



RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

Eating Qualities of Venison

from red and fallow deer

**Report for the Rural Industries Research
and Development Corporation**

by Frank Shaw,
Food Science Australia

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Foreword

The beef industries in Australia, New Zealand and UK are addressing the question of variability in tenderness and developing 'pathway' systems to ensure that the consumer can purchase branded product of 'guaranteed' tenderness. The Australian deer and venison industries must move towards a Quality Assurance system which addresses both 'on-farm' (live animal) and 'off-farm' (processing) aspects of production. An Australian 'venison quality' brand is a logical component of such a system. This 'venison quality' brand, which would guarantee tenderness, may facilitate consumer acceptance of deer meat, and provide the consistent quality that will encourage repeat sales.

The aim of this project was to evaluate the eating quality of venison from red and fallow deer produced under best practice commercial conditions.

In the present study, the eating quality of loin muscles was evaluated using machine (Warner-Bratzler shear force measurements) and subjective (trained taste panel) measurements. There was no difference in tenderness between the muscles from the red and those from the fallow deer. The topside muscles from the red deer were found to be more tender (as assessed by Warner-Bratzler shear force measurements) than those from the fallow deer.

The knowledge gained from this project will be of value if the venison industry wishes to establish a 'pathway' system for the production of venison of 'guaranteed' tenderness.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 450 research publications, forms part of our Deer R&D program, which aims to foster an Australian deer industry as a profitable and efficient mainstream agricultural enterprise.

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Peter Core

Managing Director

Rural Industries Research and Development Corporation

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Executive Summary

The beef industries in Australia, New Zealand and UK are addressing the question of variability in tenderness and developing 'pathway' systems to ensure that the consumer can purchase branded product of 'guaranteed' tenderness. The Australian deer and venison industries must move towards a Quality Assurance system, which addresses both 'on-farm' (live animal) and 'off-farm' (processing) aspects of production. An Australian 'venison quality' brand is a logical component of such a system. This 'venison quality' brand, which would guarantee tenderness, may facilitate consumer acceptance of deer meat, and provide the consistent quality that will encourage repeat sales.

While there may be a general perception that the tenderness and eating quality of venison is invariably satisfactory there are sound reasons for believing that this may not be the case.

The aim of the project was to evaluate the eating qualities of venison from red and fallow deer. The venison was to be produced using 'best possible commercial practice' and the evaluation was to include both objective (Warner-Bratzler machine) and subjective (taste panel) methods.

A total of 20 red deer and a total of 20 fallow deer were processed at an abattoir on the same day. There was a subgroup of 10 red and 10 fallow from the same property. All 40 animals were transported on the same vehicle and processed under similar conditions. Muscle pH and temperature measurements were recorded during the initial chilling period. Topsides and loins were subsequently removed from the experimental carcasses and vacuum-pack aged for 2 weeks. *Semimembranosus* (SM) and *Longissimus* (LD) muscles were then removed from the topsides and loins, respectively, and used for objective (Warner-Bratzler machine) measurements of tenderness while the *Longissimus* muscles were also evaluated by a trained sensory panel.

Muscle pH and temperature measurements recorded during the early chilling period indicated that cold-shortening (which can cause toughness) was unlikely to have occurred.

Warner-Bratzler tenderness measurements indicated that the *longissimus* muscles were tender (mean shear force < 3 kg) and that there were no differences between the groups. The SM muscles were less tender, as would be expected, than the LD muscles. The SM muscles from the red deer were significantly more tender (3.2 vs 4.4 kg) than those from the fallow.

For the taste panel assessment, the venison steaks were cooked for 4 minutes at 240°C on 'SILEX' grills. The steaks were wrapped in silverfoil and allowed to 'rest' for 5 minutes before slicing to give even distribution of juices and colour. The steak cooking temperature endpoint was in the 60 – 65°C range or a 'medium' doneness level. The samples were presented to 12 panellists, experienced in meat quality assessment, who assessed the samples for differences in tenderness, juiciness, flavour and overall quality attributes.

The trained taste panel scores showed that there was no significant difference in eating quality of loins from red and fallow deer. Loins were judged to be in the 'tender' range and overall quality of the product was in the 'moderate-good' range.

Beef carcasses with an LD muscle pH greater than 6.0 often have dark muscles and are referred to as 'dark-cutters'. In the present trial there were no LD muscles with 'high' pH values (>6.0) but there were several fallow carcass LD muscles, but no red carcass LD muscles, with 'intermediate' pH values (5.7-6.0). For both the SM and LD muscles, mean ultimate pH values were significantly greater for the fallow deer group. Measurements of meat colour with a Minolta Chromameter indicated that muscles with 'intermediate' pH values were darker than those with normal pH values.

For the red and fallow deer from the one property, transported in the same vehicle and processed at the same abattoir on the same day, the mean ultimate pH of both the LD and SM muscles was significantly greater for the fallow than for the red deer. This would suggest that fallow deer are more susceptible to stress than red deer. If further research substantiates this to be the case, then refinement of the handling practices for fallow deer may be necessary. For example, an increase in handling and human contact on the property may be advisable.

It is well documented that there is a relationship between tenderness and muscle ultimate pH. The Meat Standards Australia (MSA) grading system for beef will not accept for grading carcasses with an LD muscle pH > 5.7. If this system was applied to all carcasses in the present trial, there would be 6 carcasses ineligible for grading. Of these 6 carcasses, 2 had low sensory panel tenderness scores.

If the venison industry wishes to set up a grading system for meat quality, similar to the MSA system for grading beef, then the commercial procedures followed throughout this project could form part of the 'pathway' for the production of venison of guaranteed tenderness. It appears that ultimate pH values greater than 5.7 were sometimes associated with tough product. Ultimate pH may be a simple, but important, measurement to assist in the elimination of tough product. Ultimate pH values suggest that fallow deer may be particularly susceptible to stress and further refinement of handling practices for these animals may be necessary.

1. Background

While there may be a general perception that the tenderness and eating quality of venison is invariably satisfactory there are sound reasons for believing that this may not be the case.

The Meat Standards Australia (MSA) grading system for beef has revealed that the consumer has higher standards with regard to tenderness of product than previously believed. A significant amount of conventionally produced and processed beef has failed to meet the minimum '3 star' MSA grade. Similarly, other countries have introduced more demanding standards for beef. In New Zealand there is the Q. Mark system while in the UK there are 'Blueprint' specifications for improved meat quality. The Australian venison industry may wish to introduce a 'pathway' system similar to that developed by MSA.

