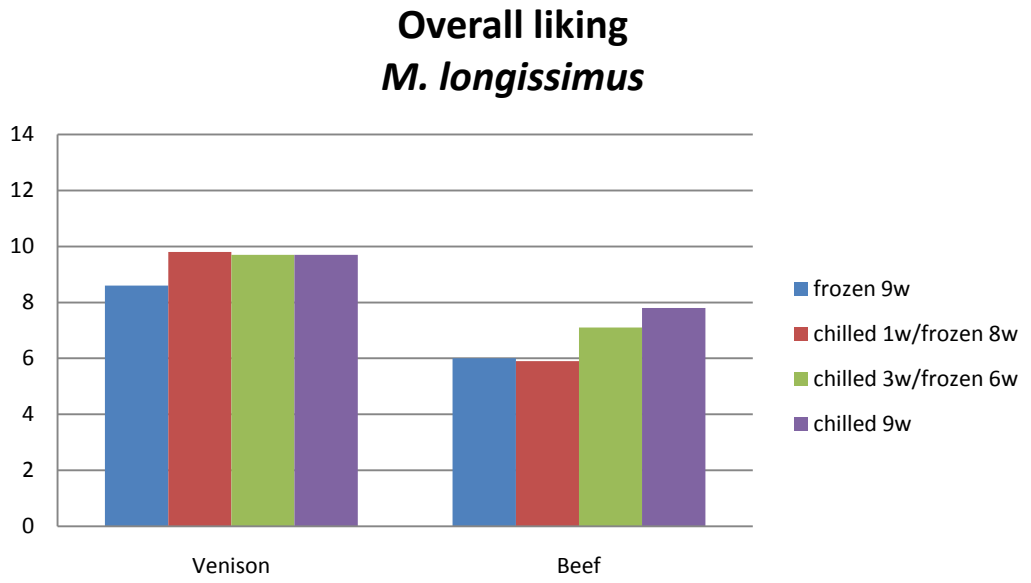

FIGURE 9. Consumer scores for overall liking in oven roasted beef and venison LD (*M. longissimus*) stored 9 weeks using the following treatments; 1) frozen 9w, 2) chilled at -1.5ºC for 1w then frozen for 8w, 3) chilled at -1.5ºC for 3w then frozen for 6w and 4) chilled at -1.5ºC for 9w.

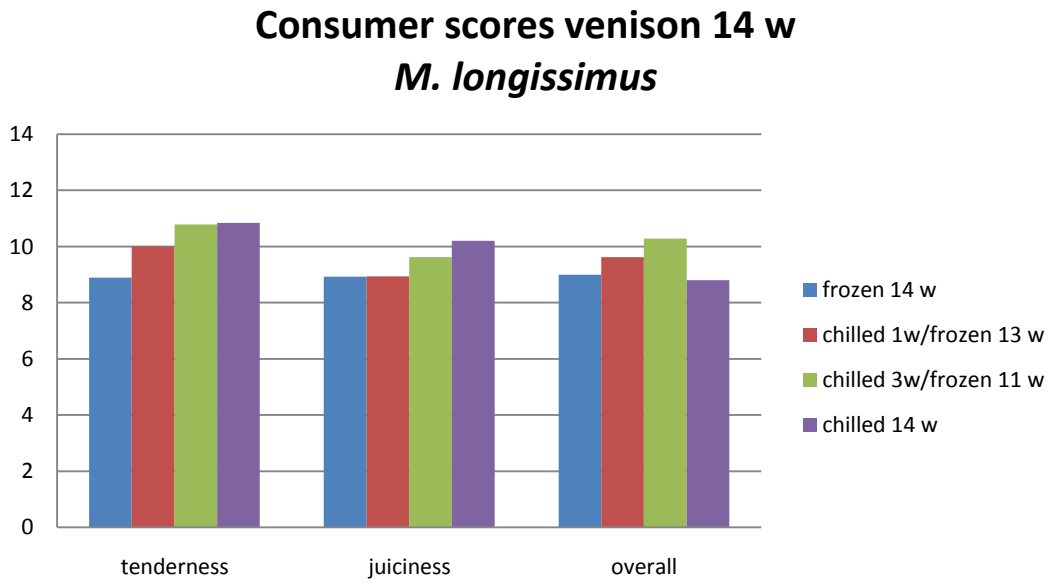

FIGURE 10. Consumer scores for tenderness, juiciness and overall liking in oven roasted venison LD (*M. longissimus*) stored 14 weeks using the following treatments; 1) frozen 14w, 2) chilled at -1.5ºC for 1w then frozen for 13w, 3) chilled at -1.5ºC for 3w then frozen for 11w and 4) chilled at -1.5ºC for 14w.

