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**Rural Industries Research and
Development Corporation**

Venison Quality

The relationship of body condition score with consumer perception

**A report for the Rural Industries Research
and Development Corporation**

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Foreword

Meat quality and quality assurance have been identified as priority areas for research and development in successive 5 year strategic plans developed by the Australian deer industry. To meet quality assurance objectives all aspects of the value chain need to be evaluated.

Understanding the relationships between live animal body condition, slaughter techniques and post-slaughter carcass management are critical elements for quality assurance of meat. The task for the deer industry is to now link production efficiency and processing to consumer acceptance of the final product in a whole of value chain approach. This project assesses the association between live animal and carcass characteristics and consumer acceptance of venison, by matching quality characteristics of venison to body condition scores and post-slaughter carcass treatments and testing these with consumers.

The project design followed a systems approach to venison quality; from on farm growth and development, immediate post slaughter management, optimum food preparation through to consumer appraisal and perception. Experimental work was carried out on selected slaughter age red and fallow deer of body condition scores 2, 3 and 4 (Lean, Prime and Fat). The research focused on post-slaughter handling and biochemical assessment of the three body condition scores to determine optimum eating quality as determined by a random representation of consumers. In addition, eating quality and consumer acceptance of venison from deer raised on pasture versus supplementary feeding was evaluated.

This project was funded from industry revenue, which is matched by funds provided by the Australian government.

This report, an addition to RIRDC's diverse range of over 1500 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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We thank Mr Roger Littlejohn from AgResearch, Invermay, New Zealand for statistical analysis of data in chapter 2. This research was jointly funded by RIRDC and the University of Western Sydney.

Abbreviations

| | | | |
|-------|---|--------------------|--|
| QA | Quality Assurance | (%) | Percentage |
| BCS | Body Condition Score | LD | M.longissimus dorsi (striploin) |
| RIRDC | Rural Industries Research and Development Corporation | GenStat | Statistical package |
| pH | - log ₁₀ of the concentration of hydrogen ions | g/cm ² | Shear force required to break muscle (tenderness studies) |
| C° | Degrees centigrade | kg/cm ² | Shear force required to break muscle (tenderness studies) |
| (kg) | Kilogram | MSA | Meat Standards Australia |
| h | Hour | USDA | United States Department of Agriculture |
| P | Statistical probability | L* | A measurement for lightness when analysing colour of meat |
| < | Less than | a* | A measurement for redness when analysing colour of meat |
| ± | Variance around the mean | b* | A measurement for yellowness when analysing colour of meat |
| se | Standard error | IM fat | Intramuscular fat |
| > | Greater than | g | Gram |
| NS | Not significant | AT | Achilles tendon |
| n | number | TS | Tenderstretch (pelvic suspension) |
| EU | European Union | | |
| \$A | Value in Australian dollars | | |
| UWS | University of Western Sydney | | |
| ≤ | Less than or equal to | | |

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Executive Summary

This report describes experimental work conducted to determine the relationship between body condition score (BCS) of deer and consumer acceptance of the venison from them. Biochemical and physical attributes of red and fallow deer carcasses with BCS ranging between 2 and 4 were tested. Post-slaughter management of carcasses compared Achilles tendon and pelvic suspension methods of hanging to determine effects on venison quality. Further experimental work compared deer raised on pasture with deer fed barley prior to slaughter to determine effects on venison quality. Venison from deer subjected to each of the experimental procedures was tested by sensory panellists from a range of quality attributes and overall liking of the meat.

In the present study red and fallow deer between 12 and 30 months of age raised on pasture usually had a BCS between 2 and 3. Animals with BCS of 4 were achieved by feeding grain for greater than 100 days prior to slaughter. Variation in BCS did not result in significant differences for most of the measured meat quality attributes for either fallow or red deer. Sensory evaluation by taste panellists determined that there was a greater overall liking of venison from animals with BCS 3 and 4, compared with BCS 2 but this trend was not significant. There was a significant increase ($p < 0.05$) in intramuscular fat as BCS rose from 2 to 4 for both species. This difference was not detected by sensory panellists. There was a gradual increase in tenderness of venison as BCS increased with venison from animals with BCS 4 being significantly more tender than venison from animals with BCS 2. However venison from animals with BCS 3 was not significantly more tender than venison from animals with BCS above or below condition score 3 and the difference in shear force values from cooked venison across the range of condition scores was low overall. It was concluded that deer with BCS ranging from 2 to 4 can be slaughtered for venison with no significant loss of eating quality.

In the present study venison from deer fed grain (barley) for greater than 100 days prior to slaughter had a higher flavour strength according to sensory panellists. Venison from grain-fed deer also had lower colour stability and therefore lower display life than venison from pasture-fed deer when sold as fresh or chilled product. Both of these outcomes need to be considered by wholesalers sending product into selected markets.

Hanging carcasses from 5 to 10 days post-slaughter did not improve meat quality parameters, including tenderness. Deer carcasses are usually broken into primal cuts between 1 and 3 days post-slaughter and results of the current study show that carcasses with a BCS of 2 to 3 can be processed at a range of times after slaughter without adversely affecting meat quality parameters. This finding was consistent for fallow does and bucks. It was concluded that factors other than post-slaughter hanging time of carcasses were more likely to affect venison quality.

The pelvic suspension (tender stretch) method of hanging carcasses post-slaughter was compared with traditional hanging by the Achilles tendon to determine effects on meat tenderness. Pelvic suspension of red and fallow deer carcasses significantly increased meat tenderness in all sexes in every experiment where this technique was tested. Pelvic suspension also had a positive effect on water holding properties by reducing moisture loss of fresh chill-stored venison, an important consideration given that juiciness is the second most important characteristic of meat according to consumers. It was concluded that the carcasses from all deer slaughtered should be subjected to pelvic suspension hanging post-mortem to increase tenderness, juiciness and overall liking of the meat.

Overall this study has shown that venison is a high quality product with biochemical parameters similar to, or more desirable than, other domestic meats. Sensory evaluation showed the product to be strongly appreciated by men and women between the ages of 25 and 55, and differences in overall liking between red and fallow deer venison were not detected by panellists in this study.

Introduction

Quality Assurance (QA) of venison is a key to long-term product marketability and has been identified as a priority component of the long term strategic plan for the Australian deer industry. The recently developed body condition scoring system (BCS) for fallow deer (Flesch et al 2002) is an example of recent methods developed for quality assurance at the production and processing level. This system provides a common language, which can be used by farmers, processors and marketers to describe carcass characteristics. QA success will not, however, be achieved by meat description alone and the task for the deer industry is to now link production efficiency and processing to consumer acceptance of the final product. There is now more emphasis on food chain management in most countries of the world where food is produced in surplus, especially meat.

The aim of this study was to assess the association between live animal and carcass characteristics and consumer acceptance of venison, by matching the eating quality parameters of venison to body condition scores and testing these with consumers. This paddock to plate approach will link the outcomes of a series of projects completed independently of each other to provide clear guidelines on carcass characteristics that will guide production efficiency and value adding on farms and will clearly enhance the credibility, application and adoption of QA by strengthening links between various sections of the deer industry.

Estimations of body condition score (BCS) have traditionally been used in animal production systems to relate the performance of animals to seasonal, nutritional, health and reproductive variants. Most BCS systems developed for domestic ruminants, including red and fallow deer, are based on a 5 point scale of measurements that can be readily applied in the field by either visual assessment or palpation of the live animal. Examples of condition scoring systems for domestic species include fallow deer (Flesch et al 2002), red deer (Audige et al 1998), pigs (Elsley et al 1964), dairy cattle (Gregory et al 1998), beef cattle (Gresham et al 1986; Bullock et al 1991), sheep (Hopkins et al 1995) poultry (Gregory and Robins 1998) and goats (Mitchell, 1986; May et al 1995). None of these studies linked BCS with meat eating quality.

More recently grading systems for meat, in particular beef, have related aspects of BCS to meat eating quality with many international markets now purchasing product using USDA and Meat Standards Australia (MSA 2001) grading methods. There is now a significant amount of research data available on the eating quality of meat from a range of domestic ruminant species, particularly sheep and cattle. Research on deer has so far been limited, however the eating quality aspects of reindeer (*Rangifer tarandus tarandus*) venison in relation to pre-slaughter handling and supplementary feeding has been studied (Wiklund et al, 1996, 1997a, 2000, 2003a), as well as the effects of various feeding regimens on eating quality attributes in red deer venison (Wiklund et al, 2003b).

The need to link carcass production with eating quality has long-term implications for acceptance of venison as a favoured consumer selection. Hence, definition of the relationship of BCS with cooking and eating quality will increase opportunities for target marketing, which should increase farm profitability and consumer satisfaction if product consistency is enhanced. However, it is acknowledged that factors such as methods of slaughter, post-slaughter carcass management and methods of meat storage can have a significant impact on eating quality of the final product. Texture, flavour and tenderness are attributes valued by consumers as very important in relation to the eating quality of meat. Different populations of consumers have different preferences for these quality attributes, something that affects the market for all types of meat. However, regardless of the consumer group, the consistency of meat quality is very important, and the product should be of the same quality every time it is purchased. In the Australian beef grading system Meat Standards Australia (MSA) these consumer important sensory quality attributes have been weighted in an overall score where tenderness represents 40(%), flavour 20(%), juiciness 10(%) and overall liking 30(%) (MSA, 2001).

In addition to the association between BCS and various meat quality parameters, other techniques employed in this study tested the effect of pelvic suspension (tender stretching) of carcasses for product enhancement, evaluated vacuum package aging of various meat cuts from fallow and red deer, and looked at the effect of supplementary feeding of deer pre-slaughter compared with pasture-fed deer on consumer sensory perception of meat flavour. All of these factors were comparatively evaluated for the body condition scores 2, 3 and 4.

Objectives

Characterise the biochemical and physical attributes of deer carcasses for condition scores 2, 3 and 4 (commercial grades) to increase consumer confidence and quality of supply.

Develop industry best practice for post-slaughter management of carcasses and/or cuts to enhance the three major quality components of venison, being tenderness, juiciness and flavour.

Determine the impact of supplementary feeding on the eating quality characteristics of venison.

General Materials and Methods

On farm BCS and validation after slaughter

Several measurements were taken from both live animals and carcasses to confirm the body condition score of animals used in these experiments. Measurements were made ante and post-mortem, as follows:

Live animal measurements

Live deer were palpated whilst restrained in a drop-floor crush as a determinant of fat coverage when allocating the animal a condition score. Variations in subcutaneous fat depth were easily detectable along the spine, rump and brisket. Musculature and body shape were also used as determinants of condition, and were used in conjunction with palpation. To a lesser extent, the perineum also served as a guide to fat depth.

Carcass Measurements

Four areas of sub-cutaneous fat depth were measured on carcasses. Fat coverage on the foreleg was measured approximately halfway between the elbow joint and shoulder. An incision was made through the fat to muscle tissue and fat depth was measured with a Hennessy probe to the nearest millimetre. Back fat thickness was also determined with a Hennessy probe, from an incision made perpendicular to the backbone at the last sacral vertebra and measuring fat depth at the thickest point in millimetres.