There are scientific papers that raise questions about the level of tenderness of venison. In a New Zealand trial, venison derived from red deer was vacuum-packed and used for storage trials. Sensory evaluation by a consumer panel showed that none of the venison samples were rated over 6 (like slightly) for acceptability. Other trials in New Zealand indicated problems with tenderness, particularly with animals slaughtered post-rut. Both consumer panellists and experienced taste panellists gave mean scores of about 5 which corresponds to 'moderately' tender on a 1 (extremely tough) to 8 (extremely tender) scale.

Despite these question marks about the tenderness and acceptability of NZ venison it appears that it is perceived by users in the Australian Food Service Sector as superior to the Australian product with regard to consistency and tenderness. That is, it is possible that the Australian product is inferior to the NZ product which itself, is not totally satisfactory.

In Australia, researchers claimed that values for tenderness, as assessed by both objective (Warner-Bratzler) and subjective (taste panel) measurements, indicated that the venison was of an 'acceptable' quality. However, mean taste panel scores for tenderness of some of the treatment groups were < 4 (9 point scale: 1 = poor, 9 = very tender). In these experiments, muscles were removed at 24 hours post slaughter and there was no ageing.

For maximum confidence in tenderness results, it is advisable to use sensory evaluation systems similar to those developed for the MSA beef grading system. However, we still need to use the laboratory tenderness measurements to find why a particular muscle is tender or tough.

The beef industries in Australia, New Zealand and UK are addressing the question of variability in tenderness and developing 'pathway' systems to ensure that the consumer can purchase branded product of 'guaranteed' tenderness. The Australian deer and venison industries must move towards a Quality Assurance system, which addresses both 'on-farm' (live animal) and 'off-farm' (processing) aspects of production. An Australian 'venison quality' brand is a logical component of such a system. This 'venison quality' brand, which would guarantee tenderness, may facilitate consumer acceptance of deer meat, and provide the consistent quality that will encourage repeat sales.

2. Objective

The aim of the project was to evaluate the eating qualities of venison from red and fallow deer. The venison was to be produced using 'best possible commercial practice' and the evaluation was to include both objective (machine) and subjective (taste panel) methods.

3. Introductory Technical Information

The RIRDC committee requested that the following points be adhered to.

1. Best possible commercial practice shall be used at all levels of trial
2. All stages of the process from 'on-farm' to 'on-plate' to be documented
3. Deer to be killed between September and mid December, when in appropriate prime venison condition (may be different date/month between fallow and red species)
4. Transport to meet Deer Industry QA specifications
5. The trial is to include 20 fallow bucks and 20 red stags to be sourced as follows:
 - 10 fallow bucks and 10 red stags to be sourced from one property
 - 10 fallow bucks and 10 red stags to be sourced from another property
6. All the deer shall be in the 20-26 month age bracket
7. Carcase fat assessments score to be documented
8. Chill carcasses overnight, record muscle temperatures in the chiller
9. Measure pH of each carcase/or cuts as appropriate and record to be able to relate to end taste test.
10. The following day remove striploins and topsides and vacuum pack for subsequent laboratory tenderness tests and sensory panel assessment.

The trial will not include the use of electrical stimulation.

Cooking

Guidelines for the cooking of samples for the sensory panel assessments should be carefully discussed and determined in conjunction with Ms Lynelle Tume. They should be as close as possible to the MSA Steak Trials Guidelines, but with due consideration to the differences in fat marbling between the species and the need for appropriate resting times for venison.

4. Methodology

Animals/Carcases

It was originally planned to conduct the trial at Myrtleford abattoir, Victoria. There were, however, difficulties in sourcing the appropriate animals and arranging a suitable processing day. The trial was therefore transferred to Australian Game Meats abattoir, Oberon, NSW. The RIRDC were notified of, and accepted, this change to the original proposal. It was not possible to locate two properties with both red stags and fallow bucks. Deer were therefore sourced from three properties, with one property supplying both red and fallow deer, the other properties supplying either red or fallow. This enabled a comparison of 20 red with 20 fallow deer, and also a comparison of 10 red with 10 fallow deer sourced from the same property. All animals were processed at the one abattoir on the same day (30th November 1999).

All groups were transported in the one vehicle owned and driven by Mr. Terry Scifleet. This vehicle is a specially modified trailer which is almost totally enclosed (and therefore dark inside). It can be backed up to the abattoir lairage where it may remain for the day. Thus, in addition to being a transport vehicle, it is also an additional lairage area. The groups were slaughtered consecutively at the abattoir. Red deer were stunned with a Schermer penetrating captive bolt pistol, fallow deer were electrically stunned (400 volts, 3 seconds, head only). Often two animals will be stunned consecutively, followed by a break before another 2 or 3 animals are stunned. The slaughter floor dressing process is conducted partially as a batch process, rather than as a continuous chain, and thus the time on the slaughter floor varies between carcasses. There was no electrical stimulation or other electrical inputs on the slaughter floor.

All trial carcasses were held in the chiller overnight and then, due to transport difficulties, transferred to another chiller for a further day before being transported from Oberon to Sydney.

Chiller Measurements

Chiller air temperature was recorded using a Tinyview data logger (Hastings Data Loggers, Port Macquarie, NSW) and Tinyview or Tinytag data loggers were used to continuously record the *longissimus* muscle temperature of some carcasses.

Muscle (*longissimus*) pH and temperature measurements were made on all carcasses on 2 occasions during the early post mortem period. The first recording for each carcass was taken within 30 minutes of entry of the carcass into the chiller; the second recording was taken 1 to 3 hours after chiller entry. pH measurements were made by inserting a glass pH probe (KCL) through a scalpel incision in the muscle. Temperature was recorded using a stainless steel probe placed in the muscle in the vicinity of the pH probe. The pH meter (TPS Pty. Ltd. Brisbane Qld) was temperature compensated. An ultimate pH was recorded for both the SM and LD muscles at the time of the tenderness measurements.