4 Discussion

The phenomenon of increased meat pH values during long term chilled storage have previously been reported for venison (Wiklund *et al*., 2001), but was not found in this study. The measured pH values for venison (average 5.50) in the present study were lower than for beef (average 5.75). Bull beef, which was used in the present study, generally has a higher pH than beef from steers or cows as has recently been demonstrated in a New Zealand survey where bulls had an overall high mean pH (5.99) compared with steers (5.61) and cows (5.53) (Wiklund *et al*., 2009a). Shear force values similar to those found in the present venison loin samples have been reported previously (Wiklund *et al*., 2001, 2009b; Farouk *et al*., 2007). In an earlier comparison of aged venison and bull beef, similar shear force values to those of the present study were reported for both venison and beef (Barnier *et al*., 1999). According to a tenderness classification of retail meat (Bickerstaffe *et al*., 2001) the average shear force values for venison measured in the present study after 48 h, 1 week, 3 weeks, 9 weeks and 14 weeks would all fall into the "tender" and "very tender" categories. Beef values from the present study range from "very tough" (at 48 h and 1 week of ageing) to "tough" at 3 weeks ageing to "acceptable" after 9 weeks of ageing at -1.5ºC.

The improvement in the water-holding capacity demonstrated in the present study could be attributed to the structural rather than biochemical changes taking place in meat post-mortem. The lack of an overall effect of pH on the water-holding capacity difference in beef and venison in this study is one proof that factors other than pH are playing a more important role in the water-holding capacity of post rigor meat. A review (Huff-Lonergan & Lonergan, 2005) indicates that channels are formed in meat/muscle soon after post-mortem through which water from the meat structure could be lost in the form of purge or drip. It has been reported that drip and purge decreased with increased chilled storage time (Anon & Cavalo, 1980), and a more recent study (Zhang *et a*l., 2006) demonstrated reduced moisture losses with structural protein breakdown in pork. Data from the current study supports the structural basis for the improved water-holding capacity of meat in the following way: (1) pH in meat from venison and beef did not change with ageing time but moisture loss did; (2) structural changes took place in meat with ageing time before freezing as evidenced by the decrease in shear force (increased tenderness) with ageing time; (3) moisture loss in the form of purge and drip decreased with increased meat structural breakdown; (4) venison being a fast tenderising meat with potentially faster meat structural breakdown had lower levels of drip and similar levels of purge compared to beef – a comparatively slower tenderising meat; and (5) the water-holding advantages of venison over beef tended to reduce with ageing time as structural breakdown in the latter meat increased. 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.,* 2009b).

We suggest a hypothesis for the improved water-holding capacity of meat caused by structural changes during tenderisation: (a) The decrease in pH and the contraction of muscle due to *rigor mortis* releases water and creates channels for potential moisture loss; (b) the channels are well defined early post-mortem and given the right conditions water is lost through these channels; (c) as proteolysis occurs with time (faster in chilled versus frozen meat and in venison versus beef) and muscle structural proteins are broken, the channels for moisture loss are disrupted and become less defined thereby

creating a sponge effect that physically entraps the water and reduces the water loss through gravity (drip) and mild pressure as in vacuum (purge); (d) higher pressure as experienced by heating meat to higher temperatures could overcome the sponge effect and all the free water is expelled under this condition and hence there was no observable effect of ageing on cooking loss and total moisture loss in venison and beef in the present study.