Depth of rump fat was measured from an incision cut at a 45° angle from the spine, starting from the base of the tail and proceeding anteriorly across the rump, as described by Riney (1955). Brisket fat was measured at the thickest point from an incision made along the sternum parallel to the longitudinal axis of the carcass.

Following the method described by Riney (1955), kidneys were excised from carcasses with a pair of forceps after evisceration. Following removal of adrenal glands, cuts were made with scissors held against each kidney and parallel to its longitudinal axis, removing fat not directly associated with the kidney. Some studies have reported KFI measurements taken on one kidney and its fat (Watkins et al, 1991), although discrepancies in kidney weight between sex, age and size of left and right kidneys in some mammals (Torbit et al, 1988; Dauphine 1975) illustrate the need for decapsulation and weighing both kidneys and their fat. Each kidney, with and without attached fat and its capsule of connective tissue (*tunica fibrosa*) was weighed to the nearest 0.5 gram. Kidneys were refrigerated and weighed on a digital scale within 48 hours after evisceration of the carcass. The total difference in weight, which represented the fat and connective tissue from both kidneys, was divided by the combined weight of both kidneys without fat or connective tissue. The quotient multiplied by 100/1 gives the kidney fat index in percent.

Intra Muscular Fat

Intra muscular fat was assessed by means of the Soxhlet method (ISO Standard 1444, 1973). Samples were homogenised using a food processor and then evaluated. A 10g sample was analytically weighed onto filter paper and placed onto an extraction thimble and allowed to dry in an air oven overnight. Samples were placed in a Buchi 810 Soxhlet fat extraction unit and distilled using petroleum spirit. Fat extraction took place over four hours. The beakers containing the extracted fat were then dried in an air oven set at 105°C. Beakers were allowed to cool in desiccators prior to analytical weighing. Fat percentage was then calculated. All samples were analysed in triplicate. Precision percentages were within $\pm 0.5\%$.

pH and temperature

The pH of muscles was measured at slaughter (approx. 1 h *post mortem*) and then at 24 hours *post mortem* to determine the ultimate pH (pH^u). For calibration of the pH equipment, buffers of pH 7.0 and 4.0 (TPS Pty Ltd., Brisbane Australia) at room temperature were used. Temperature and pH was measured by inserting a glass electrode (IJ44, Ionode Pty Ltd., Queensland, Australia) and a temperature probe (Stab Temp/ATC Sensor, TPS Pty Ltd., Brisbane, Australia) attached to a portable pH meter (LC80A pH-mV-TEMP, TPS Pty Ltd., Brisbane, Australia) that was temperature compensated. The measurements were taken using a scalpel incision made approximately 2.5cm deep in the muscle tissue.

Tenderness

The meat samples were vacuum packaged, frozen and stored at -20° C until analysis. Half the meat samples were cooked in a water bath set at a constant temperature of 65° C. Internal temperature was measured during and after cooking to 65° C, which is equivalent to medium doneness according to the method described by Shaw (2000). Both raw and cooked meat samples were cut to a 1 cm² core, with a minimum of 5 replicate sub samples taken from each muscle for analysis. Meat tenderness was measured using a Warner Bratzler Shear force attachment on a Stable Micro System TAXT2. Texture analysis was measured by means of force versus time in compression with a crosshead speed of 0.8 mm/s and a trigger force of 10 g with a contact area of 1 mm and contact force of 5 g to determine peak force.

Colour

Objective colour dimensions (L *, lightness, a* redness, b* yellowness) were assessed using the Minolta CR300 Chromometer. The measurements were the average of three readings over the muscle surface after air blooming at 1° C for 60 minutes.

Drip loss

Drip loss was measured on fresh meat samples after hanging in plastic bags for 2 days at + 2° C. All other samples were vacuum packaged. Purge (drip loss in the vacuum bags) was measured after 1, 3 and 6 weeks of refrigerated storage by the following procedure: (1) the weight of meat and vacuum bag was recorded before opening; (2) at opening, any surplus drip on the meat was removed using a paper towel and the drip-free weight of the meat recorded. Thaw loss was measured using the same technique as described for the purge measurements after the meat samples had been removed from the freezer and thawed overnight at +2° C.

Moisture loss - cooking

Cooking loss was measured for all treatments (fresh, frozen/thawed and chilled-stored meat) after the vacuum packed meat samples had been heated to 70° C in a water bath. The samples were weighed in the same way as described for the purge measurements

Sensory evaluation

Descriptive and consumer preference sensory testing was undertaken with 42 panellists recruited via newspaper advertising and email. All procedures for recruitment of panellists and testing of samples were approved by the Human Ethics Committee of UWS (number HEC 03-206). There was a balance of male and female participants and a balanced age distribution from the target market, being 25 to 55 years of age. Panellists were screened to determine if they were eaters of red meat and were willing to try venison or were current venison consumers. Panellists were asked to refrain from smoking one hour prior to and during the sessions. Panellists undertook a familiarisation session to assist in identifying quality parameters for venison i.e. liver/game flavour, colour, tenderness and juiciness and

use of the survey tool. Samples were prepared in vacuum packages immersed in a water bath to reach an internal temperature of between 68-72°C, which is determined to produce a product which remains palatable and safe for consumption. Both the water bath and sample were monitored closely for temperature levels. Panellists were presented the sample identified by random three digit codes and answered questions on the descriptive test by indicating on a 10cm line scale how they rated the sample for flavour, colour, juiciness, tenderness and overall liking (Appendix 1). Panellists were asked to taste up to 6 samples at each panel and attended 4 panels to complete the work. Panellists were seated in individual isolation booths with a drinking cup of water (90(%)) and apple juice (10(%)) to cleanse the palate between tastes. Venison samples were examined for microbial safety prior to and after presentation to panellists, then frozen and stored for 6 months after completion of the panels.

Statistical analysis

Biochemical data and data for various sensory parameters evaluated were analysed using statistical software SPSS 11.5, analysis of variance using the GLM procedure. Treatment means were separated using Ryan's Q test (SPSS 2002). The data for studies on pelvic suspension were analysed by residual maximum likelihood (Patterson and Thompson 1971) with the random effects given by reading within muscle within animal, and the fixed effects by hanging treatment, muscle and their interaction, using the statistical package GenStat (2002). The data from experiments on water holding capacity were analysed by analysis of variance, fitting species for the slaughter data and species, hanging treatment and their interaction with animal as a blocking factor for the meat quality data, using the statistical package GenStat (2002).

Chapter 1: Biochemistry for venison from animals with BCS 2, 3 & 4

Introduction

There are a number of biochemical measurements commonly used by meat scientists for meat description that can also indicate changes to meat quality for eating, cooking, storage and processing purposes. It is well known for instance that muscle pH is associated with muscle tenderness, one of the most important consumer perception traits of meat, but also that pH will affect other important attributes like meat colour and water-holding properties (Hood and Tarrant, 1981). The colour of meat, fresh and after chilled or frozen storage, is an important characteristic for marketing, as customer selection is often associated with the appearance of the product to the exclusion of other characteristics just as important but not readily discernible to the naked eye (Risvik, 1994). Water holding capacity is another characteristic of meat that is connected to consumer perception of fresh, chilled or frozen thawed meat, and is also an important measurement for processors wanting to manufacture value added meat products and smallgoods. The drip loss (purge) often found in trays or packaging when meat is stored for various lengths of time can accelerate meat deterioration and can also decrease attractiveness of the product for consumers, whilst processors need this information to incorporate into processing technologies for a range of meat products.

Fat deposition on a carcass can affect the appearance of meat cuts, can change the rate at which a carcass cools down, can protect the carcass from microbial attack, and can alter the cooking and processing qualities of meat. Assessment of body condition score in live animals is directly associated with sub-cutaneous fat coverage on the carcass and intramuscular and intermuscular (seam) fat deposition (Flesch et al 2000, 2002). If there is a strong relationship between BCS and meat quality characteristics, particularly sensory perception by consumers, then BCS will not only be an important tool in assessing the health and productive potential of farmed deer, but will also assist in quality assurance and product description to enhance marketing opportunities and consumer confidence.

In previous studies (Mulley and Falepau 1999; Mulley and Flesch 2001) involving the slaughter of large numbers of farmed fallow deer it was evident that most fallow deer less than 24 months old presented for slaughter have BCS between 2 and 3, with a relatively smaller proportion with BCS between 3 and 4. In red deer too the most common BCS in slaughter animals less than 2 years old ranges between 2 and 3, with older stags and cull hinds reaching BCS 4 at certain times of the year (stags) and particularly in the case of hinds that did not carry or rear a calf the previous year. Younger animals with higher BCS may be commercially more valuable and suitable for niche markets if consumer acceptance is established, and this would give deer farmer's greater flexibility when establishing marketing options. The viability of getting younger animals to BCS 4 would need to be established given the low feed conversion rate for this group of animals (Mulley et al 2000).

Inconsistency of product may prove to be a major difficulty in establishing repeat purchasing of venison by consumers (Cox et al, 2005) Establishing meat quality characteristics and sensory evaluations using a common BCS language across all sectors of the deer industry should bring about greater consistency of product, as has occurred in other livestock industries such as beef and sheep. The relationship of BCS, biochemical measurements of deer venison and sensory evaluation by consumers has important implications for all sections of the value chain, especially in smaller industries such as the deer industry where it is critical that product potential is maximised.

This section contains biochemical characteristics of venison from red and fallow deer collected in a series of experiments associated with measured BCS in animals of different sex, grown under different feeding regimens, and where the carcasses were treated differently post slaughter and prior to commercial boning. The sensory evaluations of this venison are presented separately in chapter 3 of this report.

1.1 Fallow bucks of BCS 2 to 3

Materials and Methods

Entire (n=20) fallow bucks ranging from 18-24 months old and with BCS ranging between 2 and 3 (lean and prime) were slaughtered by captive bolt stunning and thoracic stick exsanguination within 3 seconds of the stun. All carcasses were split along the spine, with one of the sides hung by the Achilles tendon (AT) and the other side hung by the aitch bone (pelvic suspension) for the Tenderstretch (TS) technique. All sides were measured for core body temperature and muscle pH at 1 and 24 hours post mortem. BCS was measured ante mortem and confirmed with carcass measurements *post mortem*. The *M. longissimus dorsi* muscles (striploins) were boned out from each carcass once core body temperature was less than 7°C post slaughter and divided into 2 sections, one complying with the specified standard for mid-loin according to Ausmeat (1995) guidelines and one from the foreloin section of the muscle. These selected cuts were vacuum packed and frozen at - 21°C until analysed. Samples were analysed in triplicate, for pH, intramuscular fat, colour, shear force, moisture and water holding capacity. Kidneys were excised for later KFI calculations to assist confirmation of BCS.