Boning Room

The trial carcasses were processed as part of the routine production of the boning room. From the red deer, one striploin and one topside were removed and vacuum packed separately. From the fallow deer, both striploins and both topsides were removed and vacuum packed as a pair in the one bag (for the striploins, this is normal commercial procedure). Each vacuum pack bag was individually weighed and then placed in 20 kg cartons for chilled storage. The cartons were stored at 1°C for 14 days before being frozen. Tinytag data loggers were placed in 2 cartons and temperature logging occurred from carton chiller entry until the cuts were removed for muscle tenderness evaluation (this included all phases of road transport from the boning room in Sydney to the laboratory in Brisbane).

Meat Colour

Meat colour was measured with a Minolta Chromameter CR200 (light source 'C') on samples that had been exposed to air (blooming) for 60 minutes after slicing. Meat colour is quoted in Tristimulus values (L^* , a^* and b^*). The L^* value is a measure of lightness/darkness; the higher the L^* value the lighter the colour. The a^* value is a measure of the red colour with high numbers indicating more redness.

Objective Tenderness Measurements

Warner-Bratzler Peak Force (WBPF)

The Warner-Bratzler shear device uses a shear blade with a square hole to cut rectangular samples (1.5 x 0.67 cm) of cooked meat (70°C for 60 min). The samples were cut so that the knife blade of the device cut across the fibres at right angles. For any one sample, the recorded value is the mean of 6 sub-samples.

Instron Compression

A flat-ended plunger, 0.63 cm in diameter, is pushed, at 50 mm/min, 0.8 cm into a 1.0 cm thick sample of cooked meat. The sample is cut so that the meat fibres are parallel to the cut surface and perpendicular to the direction of plunger travel. The sample is compressed (to 0.2 cm) under the plunger twice, at the same location, and the work done on each cycle determined.

Sarcomere Length

A helium-neon gas laser, wavelength 632.8 nm, was used as the light source to obtain diffraction patterns from muscle fibre samples compressed between glass microscope slides. Sarcomere length was determined from the diffraction pattern displayed on a screen.

Preliminary Cooking Trials

Following discussions with Ms Lynelle Tume, assessments were carried out to determine degree of doneness on boneless striploins. Australian Game Meats donated two fallow deer loins and one red deer loin. The samples were aged for 2 weeks at 2°C and then frozen until assessment. The samples were then trimmed of connective tissue and allocated to objective and subjective analysis. The desired temperature endpoint was in the temperature range 60-65°C (medium), as requested at a meeting previously held with Ms. Tume. Three striploins were assessed, two from fallow deer and one from red deer.

The venison was cooked (as per MSA protocol) on a SILEX grill preset to 240°C for 4 minutes. The samples were trimmed of 'silverskin' (connective tissue) and sliced into steaks 25mm thick, 200mm long and 70mm wide. Six temperature measurements were taken and averaged for each steak using a resistive temperature detector (RTD) placed centrally along the steak, post cook and after resting. The steaks were wrapped in silverfoil for the duration of the resting period of 5 minutes.

Sensory Evaluation

When samples were required for sensory evaluation they were removed from the freezer and thawed for 24 hours at 5°C. The striploins were trimmed of 'silverskin' and sliced into steaks 25mm thick, 200mm long and 70mm wide. The venison steaks were cooked for 4 minutes at 240°C on 'SILEX'

grills (Type 610.80, 240 Volts, 2.4kWatt). The steaks were wrapped in silverfoil and allowed to ‘rest’ for 5 minutes before slicing to give even distribution of juices and colour. The steak cooking temperature endpoint was in the 60–65°C range or a ‘medium’ doneness level. The steaks were sliced into 15mm cubes for presentation to panellists and kept warm in a Bain-Marie set at 65-70°C. Two cubes per treatment were presented on white plastic plates to panellists with treatments identified by three digit codes. Four samples were randomly presented to each panellist at each of ten sensory sessions. The samples were presented to 12 panellists experienced in meat quality assessment with differences in the tenderness, juiciness, flavour and overall quality attributes assessed (Table 1).

All sensory assessments were carried out under red lighting conditions to disguise any differences due to colour or appearance. Panellists were seated in individual isolation booths with a drinking cup of water with 10% apple juice to cleanse the palate between tastes. All data was recorded directly onto a multi-user computer system.

Table 1: Sensory Profile to Evaluate Venison (line scale: 0 to 100)

No.	Sensory Attribute	Anchors
1	Tenderness	Very tough - Very tender
2	Juiciness	Very dry - Very juicy
3	Flavour	None - Very Strong
4	Overall Quality	Very Poor - Very Good

Statistical Analysis

The objective data were analysed using the General Linear Models program of SAS (SAS Institute Inc. 1998). The sensory data were tested for differences due to treatment and panellist using a two-way analysis of variance. The SAS System for Windows, Release 7 TS Level 00P1 was used to analyse this data (SAS Institute Inc. 1998).

5. Results

Animal and Transport Factors

Details of the four groups of animals are listed in Table 2.

Table 2: On-farm to abattoir history of the four groups

	GROUP I	GROUP II	GROUP III	GROUP IV
	Red	Red	Fallow	Fallow
Property	A	B	A	C
Location	Mudgee	Orange	Mudgee	Orange
Time yarded	0600	0700	0600	0700
Time loaded	0700	0900	0700	0930
Hours on truck	5	3	5	2.5
Arrive abattoir	1200	1200	1200	1200
Slaughter	1330	1400	1445	1500

Carcase and Cuts Data

Mean values for the carcase and cut weights are listed in Table 3.

Table 3: Mean values for carcase and cuts data for the four groups

	Group I	Group II		Group III	Group IV	
Cuts	Red	Red	P <	Fallow	Fallow	P<
Carcase weight (kg)	67.9	63.9	NS	24.9	23.1	0.05
Loin weight (kg)	3.1	3.0	NS	1.4	1.3	NS
Loin fat (mm)	1.1	1.4	NS	5.7	5.6	NS
Topside weight (kg)	2.5	2.3	NS	1.1	0.9	0.05

NS: Differences between the groups were not statistically significant

P: Level of statistical probability at which means are significantly different.

pH/ Temperature Measurements

Figures 1 and 2 illustrate the relationship between LD muscle pH and temperature for the red and fallow deer.