Consumers judge the acceptability of meat colour by how bright red the meat looks on display, and a strong correlation exist between redness (Minolta a* values), hue angle and consumer colour acceptability (Farouk *et al*., 2007b). Hue angle (a measure of brownness), is also a good indicator of colour stability of meat on display. Regardless of meat type (venison or beef), in this study meat colour became lighter (higher Minolta L* values) and more yellow (higher Minolta b* values) with longer ageing time prior to freezing (data not shown). The increase in lightness could be due to lipid oxidation considering pH did not differ with ageing time (Farouk & Swan, 1998). The reduction in the metmyoglobin reducing activity of meat with storage and/or the increase in lipid oxidation in the samples could be the reason for the colour deterioration with the longer display storage time (Ledward, 1985; Renerre, 1999).

Venison contains a higher concentration of myglobin (muscle pigment) (Young & West, 2001) and pro-oxidants such as iron and copper (Drew & Seman, 1987; Stevenson-Barry *et al*., 1999) compared to beef. This fact probably explains the present overall poorer colour (duller, lower redness and more brown) of venison relative to beef. In addition, the higher enzymatic activities of venison compared to beef may have resulted in venison losing its metmyoglobin reducing activity, oxidising faster than beef and therefore had a decreased colour display life as a consequence (Farouk *et al*., 2007a).

One of the primary objectives of the red meat industry has been an attempt to deliver consistently high quality meat to consumers. Eating quality has long been recognised as a determinant for repeat purchasing. Many forms of assessment are utilised to ensure a good eating experience by the consumer, including monitoring of pre and post slaughter parameters and physical measures such as shear force, water holding capacity and colour. These measures attempt to predict the eating experience of the consumer however; the ultimate way of testing a product is to place it with a consumer panel for sensory analysis (Russell *et al*., 2005). In a recent Australian study, factors including physical condition (body condition score), sex, age and effects of carcass suspension technique of fallow deer and red deer were evaluated by consumer panels (Mulley *et al*., 2006). The three most important sensory attributes used in that study were tenderness, juiciness and overall liking.

The present results for both venison and beef confirmed that tenderness is an attribute that has a large influence over the consumer scores for overall liking. The very obvious difference in tenderness measured as mechanical shear force between venison and beef was reflected in the consumer scores for tenderness.

5 Conclusions

The outcomes in this study have the following implications for the meat industry:

- The water-holding capacity and colour of frozen beef and venison can be improved by ageing the meat prior to freezing.
- Value can be added to frozen beef and venison relative to chilled by the improvement in the water-holding capacity and colour.
- Venison should be aged for a shorter period and frozen earlier than beef to optimise its water-holding capacity and colour. The ideal ageing times should be ≥ 3 weeks for beef and 1-2 weeks for venison.
- The results from this study also demonstrate a positive effect of ageing before freezing on the eating quality of beef and venison.
- The significant difference observed between beef and venison in the water-holding capacity, tenderness, colour and eating quality attributes measured in this study strongly suggest species-specific tailoring of process inputs is required by the meat processors if the quality of these meats is to be optimised.
- In conclusion, the results from this study support the hypothesis that ageing of meat prior to freezing will narrow or eliminate the difference in quality between CNF meat and frozen AC&A meat.

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. DEEResearch 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.

Conference proceedings

- Wiklund, E., Farouk, M., Stuart, A. & Dobbie, P. 2009. Consumer evaluation of chilled-never-frozen versus chilled-frozen-thawed beef and venison. Proceedings: 55th International Congress of Meat Science and Technology, 16-21 August, Copenhagen, Denmark.
- Farouk, M., Wiklund, E., Stuart, A. & Dobbie, P. 2009. Ageing prior to freezing improves water-holding capacity in beef and venison. Proceedings: 55th International Congress of Meat Science and Technology, 16-21 August, Copenhagen, Denmark.
- Farouk, M., Wiklund, E., Stuart, A. & Dobbie, P. 2009. Ageing Prior to Freezing Improves the Colour of Frozen-Thawed Beef and Venison. Proceedings: 55th International Congress of Meat Science and Technology, 16-21 August, Copenhagen, Denmark.

Scientific publications

- The results from the project will be prepared for 2 publications in the international journal Meat Science.

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