Results

Tables 1 and 2 display means for meat quality parameters and relationships between hanging method and BCS respectively. There were no statistical differences between carcasses hung post-mortem by the Achilles tendon or Tenderstretch for the meat quality parameters of pH, colour, moisture or fat (Table 1). While there was no detectable difference of hanging method on raw shear (P=0.06), tenderstretch carcasses had significantly lower cooked shear force values than Achilles hung carcasses (P<0.001; Table 1). In this experiment, no significant differences were detected between animals of BCS 2 and BCS 3 in any of the parameters of meat quality, with the exception of water holding capacity (P<0.001; Table 2).

Table 1.1 Meat quality attributes of *M.longissimus dorsi* from fallow bucks hung by the Achilles tendon and pelvic suspension methods.

| Hanging | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) |
|-------------------|-----------------|--------------------|--------------------|------------------|------------------|------------------|------------------|-----------------|----------------------|
| Achilles Hung | 5.80a (0.04) | 5889.5a (341.7) | 2177.4a (115.2) | 20.46a (0.39) | 12.29a (0.52) | 0.088a (0.20) | 75.70a (0.17) | 2.74a (0.16) | 13.56a (0.98) |
| Pelvic suspension | 5.80a (0.03) | 4402.2b (157.8) | 2598.4a (165.6) | 21.21a (0.55) | 11.56a (0.36) | 0.117a (0.11) | 76.02a (0.15) | 3.06a (0.24) | 13.69b (0.76) |

Means and standard error of means (in parenthesis) are shown

Treatments followed by the same letter in the columns are not significantly different (P<0.05)

Table 1.2 Meat quality attributes of *M.longissimus dorsi* from fallow bucks of Body Condition Score 2 and 3.

| BCS | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) |
|-------|-----------------|--------------------|--------------------|-------------------|------------------|------------------|------------------|-----------------|----------------------|
| BCS 2 | 5.80a (0.17) | 5401.5a (386.0) | 2424.9a (176.3) | 20.23a (0.345) | 12.28a (0.47) | 0.084a (0.15) | 75.73a (0.13) | 2.85a (0.21) | 11.24a (0.49) |
| BCS 3 | 5.81a (0.43) | 4890.2a (240.2) | 2350.8a (123.8) | 21.33a (0.57) | 11.58a (0.41) | 0.122a (0.17) | 76.00a (0.19) | 2.96a (0.21) | 16.00b (0.74) |

Means and standard error of means (in parenthesis) are shown.

Treatments followed by the same letter in the columns are not significantly different (P<0.05)

1.2 Differences between slaughter premises for muscle pH

Materials and Methods

Entire (n=32) fallow bucks ranging from 18-24 months old and with body condition scores ranging between 2 and 3 were slaughtered at 3 different slaughter premises. One group (n=8) were slaughtered as described in Experiment 1 at the University experimental abattoir. One group (n=12) were slaughtered at a domestic commercial works using the slaughter technique described in Experiment 1. The final group (n=12) were slaughtered at an export commercial works using the reversible electric stun and gash cut method (Mulley and Falepau, 1999). Carcasses were measured for pH and core body temperature at 1 and 24 hours post slaughter.

Results

Table 1.3 Ultimate pH in *M.longissimus dorsi* from fallow bucks slaughtered at three different slaughter plants.

| Slaughter Premises | pH |
|-----------------------|-----------------|
| Abattoir 1 (UWS) | 5.52a (0.05) |
| Abattoir 2 (domestic) | 5.80a (0.02) |
| Abattoir 3 (Export) | 6.09b (0.09) |

Means and standard error of means (in parenthesis) are shown.

Treatments followed by the same letter in the columns are not significantly different (P<0.05)

There was a significant difference between slaughter plant 3 (export) and the other two premises examined (Table 3). This trial indicates that captive bolt stunning and thoracic stick exsanguination results in carcasses with significantly lower ultimate pH values. Animals held in lairage at the export works were subjected to stresses and noise from working dogs, cattle and sheep held in close proximity. Slaughter plants 1 and 2 were used exclusively for deer with no dogs present.

1.3 Fallow does of BCS 2 to 3

Materials and Methods

Ten non-pregnant fallow does, approximately 36 months old, with a history of one previous lactation were slaughtered using the methods described in Experiment 1. All carcasses were split along the spine, with one of the sides hung by the Achilles tendon and the other side hung by the aitch bone (pelvis) for the Tenderstretch technique. All sides were measured for core body temperature and muscle pH at 1 and 24 hours *post mortem*. BCS was measured ante mortem and confirmed with carcass measurements *post mortem*.

Results

There was no interaction between body condition score and method of hanging the carcass for all parameters measured. Data for BCS were analysed for differences between carcasses hung by the Achilles tendon and carcasses hung by pelvic suspension. There were significant differences between BCS for mid-loin fat ($F_{1,16} = 32.713$, $p < 0.001$) and colour a^* (redness)($F_{1,16} = 4.414$, $p = 0.05$). The data for method of suspension were averaged over BCS. There was a significant difference between methods of suspension for cooked shear ($F_{1,16} = 7.427$, $p = 0.015$) but not for other parameters tested.

Table 1.4 Meat quality attributes of venison from fallow does of BCS 2 (n=8) and BCS 3 (n=12) for *M. longissimus dorsi* , mid- loin section (AusMeat 0079).

| BCS | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) |
|-------|-----------------|--------------------|--------------------|------------------|------------------|-----------------|------------------|-----------------|----------------------|
| BCS 2 | 5.70a (0.02) | 4206.9a (245.7) | 2640.1a (394.8) | 21.91a (0.31) | 12.93a (0.44) | 1.43a (0.29) | 74.91a (0.43) | 1.30a (0.12) | 15.51a (1.42) |
| BCS 3 | 5.72a (0.02) | 4143.1a (214.6) | 2629.5a (194.2) | 22.37a (0.46) | 13.98b (0.27) | 1.84a (0.31) | 74.94a (0.42) | 2.19b (0.09) | 15.02a (0.99) |

Treatments followed by the same letter in the columns are not significantly different ($p < 0.05$)

Table 1.5 Meat quality attributes of venison from fallow doe carcasses hung by either at the Achilles tendon or by pelvic suspension for *M longissimus dorsi*, mid- loin section (AusMeat 0079).

| Method of suspension | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) |
|----------------------|-----------------|--------------------|--------------------|------------------|------------------|-----------------|------------------|-----------------|----------------------|
| Achilles Tendon | 5.73a (0.03) | 4558.6a (217.2) | 2545.9a (277.3) | 22.13a (0.45) | 13.56a (0.39) | 1.68a (0.28) | 75.49a (0.47) | 1.78a (0.18) | 16.67a (1.04) |
| Pelvic Suspension | 5.69a (0.02) | 3778.6b (155.9) | 2721.6a (271.5) | 22.24a (0.43) | 13.56a (0.37) | 1.68a (0.35) | 74.35a (0.28) | 1.89a (0.17) | 13.76a (1.08) |

Treatments followed by the same letter in the columns are not significantly different ($p < 0.05$)

1.4 Fallow bucks and havers

Materials and Methods

Entire (n=25) and castrated (n=11) fallow bucks ranging from 18-24 months old and with BCS ranging between 2 and 3 (lean and prime) were slaughtered as per experiment 1. All carcasses were hung by the Achilles tendon and measured for core body temperature and muscle pH at 1 and 24 hours post mortem. The loin cut from each animal was vacuum packaged and frozen at -21°C until analysed. Samples were analysed in triplicate, for pH, intramuscular fat, colour, shear force moisture and water holding capacity.

Results

A number of meat quality attributes for bucks and havers are shown in Table 6. The data show that there was no statistical difference between bucks and castrated bucks (havers) for intra muscular fat, meat colour lightness (L*), tenderness and moisture content. However, the bucks had higher a* and b* values compared with the meat from havers.

Table 1.6 Meat quality attributes in *M.longissimus dorsi* from fallow bucks and havers of BCS between 2 and 3.

| Sex | HSCW (kg) | pH | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) |
|--------|------------------|-----------------|---------------------|------------------|------------------|------------------|------------------|-----------------|
| Bucks | 25.75a (0.94) | 5.45a (0.08) | 2404.2a (217.67) | 21.27a (0.63) | 12.05a (0.40) | 0.56a (0.39) | 74.99a (0.17) | 0.73a (0.13) |
| Havers | 24.69a (0.60) | 5.42a (0.06) | 2073.9a (283.0) | 19.17a (0.50) | 10.60b (0.41) | -0.80b (0.18) | 75.04a (0.16) | 0.69a (0.17) |

Means and standard error of means (in parenthesis) are shown.

Treatments followed by the same letter in the columns are not significantly different (P<0.05)

1.5 Impact of Supplementary Feeding on meat quality parameters

Materials and Methods

Twenty four non-pregnant fallow deer does approximately 36 months old were slaughtered using methods described in Experiment 1. Twelve of the does were grazed on kikuyu pasture oversown with ryegrass and oats in winter. The remaining twelve animals were fed *ad libitum* lucerne hay and steam rolled barley. Animals were slaughtered in two groups; Group one after 135 days and Group 2 after 170 days of feeding treatment. Samples were analysed for colour stability, drip loss, pH and tenderness. This trial also provided BCS 4 animals for establishing relationships between BCS and eating quality.

Results

There were significant differences between BCS for cooked shear ($F_{2,18}=3.984$, $P=0.037$) and intra muscular fat content ($F_{2,18} = 7.988$, $P=0.010$), and between meat from animals fed concentrate and grazing pasture for cooked shear ($F_{1,18}=5.524$, $P=0.03$). There were also significant differences in meat colour between animals fed concentrates for 135 and 170 days, L ($F_{1,18} = 9.346$), $P=0.007$) a* ($F_{1,18} = 5.903$, $P=0.010$) and b* ($F_{1,18} = 5.671$, $P=0.028$).

There were no significant differences for other parameters tested.

Table 1.7 Meat Quality attributes in *M.longissimus dorsi* from fallow deer does measured at either 135 or 170 days after commencement of feeding with concentrates (n=6 per group), compared with pasture-fed controls.

| Parameters | 135 days Concentrate feeding | | 170 days Concentrate feeding | |
|---|------------------------------|--------------------|------------------------------|--------------------|
| | Pasture | Concentrate | Pasture | Concentrate |
| pH | 5.50 a (0.04) | 5.45a (0.02) | 5.48a (0.09) | 5.47a (0.12) |
| IM fat (%) | 2.36 a (0.57) | 3.49a (1.23) | 2.49a (0.83) | 3.61a (2.27) |
| Colour L* | 21.74a (1.22) | 21.45a (2.15) | 20.94a (1.08) | 21.45a (1.24) |
| Colour a* | 12.14a (0.87) | 12.17a (0.70) | 11.18b (0.78) | 11.18b (0.89) |
| Colour b* | 3.26a (0.73) | 3.06a (1.21) | 2.27a (0.54) | 2.82a (0.91) |
| Cooked Shear Force (g/cm ²) | 4418.6a (457.1) | 3764.7a (564.5) | 4625.5a (618.2) | 3935.3a (780.9) |
| Moisture (%) | 75.66a (1.08) | 74.93a (0.36) | 75.72a (0.36) | 75.24a (0.50) |
| Freeze Thaw loss (%) | 19.69a (3.16) | 19.79a (3.90) | 17.89a (2.06) | 18.43a (2.20) |
| HSCW# (kg) | 28.42a (0.97) | 30.04a (1.62) | 25.25a (1.36) | 27.17a (2.15) |

#Hot standard carcass weight. Means and standard error of means (in parenthesis) are shown. Treatments followed by the same letter in the rows are not significantly different (P=0.05).