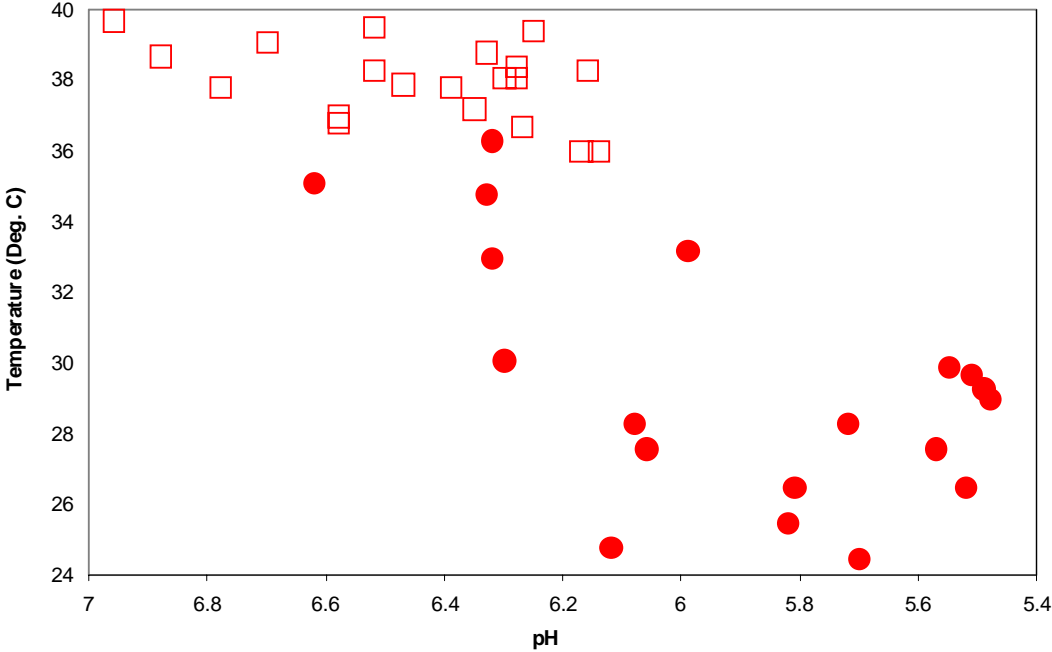


Figure 1: Relationship between temperature (°C) and pH for the LD muscle of red deer
 □ - Reading 1 ● - Reading 2

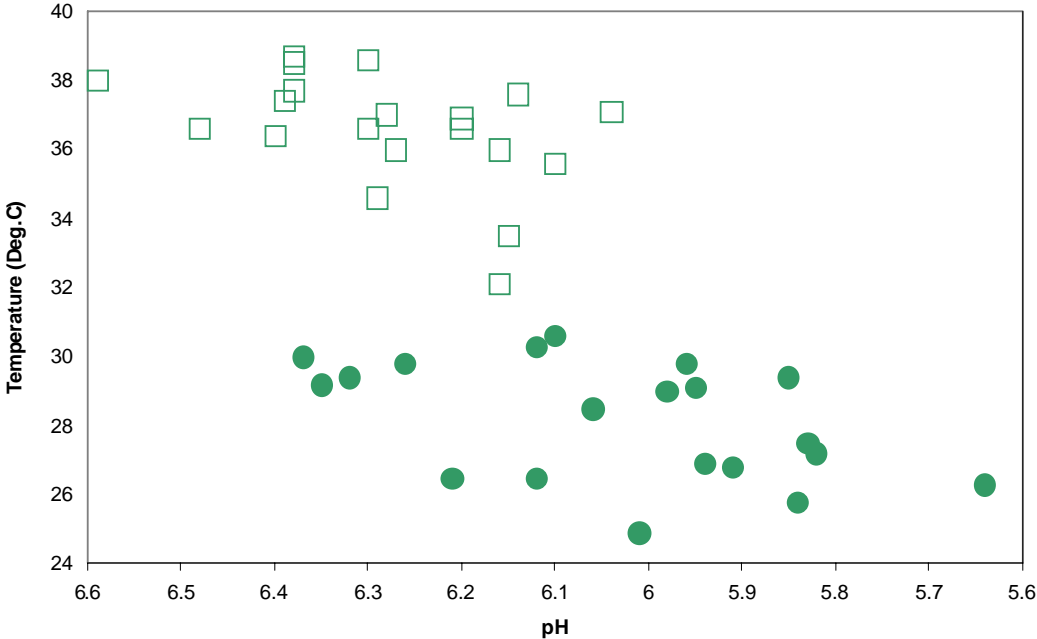


Figure 2: Relationship between temperature (°C) and pH for the LD muscle of fallow deer
 □ - Reading 1 ● - Reading 2

Chilling Rates

Figure 3 displays the air temperature in the chiller while figures 4 - 6 give cooling rates for the longissimus muscle of individual carcasses.

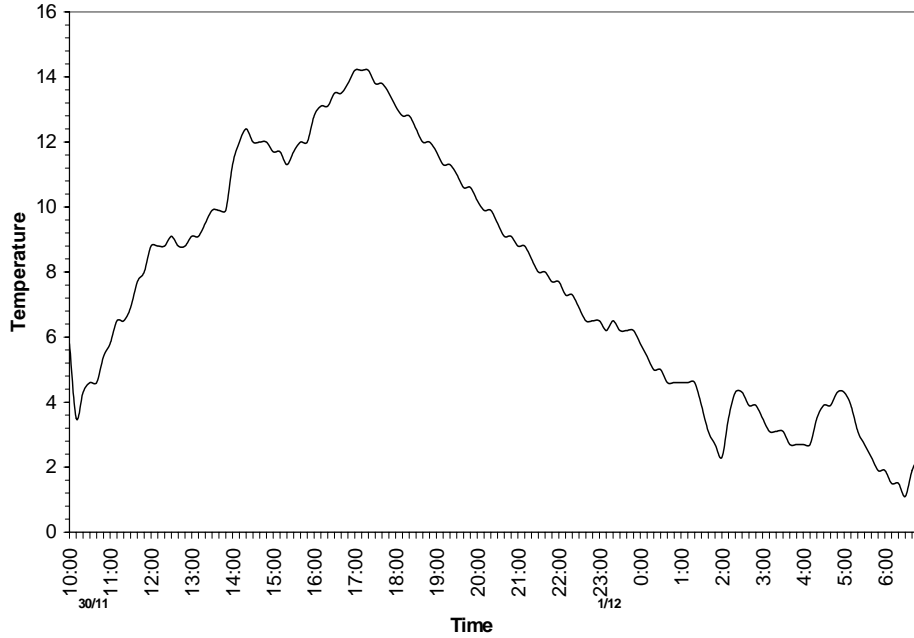


Figure 3: Chiller air temperature

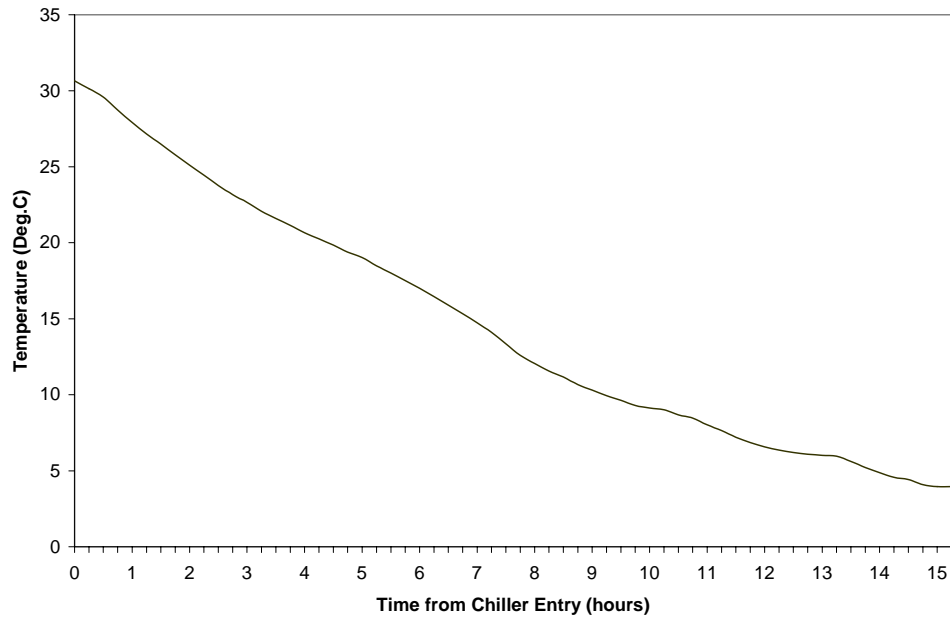


Figure 4: Cooling rate of loin muscle in a fallow deer carcase (Body no. 82)

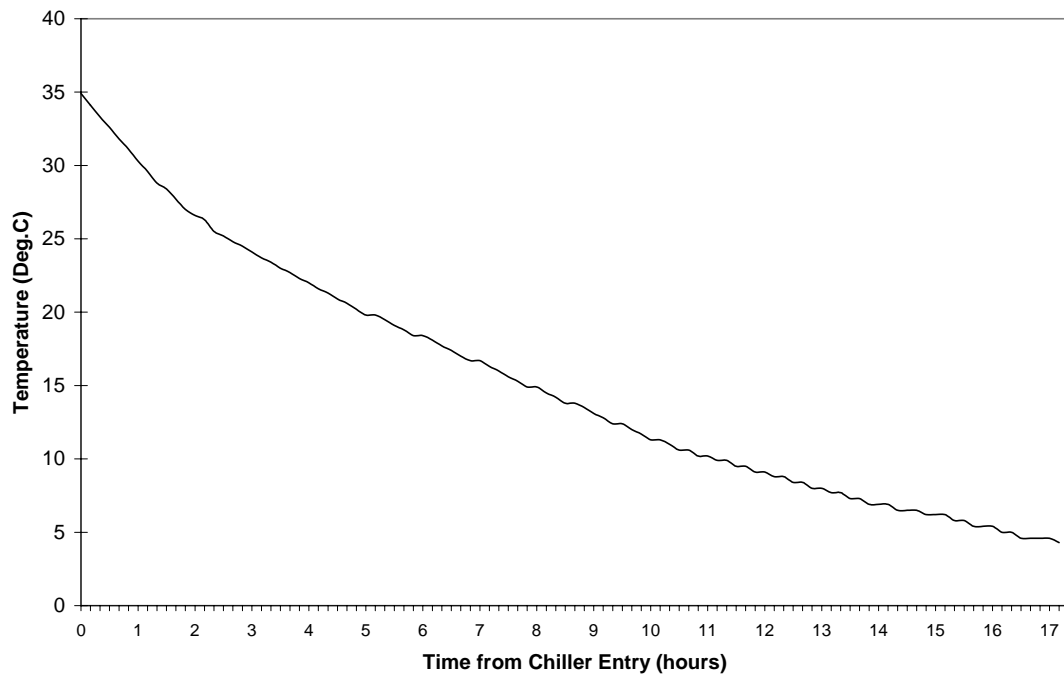


Figure 5: Cooling rate of loin muscle in a red deer carcase (Body no. 58)

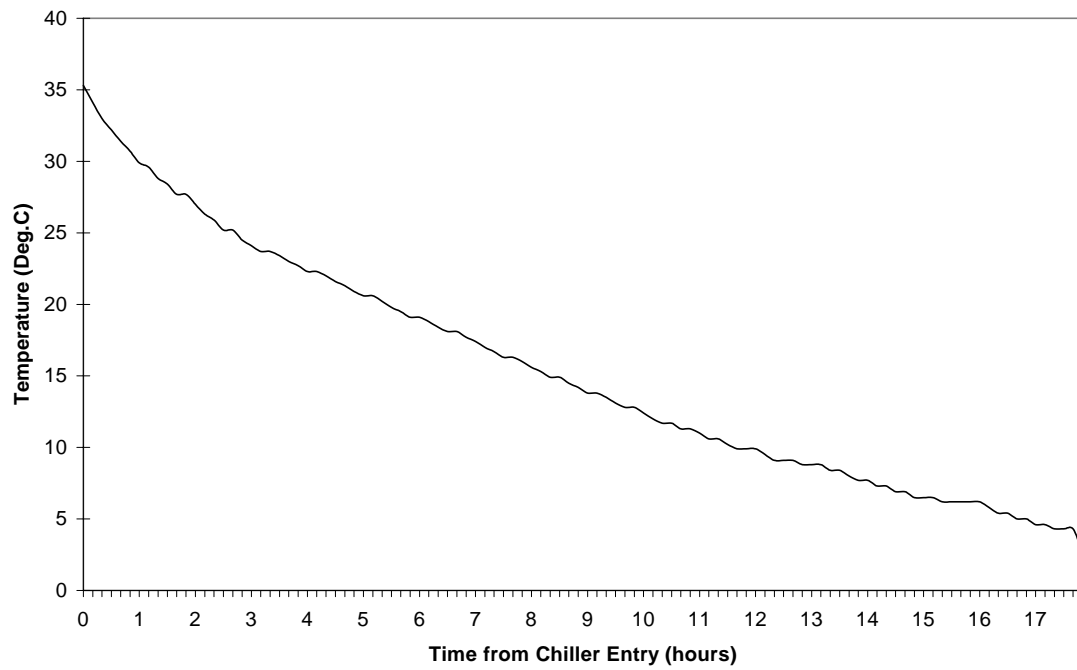


Figure 6: Cooling rate of loin muscle in a red deer carcase (Body no.48)

Preliminary Cooking Trials

The temperatures recorded during the preliminary cooking trial are listed in Table 4.