Table 1.8 Meat Quality attributes in *M.longissimus dorsi* from fallow deer does with BCS 2, 3 and 4 fed on pasture or concentrates.

| Parameters | pasture feeding | | | concentrate feeding | | |
|---------------------------------------|--------------------|--------------------|----------------|---------------------|--------------------|--------------------|
| | BCS 2 n = 6 | BCS 3 n = 5 | BCS 4 n = 1 | BCS 2 n = 1 | BCS 3 n = 2 | BCS 4 n = 9 |
| pH | 5.48a (0.05) | 5.49a (0.10) | 5.52a | 5.48a | 5.46 a (0.01) | 5.46 a (0.10) |
| IM fat (%) | 2.23a (0.07) | 2.51a (0.73) | 3.15a | 1.36a | 2.70 a (0.70) | 3.99 a (1.76) |
| Colour L* | 21.60 a (1.12) | 20.96a (1.38) | 21.69a | 20.86a | 19.71a (0.27) | 21.90a (1.68) |
| Colour a* | 11.77a (1.20) | 11.66a (0.67) | 10.97a | 11.53a | 11.67a (0.20) | 11.69a (1.08) |
| Colour b* | 3.16a (0.70) | 2.80a (0.74) | 2.96a | 2.14a | 2.24a (0.28) | 3.19a (1.08) |
| Cook Shear force (g/cm ²) | 4476.6a (452.3) | 4638.9a (686.1) | 4210.6b | 4800.5a | 4444.9a (118.0) | 3612.2b (569.6) |
| Moisture (%) | 75.78 (1.09)a | 75.60 (0.31)a | 75.61a | 75.79a | 74.53 (0.11)a | 75.13 (0.36)a |
| Freeze Thaw loss (%) | 20.44a (2.24) | 16.65a (1.99) | 19.60a | 14.60a | 22.89 a (4.07) | 18.77a (2.22) |

Means and standard error of means (in parenthesis) are shown. Treatments followed by the same letter in the rows are not significantly different (P=0.05).

1.6 Red deer stags with BCS between 2 and 3

Introduction

In the previous section studies on fallow deer were conducted to assess changes in meat quality attributes for animals of different sexes. Trials were also conducted to assess the impact of pre-slaughter nutrition and post-slaughter carcass hanging techniques on meat quality. In Australia red deer now comprise half of the national herd of deer, and yield two thirds of the venison harvested each year (Tuckwell, 2003). Studies on red deer carcasses and venison were therefore included in the current project to complement the fallow deer work. Even though more scientific literature on red deer venison is available compared with reports on fallow deer venison, the pelvic suspension (tenderstretch) technique has to our knowledge not previously been evaluated for red deer carcasses and venison quality. Thus, this report provides a unique approach to product quality and consumer acceptance of two types of venison and adds valuable information to the limited overall knowledge about this product.

Materials and Methods

Fourteen rising 2 year old red deer stags averaging BCS 2 were sourced from properties at Blayney and Young, NSW. Body condition score was estimated on the live animal using palpation techniques as described by Flesch et al (2002). Animals were trucked to Myrtleford abattoir and held overnight prior to slaughter with *ad libitum* access to water. All animals were slaughtered as described for fallow deer in experiment 1. Skinning and evisceration were performed with carcasses hanging from a meat rail by the Achilles tendon. At slaughter the hot standard carcass weight was recorded, as was pH in *M.longissimus dorsi* (LD, striploin) and *M.M.gluteus medius* (GM, rump), and core body temperature. Kidneys were excised for later KFI calculations. While hot, carcasses were split along the spine by bandsaw and one half randomly assigned to Achilles tendon suspension whilst the other side was hung by pelvic suspension through the aitch bone.

At 24 hours post mortem carcasses were weighed to determine standard carcass weight. Ultimate pH and final core body temperature was recorded. Fat depth measurements were taken at the GR site with a ruler to confirm BCS post mortem. KFI was also calculated to confirm live animal and carcass BCS assessments.

Three days post mortem the LD muscle from each of the carcasses was removed along with the GM muscle. Samples removed from the carcasses for analysis were placed on marked trays and vacuum packed, aged for 1 week at 4°C, then frozen at -21°C until used for sensory analysis.

Results

There was a significant difference between carcasses hung by the Achilles tendon compared with pelvic suspension for cooked shear ($F_{1,26} = 16.204$, $P < 0.001$) but not for other parameters tested (table 1.9).

Table 1.9 Meat quality attributes in *M. longissimus dorsi* from red deer stags hung by the Achilles tendon or pelvic suspension after slaughter (n = 14 per group)

| Method of Hanging | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) | HSC W# (kg) |
|-------------------|-------------|--------------------|--------------------|----------------|----------------|---------------|----------------|---------------|----------------------|--------------|
| Achilles tendon | 5.63 (2.67) | 5475.78 a (298.13) | 3535.01 a (184.00) | 23.01 a (0.39) | 11.44 a (0.35) | 2.96 a (0.22) | 75.95 a (0.14) | 1.72 a (0.28) | 12.06 a (0.67) | 51.56 (2.67) |
| Pelvic Suspension | As above | 4124.12 b (154.49) | 3761.80 a (167.87) | 23.19 a (0.28) | 11.80 a (0.21) | 3.05 a (0.15) | 75.96 a (0.20) | 1.47 a (0.22) | 10.39 a (0.57) | As above |

Hot standard carcass weight

Treatments followed by the same letter in the columns are not significantly different ($p < 0.05$)

1.7 Red deer stags with BCS of 2,3 and 4

Materials and Methods

Rising 2 year old red deer stags with BCS 2 (n=14), BCS 3 (n=6) and BCS 4 (n=6) were sourced from farms at Neville, NSW (BCS's 3 and 4) and Blayney, NSW (BCS 2). Body condition score was estimated on the live animal using palpation techniques as described by Flesch (2001). Animals were trucked to either Wodonga abattoir (BCS 3 and 4) or Myrtleford (BCS 2) and held overnight prior to slaughter with *ad libitum* access to water. All animals were slaughtered using techniques described in experiment 1, and the carcasses were skinned and eviscerated as described in experiment 6. Carcass measurements and venison samples were also collected as described for experiment 6.

Results

In this experiment there was a significant difference between BCS 3 and BSC 4 in tenderness of raw shear ($F_{2,23} = 4.341$, $p=0.025$) but there was no difference between BSC 2 and BSC 3 or between BCS 3 and BSC 4. There was also no difference between BSC 2, BSC 3 and BSC 4 for cooked shear (Table 10). There were significant differences between BCSs in redness ($F_{2,23} = 5.588$, $p=0.011$) but not in other measured colour parameters (Table 10). There were also significant differences between BCS in intramuscular fat ($F_{2,23} = 70.234$, $p<0.001$) and in HSCW ($F_{2,23} = 35.165$, $p<0.001$) (Table 10), but no significant differences between BCSs for other measured parameters.

Table 1.10 Meat quality attributes of red deer stags of BCS 2, 3 and 4.

| BCS | pH | Cooked Shear (g) | Raw Shear (g) | Colour L* | Colour a* | Colour b* | Moist (%) | IM Fat (%) | Freeze Thaw loss (%) | HSCW # (kg) |
|----------------|-------------------------|----------------------------|-----------------------------|--------------------------|--------------------------|-------------------------|--------------------------|-------------------------|--------------------------|--------------------------|
| BCS 2 (n = 12) | 5.66 a (0.03) | 5403.5 a (292.8) | 3330.4 ab (184.5) | 22.82 a (0.48) | 11.16 a (0.34) | 2.78 a (0.25) | 75.91 a (0.15) | 1.31 a (0.17) | 12.49 a (0.80) | 48.93 a (2.47) |
| BCS 3 (n = 6) | 5.57 a (0.03) | 5724.3 a (397.7) | 3810.6 b (243.2) | 22.64 a (0.34) | 12.88 b (0.34) | 3.35 a (0.11) | 75.67 a (0.26) | 3.22 b (0.34) | 11.51 a (0.97) | 68.05 b (2.96) |
| BCS 4 (n = 8) | 5.63 a (0.01) | 4942.5 a (230.4) | 2846.1 a (201.2) | 23.62 a (0.37) | 12.30 b (0.41) | 3.58 a (0.21) | 76.13 a (0.34) | 4.84 c (0.33) | 12.34 a (0.58) | 75.86 b (1.72) |

Hot standard carcass weight

Means and standard error of means (in parenthesis) are shown.

Numbers in the columns with the same letter are not significantly different ($P<0.05$)

Discussion

Seven different experiments are included in this chapter and will be referred to in the discussion as Experiment 1 – 7. In this series of experiments carcass quality characteristics for entire, castrated fallow bucks and fallow does as well as red deer stags with a BCS between 2 and 4 were established.

The variation in BCS did not result in big differences in any of the measured meat quality attributes for fallow and red deer (Expts. 1, 3 and 7). The fallow does with BCS 3 (Experiment 3) had higher IMF (intra muscular fat) content than does of BCS 2. This difference in IMF content was also the most obvious quality variation between BCS 2 – 4 for red deer (Experiment 7). Sensory analysis and consumer acceptance data has been collected in order to test the hypothesis that BCS and venison quality attributes are related to consumer expectation for the primary measures of eating quality such as tenderness, juiciness and flavour (see further Chapter 3 in this report).

A relationship between BCS and consumer acceptance has previously been established for sheep (Glimp et al 1998) and beef cattle (Gresham et al 1986, Apple et al 1999, Hoving-Bolink et al 1999), with USDA and Meat Standards Australia (MSA) grading systems well established on domestic and international markets. This has re-established consumer confidence and premium prices for product of consistent description and quality in those industries. It remains to be seen if the BCS descriptor system established for deer can be used in a similar way to bring about product consistency for venison.

In Experiment 2 it was demonstrated that the prolonged pre slaughter handling in connection with slaughter at an export abattoir had negative effects on venison pH values. Stress before slaughter can induce muscle glycogen depletion so meat pH stays above 6.2 and dark firm dry meat (DFD) occurs. High pH venison has undesirable characteristics, with a decreased shelf life as one of the major problems. The high pH will promote microbial spoilage, an effect which is especially critical for vacuum packed meat. The frequencies of DFD (meat pH above 6.2 in *M. longissimus dorsi*) in venison have been estimated in Sweden (reindeer, $n=3,500$, Wiklund et al 1995) and New Zealand (red and fallow deer, $n=3,600$, Pollard et al 1999) to 6% in reindeer, 1.5% in red deer and 1% in fallow deer venison.