Table 4: Average internal temperature of venison steaks post-cook and after resting for 5 minutes

	Species	Temperature Endpoint T_{av} (°C)		Sample Weight (g)
		Post Cook	Rested (5mins)	
1	Fallow	62.0	64.2	295
2	Fallow	60.1	63.5	307
3	Red	60.5	63.8	301

Meat Quality Measurements

The meat quality measurements for the SM and LD muscles are listed in Tables 5 and 6.

Table 5: Mean values and statistical significance of meat quality measurements for the *semimembranosus* muscle (SM) of the topside

		Red	Fallow	Statistical Significance (P)
Ultimate pH	All groups	5.68	5.86	< 0.01
	Property 1	5.71	5.89	< 0.05
Minolta L*	All groups	37.45	32.99	<0.001
	Property 1	38.19	33.73	<0.001
Minolta a*	All groups	24.54	18.63	<0.001
	Property 1	24.73	18.83	<0.001
Cooking loss (%)	All groups	22.51	21.05	<0.05
	Property 1	22.31	20.85	<0.05
WBPF (kg)	All groups	3.20	4.36	<0.01
	Property 1	3.33	4.50	<0.01
Compression (kg)	All groups	1.84	1.80	NS
	Property 1	1.89	1.85	NS
Sarcomere (μ)	All groups	1.73	1.67	NS
	Property 1	1.74	1.68	NS

NS: Differences between the groups were not statistically significant
For 'All groups' n = 20 per breed, for 'Property 1' n = 10 per breed

Table 6: Mean values and statistical significance of meat quality measurements for the *longissimus* (LD) muscle of the striploin

		Red	Fallow	Statistical significance (P)
Ultimate pH	All groups	5.62	5.70	< 0.05
	Property 1	5.61	5.68	< 0.01
Minolta L*	All groups	34.48	34.75	NS
	Property 1	34.59	34.87	NS
Minolta a*	All groups	23.90	22.13	<0.05
	Property 1	23.81	22.04	<0.05
Cooking loss (%)	All groups	23.78	24.61	NS
	Property 1	23.64	24.47	NS
WBPF (kg)	All groups	2.57	2.70	NS
	Property 1	2.74	2.87	NS
Compression (kg)	All groups	1.26	1.15	NS
	Property 1	1.25	1.15	NS
Sarcomere (μ)	All groups	1.75	1.68	NS
	Property 1	1.75	1.68	NS

NS: Differences between the groups were not statistically significant
For 'All groups' n = 20 per breed, for 'Property 1' n = 10 per breed.

Sensory Panel Assessment

Table 7: Mean values for red and fallow deer sensory evaluation

Attribute	Red Deer	Fallow Deer
Tenderness	64.17	64.98
Juiciness	52.70	49.50
Flavour	62.69	62.46
Overall Quality	59.04	58.42

The results for Red and Fallow deer are tabulated in Table 7 and illustrated in Figure 7. There was no significant difference between species for any attribute assessed. A further analysis was carried out to determine if there was a difference due to the properties from which the venison striploins were sourced. The results are shown in Table 8 and displayed in Figure 8. There was no significant difference in meat quality attributes due to the property from which the deer were sourced.

Table 8: Mean values for sensory attributes of venison from Red & Fallow Deer - Properties A, B & C

Attribute	Property A	Property B	Property A	Property C
Tenderness	64.60	64.08	63.73	66.64
Juiciness	53.53	52.35	48.53	51.29
Flavour	61.62	63.65	61.93	62.46
Overall Quality	60.67	58.34	58.02	59.60

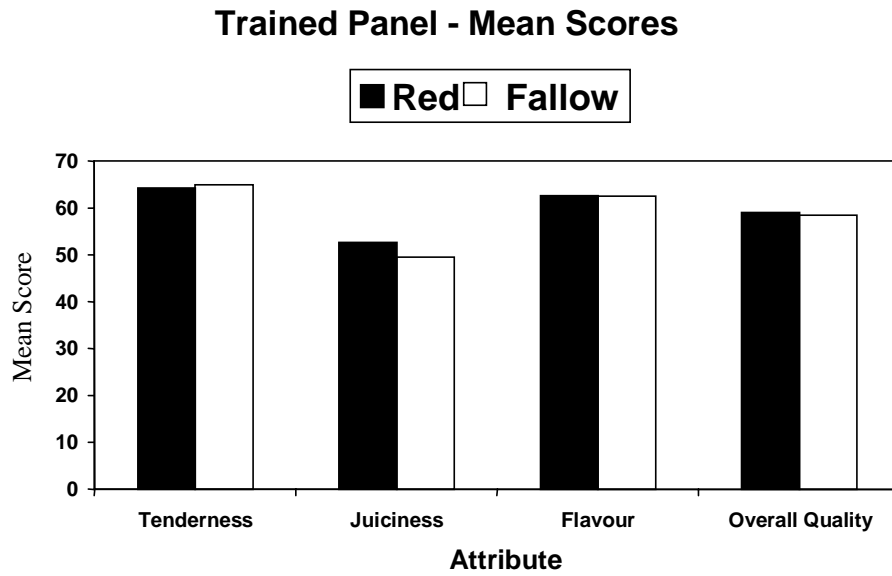


Figure 7: Mean values of sensory attributes for striploin from Red and Fallow deer