As the New Zealand deer industry was being established, the use of a mobile slaughter plant was experimented with in order to reduce pre-slaughter handling (Yerex, 1979). However, its use was soon dismissed as an option because it proved to be economically impractical (Seamer, 1986). More recently, mobile plants for deer have operated in Canada (Diversified Animal Management, 1997) and the UK (Anon, 1993; Pollard et al 2002). Mobile slaughter facilities have been used for reindeer in Sweden since 1993, when new directives regarding meat inspection at reindeer slaughter were instituted (National Food Administration, 1998) and consequently many of the former outdoor slaughter sites were closed and the numbers of reindeer transported to slaughter increased (Wiklund, 1996). According to Wilson (1999), regular handling of the deer can reduce the occurrence of pre-slaughter stress since it improves the animal's ability to cope with management practices. Selection of tamer and calmer animals is also an important measure to reduce stress (Wilson, 1999). These practices should be implemented in particular for fallow deer, since it has been demonstrated that they require very careful, slow handling and are prone to panic (Diverio et al 1998; Pollard et al 2002).

The technique to hang carcasses by the pelvic bone ('tenderstretch') instead of in the normal position by the Achilles tendon resulted in more tender meat in the *M. longissimus dorsi* (striploin) for fallow deer bucks and does (Expts. 1 and 3) and red deer stags (Experiment 6). In the Australian beef grading system Meat Standards Australia (MSA) consumer important sensory quality attributes have been weighted in an overall score where tenderness represents 40%, flavour 20%, juiciness 10% and overall liking 30% (MSA, 2001). It is well known that the conditions during rigor development (*e.g.* muscle pH decline, temperature/pH relationship and carcass treatment) are very important in controlling meat tenderisation (Dransfield, 1994). Therefore, carcass suspension techniques have been studied for beef (Hostetler *et al.*, 1970; Lundesjö Ahnström *et al.*, 2003) where the variation in tenderness is considered to be the main reason for consumer dissatisfaction (Koochmaria, 1996). The tenderstretch technique generally improved tenderness in most of the studied muscles, but responses to suspension method were inconsistent and differed by muscles and genders (bulls, heifers and cows), so that equal changes in sarcomere length did not produce equal changes in tenderness (Lundesjö et al 2005). A more detailed description of carcass suspension techniques and their effects on various meat quality attributes is included in Chapter 2 of this report.

In Experiment 5 it was clearly demonstrated that concentrate feeding of the fallow deer does increased BCS (9 animals of 12 classified as BCS 4 compared with 1 of 12 for animals grazing pasture). Also, the concentrate feeding and higher BCS had a strong tendency to increase IMF content and tenderness in the meat. Good pasture and feeding with grain-based pellets improved the nutritional status and physical condition of both reindeer and red deer, and had a considerable effect on muscle glycogen content and meat ultimate pH values (Wiklund et al, 1996; Wiklund et al, 2003b).

The chemical composition of the meat changed so that meat from grazing animals contained more polyunsaturated fatty acids while meat from animals fed grain-based feeds had more saturated fat (Wiklund et al, 2001; Wiklund et al, 2003b). Venison generally has a low fat content but the fatty acid composition is still important for meat shelf life and for the quality of processed meat products. Polyunsaturated fatty acids (PUFA) are more prone to oxidation compared with saturated fats. Therefore the difference in fat composition between grazing animals and animals fed grain-based feeds might also affect the quality of processed meat products (Sampels et al, 2004).

In the present study red and fallow deer between 12 and 30 months of age raised on pasture usually had a BCS between 2 and 3. In Australia most deer are raised on pasture and slaughtered for venison within this age range, so changes to the fatty acid composition of the venison from red and fallow deer grown on pasture is probably rich in PUFA, as described by Wiklund et al (2001, 2003b).

Chapter 2: Post Slaughter Carcass Management

2.1 Relationship of carcass hanging time to meat quality

Introduction

The optimum length of time between slaughter of an animal and boning the carcass into commercial cuts has been a source of constant debate across all sections of the meat industry, from paddock to plate, and for many years. Given the interest in this question it is surprising that there has not been more extensive work done to evaluate the effect of hanging time on meat quality parameters. Lack of chiller storage space and interruption to cash flow have been reasons given by abattoirs and wholesalers to limit the time between slaughter and carcass boning, while retail traders argue that meat quality is more important than storage costs and should dictate when carcasses are on-sold. The meat industry is full of anecdotes on this question and there is little evidence to support many of the claims on the relationship between length of post-slaughter hanging times of carcasses and meat quality parameters. Even more important for the deer industry is the question of whether commercial practices applied to carcasses from traditional domesticated species such as sheep and cattle are appropriate for the much leaner deer carcasses.

This section describes an experiment designed to test whether length of carcass hanging time post-slaughter affects the main meat quality parameters in deer venison. The animals tested represented commercial age and body condition scores for fallow deer of two sexes. Only one deer species (fallow deer) was tested to minimise costs.

Materials and Methods

Entire (n=25) and castrated (n=11) fallow bucks (havers) ranging from 18-24 months old and with body condition scores ranging between 2 and 3 (lean and prime) were slaughtered by captive bolt stunning and thoracic stick exsanguination within 3 seconds of the stun. All carcasses were hung by the Achilles tendon and measured for core body temperature and muscle pH at 1 and 24 hours post mortem. Body condition score was measured ante mortem and confirmed with carcass measurements post mortem according to the method of Flesch et al (2002). Longissimus dorsi muscles were boned out from each carcass at 5 and 10 days post slaughter and divided into 3 sections, one complying with the specified standard for mid loin according to Ausmeat (1995) guidelines, one from the foreloin section of the muscle and a third from the hind loin (distal end). These selected cuts were Cryovac packaged and frozen at -21°Celsius until analysed. Samples were analysed in triplicate, for pH, intramuscular fat, colour, shear force moisture and water holding capacity. All analyses were carried out in triplicate on M longissimus dorsi divided into 3 equal sections, fore (caudal), mid and hind loin.

Results

A number of meat quality attributes for bucks and havers are shown in Table 2.1. The data show that there was no statistical difference between bucks and castrated bucks (havers) for intra muscular fat, meat colour lightness (L*), tenderness and moisture content. There was also no difference in moisture content and tenderness for samples collected between 5 days and 10 days post mortem for the fore-loin, mid-loin and hind-loin samples (Table 2.2).

There was significantly more intra-muscular fat (P=0.039) and moisture (P<0.001) in the forequarter loin when compared with mid and hind-loin samples, although there were no significant differences between mid and hind-loin (P>0.05). Muscle pH changed significantly for all loin sections between 5 and 10 days post-mortem.

Table 2.1 Meat Quality attributes for fallow deer bucks and havers with BCS between 2 and 3, measured at 5 days and 10 days post-mortem.

| Parameters | 5 days post-mortem | | 10 days post-mortem | |
|-------------------|----------------------|----------------------|----------------------|-------------------|
| | Entire bucks | Havers | Entire bucks | Havers |
| PH | 5.45 a (0.08) | 5.42 a (0.06) | 5.63a(0.03) | 5.66a(0.02) |
| IM fat (%) | 0.73a (0.13) | 0.69a (0.17) | not analysed | not analysed |
| Colour L* | 21.27a (0.63) | 19.17a (0.50) | not analysed | not analysed |
| Colour a* | 12.05a (0.40) | 10.60b (0.28) | not analysed | not analysed |
| Colour b* | 0.56a (0.39) | -0.80b (0.18) | not analysed | not analysed |
| Shear force (g) | 2404.20a (217.67) | 2073.87a (283.02) | 2364.14a (148.34) | 1996a (128.47) |
| Moisture (%) | 74.99a (0.17) | 75.04a (0.16) | 74.77a (0.78) | 74.95a (0.12) |
| Water holding (%) | not analysed | not analysed | 0.58a (1.51) | 0.37a (2.35) |
| HSCW# (kg) | 25.75a (0.94) | 24.69a (0.60) | not analysed | not analysed |

#Hot standard carcass weight.

Means and standard error of means (in parenthesis) are shown. Treatments followed by the same letter in the rows are not significantly different (P=0.05).

Nb. not analysed - samples destroyed following bushfire and consequent power loss to freezers

Table 2.2 Mean pH, moisture, shear force and intramuscular fat measurements for fore, mid and hind-loin samples measured at 5 and 10 days post-mortem.

| Parameters | 5 days post-mortem | | | 10 days post-mortem | | |
|-----------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| | fore-loin | mid-loin | hind-loin | fore-loin | mid-loin | hind-loin |
| pH* | 5.46a (0.08) | 5.52a (0.06) | 5.45a (0.08) | 5.57a (0.02) | 5.62a (0.02) | 5.63a (0.03) |
| Moisture (%) | 75.28a (0.18) | 74.99b (0.17) | 74.95b (0.15) | 75.46a (0.14) | 74.78b (0.08) | 74.53b (0.16) |
| Shear force (g) | 3168.43a (389.32) | 2404.20a (217.67) | 2244.31a (181.94) | 2310.37a (124.54) | 2364.14a (148.33) | 2095.45a (163.13) |
| IM fat (%) | 1.20a (0.14) | 0.73b (0.13) | 0.79b (0.12) | not analysed | not analysed | not analysed |

*There was a significant change of pH between 5 and 10 days post-mortem.

Treatments followed by the same letter in the rows are not significantly different (p<0.05)

Discussion

There was no significant difference in meat quality parameters, including tenderness between carcasses sampled 5 days and 10 days post-slaughter. There has long been anecdotal debate about the merits of hanging venison carcasses longer, and the affect this has on meat tenderness, but for animals in the current study with BCS between 2 and 3 there was no apparent difference resulting from hanging carcasses longer. These results in fallow deer agree with previous studies on reindeer where optimal tenderness in the meat was achieved already after 1-3 days of ageing of the meat (Wiklund et al, 1997). Most commercial venison carcasses in Australia are broken into primal cuts between 1 and 3 days post-slaughter to avoid weight loss from dehydration in the chiller. It would appear that commercial carcasses with BCS between 2 and 3 can be processed at a range of times after slaughter, without changing venison quality parameters, as longer hanging times did not enhance or adversely affect parameters that are associated with tenderness, juiciness and flavour for either of the sexes tested. This adds considerable flexibility to commercial practice, especially given the circumstance that deer are usually slaughtered in abattoirs primarily used for the slaughter of other species, and operating under the commercial constraints developed to service the wider meat industry.

In this experiment there was no difference in intra-muscular fat between entire and castrated bucks, yet Mulley et al (1996) showed castrates to be fatter in all depots than entires at this age. Results in the current study may just relate to animals of BCS 2 to 3, as BCS was not estimated for animals used by Mulley et al (1996). In previous studies of venison characteristics, for most species of deer, there has been only rudimentary information given about the age, weight and management of the animals used to derive the data. From the data provided by Flesch et al (2002) for fallow deer, and Audige et al (1998) for red deer on physical and carcass differences between various BCS categories, it may be necessary to redefine some of those meat quality measurements. In the commercial deer industry carcass weight is a primary descriptor for payment to farmers, yet it is possible that 2 animals with the same carcass weight could have very different BCS and provide very different results for sensory evaluation. Meat quality parameters such as intra-muscular fat, moisture, water holding capacity and possibly shear force could change with BCS, along with changes that occur between sexes and between seasons of the year.

The fore-loin (caudal end) had significantly more fat and moisture than the mid and hind-loin, a result consistent with the way in which fat accretion develops in other livestock species. These data are unlikely to be of any commercial consequence in fallow deer given the small size of the meat cut and the way in which this primal cut is marketed (i.e. as one whole piece, either bone-in (rack) or bone out.)

Given the outcomes of this study it was concluded that factors other than post slaughter hanging time of carcasses were more likely to affect venison quality.

2.2 Pelvic suspension V Achilles tendon hanging of carcasses

Introduction

Muscles in the butt and loin of a carcass can be restrained from shortening by hanging the whole carcass by the aitch bone (obturator foramen) or the pelvic ligament. This process is referred to commercially as tenderstretching or pelvic suspension, and has been shown to increase meat tenderness in several other species (Sims et al 2004). Tenderness is one of the most important parameters as rated by consumers, in terms of eating quality. Major factors which affect tenderness include cut of meat, animal age, cold shortening that can occur during chilling and pre-slaughter animal stress leading to high pH. Toughness can be prevented by the use of techniques such as electrical stimulation, which accelerates rigor and pH decline (Wiklund et al 2001a), or hanging the carcass in such a way that muscles will be stretched and not allowed to contract, hence the term 'tenderstretch'.

Cold shortening is the process whereby muscle fibres contract when the carcass is chilled rapidly below 12°C before the onset of rigor and this can result in toughness in the meat.

Lean, light carcasses, such as deer carcasses chill more rapidly than fat, heavy carcasses and can yield tougher meat in muscles that are free to shorten. The process of 'tenderstretch' may adversely affect the tenderloin cut of meat because of the way this cut contracts in the 'tenderstretch hanging position but this change may not be detectable by the consumer because this cut is naturally very tender and represents a very small proportion of each carcass. There is no effect on forequarter cuts from tenderstretch as no extra tension is applied to these muscles. Tenderstretch hanging, if found to be beneficial in producing consistently tender venison may be a useful alternative technique to electrical stimulation in Australia, where electrical stimulation is generally unavailable for deer processing.

Materials and methods

Eight fallow deer bucks (18 months old, average live weight 42 (kg), body condition score (BCS) 2-3, (7 fallow deer bucks (\geq 36 months old, average live weight 57 (kg), BCS 2-3) and 10 fallow deer does (24 months old, average live weight 38 (kg), BCS 2-4) raised at the University of Western Sydney, were included in the study. The animals were fasted for 16 h prior to slaughter, stunned with a captive bolt and bled using thoracic stick exsanguination within 10 s of the stun (ethics approval UWS 00.09). The dressed carcasses were split along the mid ventral axis approx. 45 – 75 min post slaughter. The left side of each carcass was assigned to Achilles tendon suspension (control treatment) and the right side of each carcass was assigned to pelvic suspension. At 2 days post slaughter, 9 selected muscles were collected from each carcass-half (*Mm. semimembranosus, adductor femoris, biceps femoris, semitendinosus, vastus lateralis, rectus femoris, psoas major, longissimus* and *supra spinatus*). The meat samples were vacuum packaged, frozen and stored at -20°C until analysis. Meat samples were cooked on a Silex grill for 4-7 minutes at 240°C and then wrapped in aluminium foil and allowed to rest for 5 minutes. Internal temperature was measured during and after cooking to $60-65^{\circ}\text{C}$, which is equivalent to medium doneness according to the method described by Shaw (2000). Meat samples were cut to a 1cm^2 core, with a minimum of 5 replicate sub-samples taken from each muscle for analysis. Meat tenderness was measured using a Warner Bratzler Shear force attachment on a Stable Micro System TAXT2. Texture analysis was measured by means of force versus time in compression with a crosshead speed of 0.8 mm/s and a trigger force of 10g with a contact area of 1mm and contact force of 5g to determine peak force. The data for each experiment was analysed statistically by residual maximum likelihood (Patterson & Thompson, 1971), with the random effects given by reading within muscle within animal, and the fixed effects by hanging treatment, muscle and their interaction, using the statistical package GenStat (2002).

Results and discussion

The present results suggest that pelvic suspension of the carcasses had the greatest impact on meat tenderness in venison from the young male fallow deer (18 months old, Figure 2.1), some impact on tenderness in venison from the older male deer (\geq 36 months old, Figure 2.2) but no impact at all on tenderness in venison from the female deer (24 months old, Figure 2.3). In studies of beef, similar differences in effect of pelvic suspension on meat tenderness for bulls and heifers have been reported. The tenderness in meat from bulls was more improved as an effect of pelvic suspension compared with meat from the heifers (Fisher et al, 1994; Lundesjö Ahnström *et al.*, 2003).

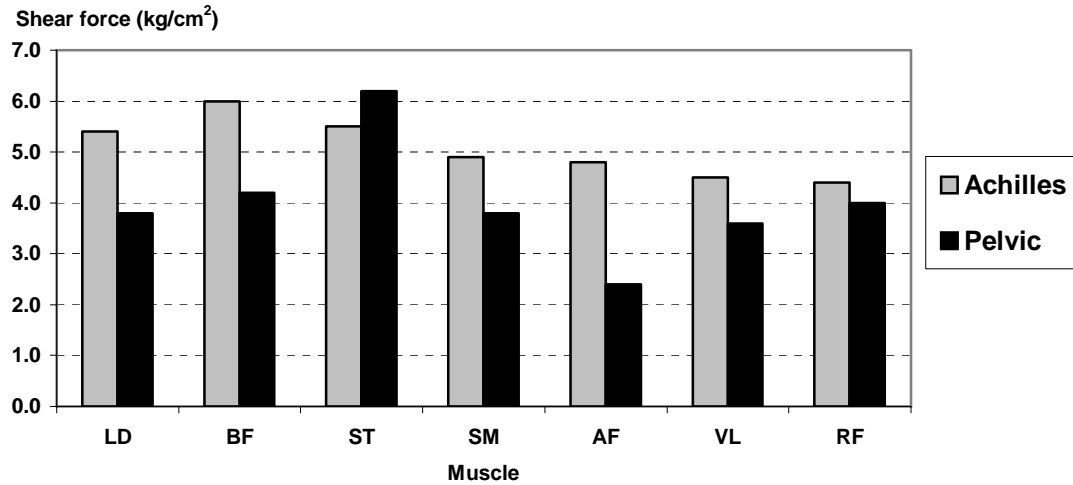


Figure 2.1 Shear force mean values in 7 muscles (LD = *M. longissimus*, BF = *M. biceps femoris*, ST = *M. semitendinosus*, SM = *M. semimembranosus*, AF = *M. adductor femoris*, VL = *M. vastus lateralis* and RF = *M. rectus femoris*) from fallow deer bucks (18 months old, n=8).

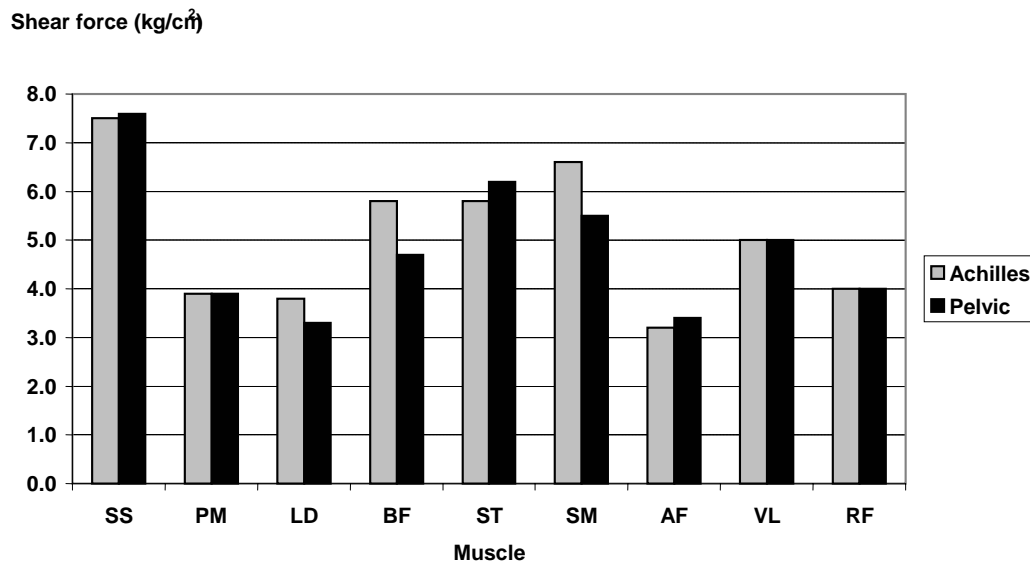


Figure 2.2. Shear force mean values in 9 muscles (SS = *M. supraspinatus*, PS = *M. psoas major*, LD = *M. longissimus*, BF = *M. biceps femoris*, ST = *M. semitendinosus*, SM = *M. semimembranosus*, AF = *M. adductor femoris*, VL = *M. vastus lateralis* and RF = *M. rectus femoris*) from fallow deer bucks (≥36 months old, n=7).

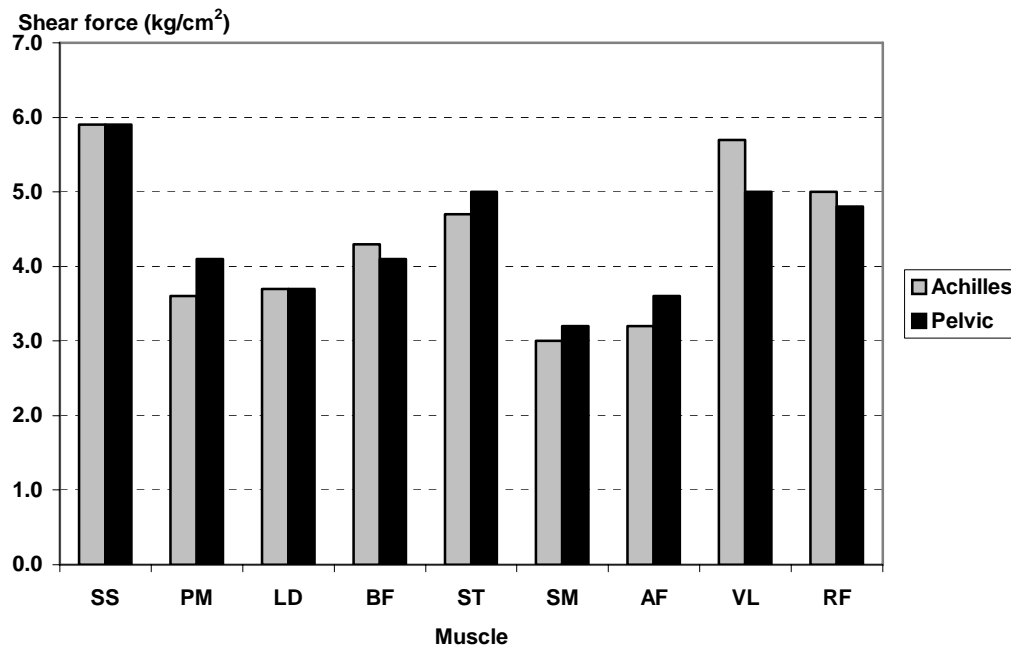


Figure 2.3. Shear force mean values in 9 muscles (SS = *M. supraspinatus*, PM = *M. psoas major*, LD = *M. longissimus*, BF = *M. biceps femoris*, ST = *M. semitendinosus*, SM = *M. semimembranosus*, AF = *M. adductor femoris*, VL = *M. vastus lateralis* and RF = *M. rectus femoris*) from fallow deer does (24 months old, $n=10$).