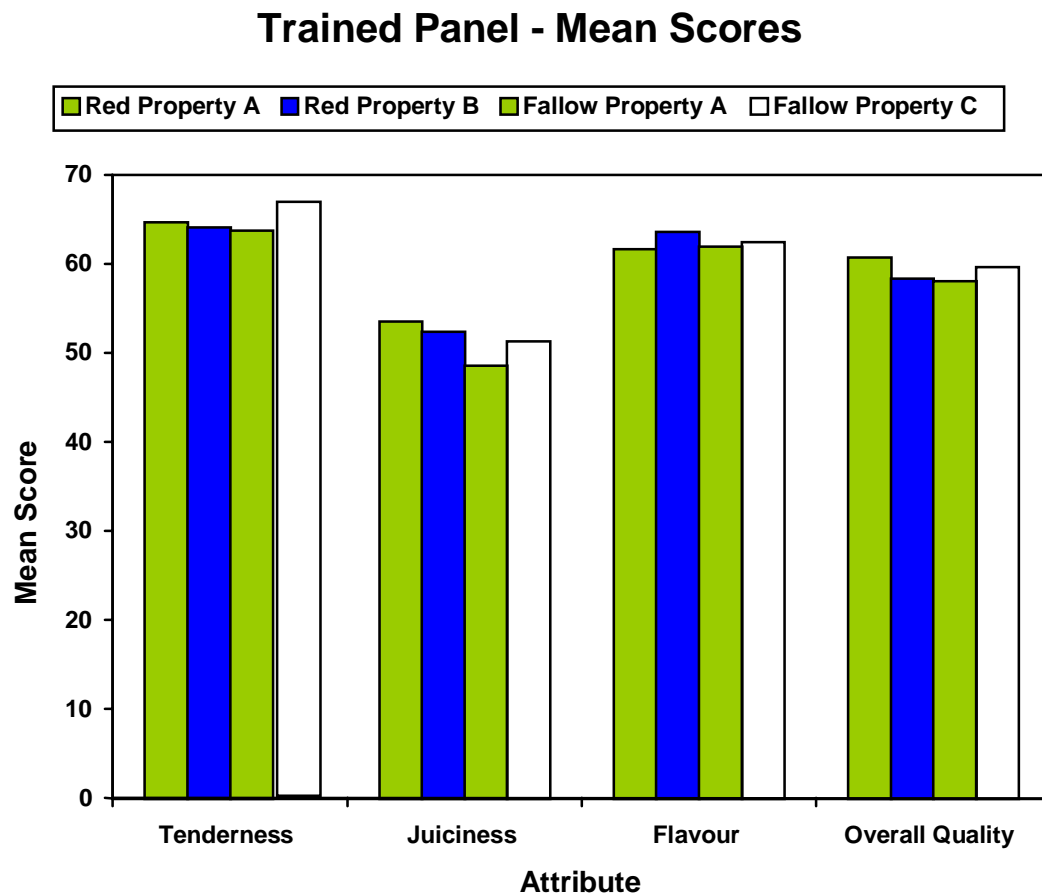


Figure 8: Mean values for Red and Fallow venison striploin from properties 'A', 'B' and 'C'.

6. Discussion

Rate of Fall of Muscle pH

At the time of death, a muscle will have a pH of about 7.0. This pH will decrease to reach a value of about 5.6 - this is the ultimate pH. The rate of decline of pH is very variable and the ultimate pH may be reached within 1 hour or within 48 hours of death. Meat scientists believe that meat tenderness is affected by the rate of decline of pH and the pH at a specified temperature, but have difficulty in finding the exact relationship between these variables.

For beef, it has been suggested that tenderness is determined by the pH/temperature relationships listed in Table 9.

Table 9: pH / Temperature Relationships for Beef Carcasses

Muscle pH	Temperature °C	Tenderness
≤ 6.0	10 - 20	Optimal
> 6.0 (slow decline)	< 12 (fast cooling)	Extremely tough (cold shortened)
< 5.9	> 30 (slow cooling)	Some loss in tenderness and juiciness (heat shortened)

From the graphs of muscle pH vs temperature (Figures 1 and 2) it can be seen that many pH values below 6.0 were reached at temperatures of 25-30°C. For these muscles, cold shortening would be unlikely. There was some evidence of pH/temperature parameters that might produce heat shortening as pH values of 5.9-6.0 occurred with temperatures in the vicinity of 30°C.

The rate of fall of pH was reasonably fast. For 55% of the carcasses, pH values less than 6.0 were reached within 3 hours of stunning. This is somewhat unexpected in view of the absence of electrical stimulation. A contributing factor to the rapid pH fall would be the initial high chiller temperatures (see Figure 3) during chiller loading. Grogan et al. (1997) recorded a mean 2 hr pH value of 6.05 for the semimembranosus muscle of female fallow deer. The animals had been electrically stunned but the carcasses had not received electrical stimulation.

The 4 muscles with the lowest sensory panel tenderness scores (< 51) all achieved a pH of less than 6.0 while at temperatures considerably in excess of 20°C. Thus, it did not appear that cold shortening would have contributed to their lack of tenderness. On this basis, there would seem to be no requirement for electrical stimulation (ES). The application of ES should, however, in theory, be decided on an individual carcass basis. In the present trial, if a small group of carcasses had been placed in an adjacent chiller, and that chiller kept closed after loading, those carcasses may have experienced a rate of cooling sufficient to induce cold shortening. Similarly, the first carcasses processed on any day may be placed a 'cold' chiller, and therefore may experience more rapid chilling than those processed later in the day, when the chiller air temperature has increased (see Figure 3). Thus, the requirement for the application of electrical stimulation may depend upon time of entry into the chiller, and the chiller in which the carcasses are placed.

Warner-Bratzler Peak Force (WBPF)

Mean Warner-Bratzler shear values for the LD muscle (< 3 kg) were similar to those recorded for fallow deer (Grogan et al 1997) and indicate a tender product. The fallow group contained LD muscles with the 2 highest (4.8 and 6.0 kg) and the 2 lowest (1.6 and 1.8 kg) WBPF values. This indicates that the fallow group had greater variability in tenderness, although the means for the 2

groups did not differ significantly. Dobbie et al (1995) reported Warner-Bratzler values (derived from MIRINZ tenderometer values) of 2 to 3 kg for red deer. Sookhareea et al (1995), however, reported mean shear force values of between 4.6 and 7.4 kg for different treatment groups of Javan Rusa deer.

In many species, the topside is not a particularly tender cut. In studies with lamb carcasses, mean Warner-Bratzler shear force values in excess of 7.0 kg have been reported for the SM muscle (Shaw et al 1996; Hanrahan et al 1998). Thus, mean WBPF values of 4 kg, as recorded in the present trial, indicate satisfactory tenderness for this muscle. For fallow deer, mean Warner-Bratzler values for SM muscles from various groups of animals were slightly, but consistently, greater than those for the corresponding LD muscles (Mojto and Kartusek 1995). For unaged topsides from Java deer, mean values for different treatment groups varied from 5.5 to 6.9 kg (Sookhareea et al 1995).

Ultimate pH, colour and tenderness

Beef carcasses with an LD muscle pH greater than 6.0 often have dark muscles and are referred to as 'dark-cutters'. In the present trial there were no LD muscles with 'high' pH values (>6.0) but there were several fallow carcass LD muscles, but no red carcass LD muscles, with 'intermediate' pH values (5.7-6.0). For both the SM and LD muscles, mean ultimate pH values were significantly greater for the fallow deer group. The mean pH value for the SM muscle of the fallow deer was 5.86. Brodowski and Beutling (1999) reported a mean pH value of 5.58 for the SM muscle of fallow deer shot under hunting conditions. Thus, it would appear that the pH values of fallow deer muscles are not invariably elevated.

The 2 LD muscles with the highest pH values (5.98 and 5.87) had the highest WBPF values (4.8 and 6.0). These 2 muscles also had the lowest Minolta L* values (29.3 and 32.0) and the lowest Minolta a* values (17.0 and 19.7), indicating that these 'intermediate' pH values were associated with tougher, darker meat.

It is well documented that there is a relationship between tenderness and muscle ultimate pH. The Meat Standards Australia (MSA) grading system for beef will not accept for grading carcasses with an LD muscle pH > 5.7 (Anon 1999). If this system were applied to all carcasses in the present trial, there would be 6 carcasses ineligible for grading. Of these 6 carcasses, 2 had low sensory panel tenderness scores (45.8 and 49.7).

Sarcomere Lengths

The mean sarcomere lengths for both muscles (1.67-1.75 μ) are less than the generally accepted sarcomere resting length of about 2 μ . This could indicate that there has been a degree of shortening. The temperature/pH relationships, however, suggest that neither heat shortening nor cold shortening were likely occurrences. Similarly, mean Warner Bratzler shear force values of less than 3 kg indicate that extensive shortening is unlikely to have occurred. Sookhareea et al. (1995) recorded mean sarcomere lengths of 1.66-1.80 μ for the LD muscle of Rusa deer. These carcasses had been electrically stimulated and thus, at least in theory, should not have undergone cold shortening.

Instron Compression

This measurement provides an indication of the contribution of connective tissue in the muscle to the overall toughness of the muscle. Compression values above 2 kg may indicate a significant connective tissue component. As would be expected with the young animals in the present trial, the LD muscles, and to a lesser extent the SM muscles, had low Instron compression values.

Sensory Panel

The trained taste panel scores show that there is no significant difference in venison striploin quality from red and fallow deer. This result is independent of the property from which the striploins were supplied. The mean scores were similar for striploins supplied from the three properties, with no significant difference between species for venison supplied from property 'A'. The venison was prepared to a 'medium' level doneness and this reflected an 'average' juiciness mean score. Juiciness was rated lowest of the four meat quality attributes assessed. The tenderness attribute was rated highest (64-67) for both the red and fallow deer and would be in the 'tender' range. Overall Quality of the venison striploins was in the 'moderate-good' range.

Stevenson et al (1992) reported a mean taste panel tenderness score of 4.9 for unaged venison from mature farmed red deer stags in New Zealand. These values correspond to an evaluation in the range of 'slightly tough' to 'slightly tender'. Similarly, the mean overall desirability score was 5.23, which corresponds to an evaluation in the range of 'slightly desirable' to 'moderately desirable'. Thus, as would be expected, the aged Australian product from younger animals was of superior tenderness to the unaged New Zealand product from older animals.

A more realistic comparison can be made between the present trial and that reported from New Zealand by Seman et al (1988). In their experiment, venison was derived from yearling red deer stags. The carcasses were stored in the chiller for 4 days before the cuts were stored vacuum packed for 1 week. The mean taste panel tenderness score was 4.8 which was in the range of 'slightly tender' to 'moderately tender'. Thus, our trial appears to have given similar taste panel tenderness scores to those reported for similar product produced in New Zealand.

7. Implications and Recommendations

Most of the loin muscles produced under the best practice commercial conditions used during the course of this project were tender. For this muscle, neither the taste panel nor Warner-Bratzler shear force measurements could demonstrate a difference in tenderness between product from red and fallow deer. For the SM muscle, Warner-Bratzler shear force measurements indicated that muscles from the fallow deer were significantly tougher than those from the red deer.

For the LD muscle, there were no 'high' pH (>6.0) values in either group, although in the fallow group there were several muscles in the 'intermediate' pH range (5.7 - 6.0). There were no red deer LD muscles with values greater than 5.7, a value sometimes used as a cut-off point for ensuring tenderness. For the fallow group, 6 of the 20 (30%) LD muscles had values greater than 5.7 and these 'intermediate' pH values were sometimes associated with tougher, darker meat. For both the SM and LD muscles, mean ultimate pH values were significantly greater for the fallow deer group.

For the red and fallow deer from the one property, transported in the same vehicle and processed at the same abattoir on the same day, the mean ultimate pH of both the LD and SM muscles was significantly greater for the fallow than for the red deer. This would suggest that fallow deer are more susceptible to stress than red deer. If further research substantiates this to be the case, then refinement of the handling practices for fallow deer may be necessary. For example, an increase in handling and human contact on the property may be advisable. Additionally, it may be necessary to have practice transport runs, which introduce the animals to loading, road transport and unloading.

If the venison industry wishes to set up a grading system for meat quality, similar to the MSA system for grading beef, then the commercial procedures followed throughout this project could form part of the 'pathway' for the production of venison of guaranteed tenderness. On the limited data available, it appears that LD muscle pH values greater than 5.7 were sometimes associated with tough product. More research needs to be done to confirm this with a greater number of samples. If found to be correct, then the incorporation of an ultimate pH specification may be advisable if venison of 'guaranteed' tenderness is to be marketed. Ultimate pH may be a simple, but important, measurement to assist in the elimination of tough product.

8. References

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