In the carcasses from the young fallow deer bucks, the tenderness of the following muscles was significantly improved ($p \leq 0.05$) as a result of pelvic suspension; *Mm. longissimus*, *biceps femoris*, *semimebranosus*, *adductor femoris* and *vastus lateralis*. These results are in good agreement with earlier studies on beef, where the tenderness of *Mm. longissimus*, *semimembranosus* and *adductor femoris* was positively affected by pelvic suspension (Hostetler *et al.*, 1970; Bouton *et al.*, 1973). For the older fallow deer bucks, significant effects of pelvic suspension on meat tenderness were found in *Mm. biceps femoris* and *semimembranosus*. The muscles that improved in tenderness as a result of pelvic suspension in the present study are all part of the most valuable cuts in a deer carcass; *M. longissimus* (striploin), *Mm. semimembranosus* and *adductor femoris* (topside), *M. biceps femoris* (silverside) and *M. vastus lateralis* (knuckle).

The positive effect of pelvic suspension on tenderness in venison from the young male fallow deer is important information to consider for the Australian deer industry. This type of animal represents the deer most likely to be supplied for commercial slaughter in Australia. In addition, the important commercial cuts from female deer were generally more tender than the same cuts from males. The slaughter of female deer therefore provides a good option for farmers wishing to supply chilled venison year-round, especially at times of the year when the quality of venison from male deer is negatively affected by the breeding season.

2.3 Carcass suspension method and drip loss

Objectives

The objective of this study was to compare two different hanging techniques of carcasses (Achilles tendon suspension and pelvic suspension) and the effects on water-holding properties of deer and lamb meat. In addition, the water holding capacity of long term chilled (up to 6 weeks post slaughter) deer and lamb meat was measured.

Materials and methods

Ten female lambs (F1 Merino/Border Leicester x Texel, 5½ months old) and 10 female fallow deer (*Dama dama*) (15 months old) raised at the University of Western Sydney, were included in the study. The animals were fasted for 16 h prior to slaughter, stunned with a captive bolt and bled using thoracic stick exsanguination within 10 s of the stun (ethics approval UWS 04.01). The dressed carcasses were split along the mid ventral axis approx. 45 – 75 min post slaughter, and each carcass side was randomly assigned to either Achilles tendon suspension (control treatment) or pelvic suspension. At 1 day *post mortem*, both *M. longissimus* (striplains) from each carcass were collected, cut in 5 pieces and randomly assigned to a treatment of 1, 3 or 6 weeks of refrigerated storage (+2° C), freezing (-20° C) or just analysed as fresh meat. Drip-loss was measured on the fresh meat samples after hanging meat samples in plastic bags for 2 days at +2° C. All other samples were vacuum packaged. Purge (drip loss in the vacuum bags) was measured after 1, 3 and 6 weeks of refrigerated storage by the following procedure: (1) the weight of meat and vacuum bag was recorded before opening; (2) at opening, any surplus drip on the meat was removed using a paper towel and the drip-free weight of the meat recorded. Thaw loss was measured using the same technique as described for the purge measurements after the meat samples had been removed from the freezer and thawed overnight at +2° C. Cooking-loss was measured for all treatments (fresh, frozen/thawed and chilled-stored meat) after the vacuum packed meat samples had been heated to 70° C in a water bath. The samples were weighed in the same way as described for the purge measurements.

Results

The lambs had higher live weights compared with the deer ($p \leq 0.01$), but lower carcass weights and dressing percentages ($p \leq 0.001$) (Table 2.4). pH decline registered 1-24 hours *pm* did not differ ($p > 0.05$) between the two carcass treatments or between species (Fig. 2.4), and the mean ultimate pH values recorded at 24 h *pm* in *M. longissimus* (LD) were 5.69 (lamb) and 5.68 (deer). However, after 1 week of refrigerated storage pH dropped below 5.60, and was significantly lower in the lamb than in the deer samples (Table 2.4). After 3 and 6 weeks of storage pH was not significantly different from ultimate pH (Table 2.4). These results are in good agreement with an earlier study of red deer meat, where the same pattern for pH variation over storage time was observed (Wiklund *et al.*, 2001b). Mean temperature was higher in lamb than in deer LD at 1 hour ($p \leq 0.05$) and lower at 24 hours ($p \leq 0.05$) *pm*, but was not significantly different between species during the main intermediate period of decline.

Table 2.3 Mean live weight, carcass parameters and pH values in *M. longissimus* after 1, 3 and 6 weeks of refrigerated storage (+2° C) of the fallow deer and lamb included in the study, with standard errors of the difference (S.E.D.)

| Trait | Deer (n=10) | Lamb (n=10) | S.E.D. | Degree of sign. ¹ |
|------------------------------------|-------------|-------------|--------|------------------------------|
| Live weight, (kg) | 36.7 | 39.9 | 1.08 | ** |
| Carcass weight, (kg) | 21.2 | 19.1 | 0.58 | *** |
| Dressing percentage | 57.9 | 47.8 | 0.72 | *** |
| pH values in <i>M. longissimus</i> | | | | |
| 1 week | 5.59 | 5.55 | 0.010 | *** |
| 3 weeks | 5.67 | 5.67 | 0.015 | n.s. |
| 6 weeks | 5.68 | 5.66 | 0.009 | * |

¹ n.s. = $p > 0.05$; * = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$.

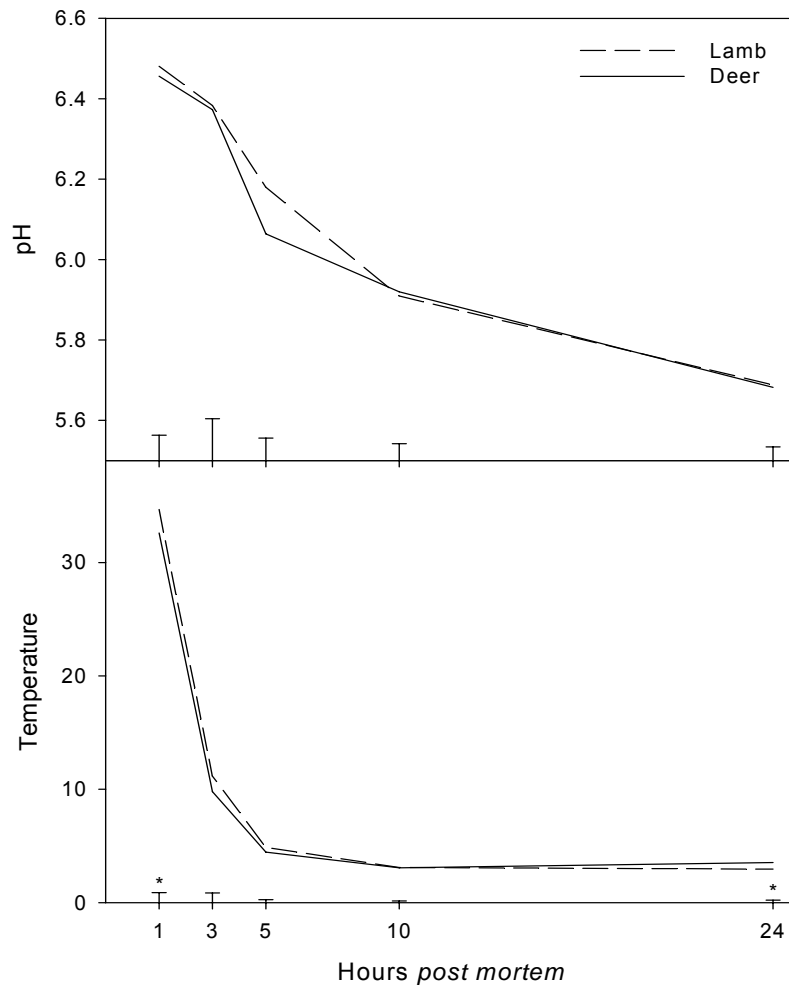


Figure 2.4. Mean temperature and pH (with standard errors of difference) measured at 1, 3, 5, 10 and 24 hours post mortem in *M. longissimus* from lamb (n=10) and fallow deer (n=10)

Among the measured water-holding traits, the carcass suspension technique had an effect on drip loss and purge. Drip loss in fresh meat was significantly lower with Achilles tendon suspension, while purge in the vacuum bags during storage was lower with pelvic suspension, significantly so for 3 weeks storage (Fig. 2.5). The only significant difference between species was found in drip loss where the deer meat had better water-holding capacity than the lamb meat (1.67%) versus 2.24(%) of drip loss). Cooking loss and freeze/thaw loss was not affected by carcass treatment ($p \geq 0.05$), although a significantly higher cooking loss in the deer samples compared with the lamb samples was registered in fresh meat (Fig. 2.6). The present results on the positive effects of pelvic suspension on purge in deer and lamb support earlier findings in beef (Lundesjö Ahnström *et al.*, 2003), though in the beef study positive effects of pelvic suspension on cooking loss and freeze/thaw loss were also reported. The present values measured for drip loss and cooking loss in lamb samples were in good agreement with previously reported values for lamb LD (Hoffman *et al.*, 2003).

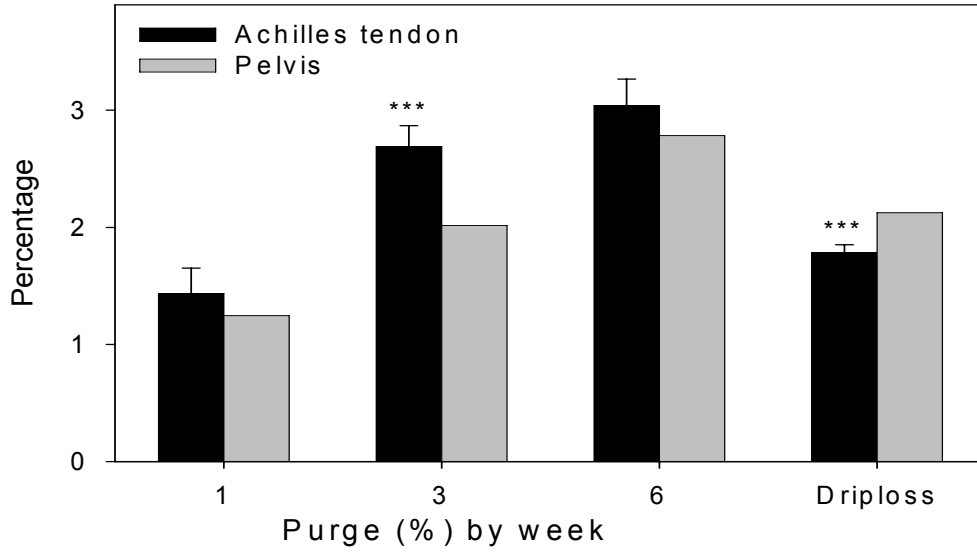


Figure 2.5 Purge (measured after 1, 3 and 6 weeks of refrigerated storage at + 2 degrees C) and drip loss in *M.Longissimus* from lamb (n=10) and fallow deer (n = 10) carcasses subjected to two different treatments: Achilles tendon suspension and pelvic suspension.

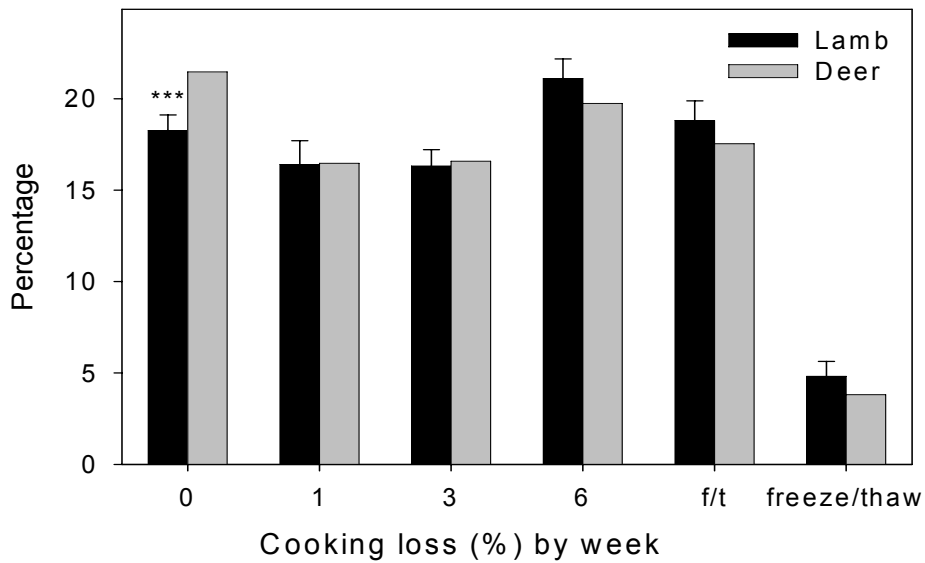


Figure 2.6 Cooking loss (in fresh meat (0), frozen/thawed meat (f/t) and meat stored for 1, 3 and 6 weeks at + 2 degrees C) and freeze/thaw loss in *M.Longissimus* from lamb (n=10) and fallow deer (n=10) included in the study.

Conclusions

Knowledge about the quality attributes of fresh chilled venison is of strategic importance to the Australian deer industry. At present much of the venison produced in Australia is sold frozen, but the demand for fresh meat is expected to increase in the future.

Slaughter and post-slaughter carcass management techniques that can be shown to bring about greater product consistency are of vital importance to the future growth of the deer industry, which is characterised by low numbers of slaughter age stock produced under variable conditions across farms.

In the present study pelvic suspension of carcasses has been demonstrated to improve tenderness in meat from young fallow deer bucks, the type of animals most likely to be supplied by fallow deer farmers for commercial slaughter in Australia. Results from chapter 1 for fallow deer of different BCS, age and sex, and for red deer, also indicate that pelvic suspension increases the tenderness of venison, the quality attribute determined by consumers as being of most importance. Given the consistency of this result and the importance of meat tenderness in the meat retail sector this technique should be adopted by the Australian deer industry, especially given the low availability of other techniques associated with increasing meat tenderness such as electrical stimulation. If electrical stimulation of carcasses were to become more widely available in slaughter premises in Australia it would also be interesting to trial the techniques of pelvic suspension and electrical stimulation of carcasses in combination with each other to evaluate possible cumulative effects. The present results also indicate that pelvic suspension has a positive effect on water-holding properties by reducing moisture loss of fresh chill-stored fallow deer venison, an important consideration given that juiciness is the second most important characteristic of meat according to consumer surveys.

In these experiments it was also demonstrated that there is no commercial advantage in hanging fallow deer carcasses for extended periods of time after slaughter to increase tenderness, a technique that has been applied to carcasses from older animals harvested from the wild in other parts of the world. Analysis of data from this study indicates that carcasses from deer farmed commercially and slaughtered for meat can be broken into primal cuts using the same time periods used on carcasses from sheep and cattle, with no loss of eating quality. This is an advantage to the deer industry because no special longer-term storage requirements are therefore necessary.

Chapter 3: Sensory evaluation of venison

Introduction

Sensory analysis of venison from red and fallow deer using consumer preference tests is described in this section.

The palatability of a food product largely determines whether a consumer chooses to include that product in their diet range, though factors such as price, availability and cultural acceptability will also influence whether particular products are consumed regularly. For meat products the characteristics of palatability most commonly referred to by consumers are tenderness, juiciness and flavour, though it is likely that considerable variation exists between consumers as to which part of this combination contributes most to their eating experience. Various machines and laboratory assays can quantify individual characteristics of meat but the palatability or overall liking is an imprecise science that can only be measured by consumers, varies between consumers and combines several characteristics in its appraisal (Aberle et al 2001). Variation in any one characteristic can alter the palatability mix and change the overall liking.

There are many areas in the value chain from paddock to plate that can affect palatability and these need to be standardised where possible for sensory evaluation to be informative. The age of an animal, husbandry and management, slaughter techniques and post slaughter carcass storage can all be standardised, therefore cooking technique and cut of meat must also be standardised for sensory evaluation work to be meaningful and comparative. Variations in cooking technique between consumers can alter the perception and palatability of meat (Aberle et al 2001) so for comparative sensory analysis of product between consumers the cooking technique must be standardised, as described in the general materials and methods section of this document. Although the cooking technique applied to sensory work is different to that which would be applied commercially in some cases, in that the charcoal layer of steak cooked on a hot plate or embellished flavours from marinades and sauces are missing, the ability to compare tenderness, juiciness and natural flavour in a standardised way between samples is retained.

There is considerable literature on the impact of animal age and cut of meat on meat quality (Berg and Butterfield 1976, Butterfield 1988, Lawrie 1991 Aberle et al 2001), particularly tenderness. Although muscles of very young animals are more tender than those of aged animals (Aberle et al 2001), changes occurring with age are not linear with increasing age (Butterfield 1988). As animals grow, muscle growth and fat deposition occur at different rates, producing considerable variation within the carcass depending on when the animal is slaughtered. During rapid phases of growth, tenderness increases with time because rapid development of muscle fibre size “dilutes” existing connective tissue. Thus, market weight beef animals (12 to 18 months of age) often have more tender meat than growing calves (6 months of age) (Aberle et al 2001). This is also likely to be the case in deer although there is no evidence based on experimental work to support this.

Aberle et al (2001) also contend that meat flavour increases as animals get older. They suggested that the likely cause of flavour change with increased age is due to an increase in concentration of nucleotides in muscle, which degrade to inosinic acid and hypoxanthine post-mortem. Flavour intensity may become so great that it is objectionable to some consumers, an example being the strong mutton flavour of mature sheep or meat from game animals.

As animals mature body composition ratios of muscle:bone:fat occur (Butterfield 1988), with body fat deposition (intramuscular and intermuscular) increasing proportionately to muscle and bone under normal growth patterns. The relationship between fat content and some quality attributes has been established for some meats (eg. Beef), though has not been considered as important with deer venison because the leanness of venison is considered to be an important marketing strength.

However, linkage of BCS with animal age can assist with standardising physical (cut size, tenderness) and biochemical (flavour, colour) characteristics once consumer preference is known, in addition to providing important information on the husbandry and management of animals pre-slaughter.

Previous chapters have described biochemical attributes and physical characteristics commonly measured for meat, and post slaughter carcass management that can influence some of those measurements. This section describes sensory analysis of venison from red and fallow deer using consumer preference tests. The data are arranged separately for fallow deer and red deer.

3.1 Fallow Deer (pasture-fed)

Introduction

A series of experiments were performed to investigate the effect of BCS and method of post-slaughter carcass management on sensory perception of venison quality by consumers. The biochemistry of meat from these carcasses is described for bucks and does in experiments 1-4, chapter 1.

Materials and methods

The methods used for sensory evaluation are described in detail in the methods section, so will not be repeated here. Briefly, on the day of testing panellists were seated in individual isolation booths with a drinking cup of water (90%) and apple juice (10%) to cleanse the palate between tastes. Panellists were presented the sample identified by random three digit codes and answered questions on the descriptive test by indicating on a 10cm line scale how they rated the sample for flavour, colour, juiciness, tenderness and overall liking. The data entry sheet provided to panellists is presented as appendix 1. Panellists were asked to taste up to 6 samples at each panel and attended 4 panels to complete the work. All meat samples tested were from the muscle *M. M.gluteus medius* (rump).

Results

The data are arranged to compare sensory evaluation of venison from bucks and does (table 3.1), differences in BCS (table 3.2) and method of post-slaughter hanging in the chiller (table 3.3). In the comparison for sex effects (table 3.1) venison from the 36-month-old does scored significantly higher for flavour strength ($F_{1,336} = 5.19, p=0.023$), for tenderness ($F_{1,336} = 13.96, p<0.001$) and for colour ($F_{1,336} = 30.027, p<0.001$) compared with the 18-24 month-old bucks.

Table 3.1 Mean (+/- SE) sensory evaluation scores for fallow deer bucks and does (n = 10)

| Sex | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tenderness | Juiciness | Overall Liking |
|------|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|------------------|
| Buck | 7.74a (0.18) | 8.48a (0.15) | 7.73a (0.17) | 9.74a (0.17) | 8.12a (0.17) | 6.56a (0.20) | 8.71a (0.22) | 8.07a (0.21) | 9.97a (0.20) |
| Doe | 9.08b (0.17) | 8.71a (0.16) | 7.53a (0.18) | 9.92a (0.18) | 8.65b (0.15) | 6.90a (0.20) | 9.76b (0.17) | 7.96a (0.21) | 10.15a (0.14) |

Numbers in columns with the same letter are not significantly different

Table 3.2 Mean (+/- SE) sensory evaluation scores for fallow deer bucks and does with BCS of either 2 (n = 8) or 3 (n = 12)

| BCS | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tender-ness | Juiciness | Overall Liking |
|-----|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|------------------|
| 2 | 8.41a (0.19) | 8.61a (0.15) | 7.60a (0.17) | 9.78a (0.18) | 8.49a (0.17) | 6.80a (0.21) | 9.22a (0.20) | 7.92a (0.20) | 10.06a (0.20) |
| 3 | 8.41a (0.18) | 8.58a (0.16) | 7.66a (0.17) | 9.87a (0.18) | 8.28a (0.16) | 6.66a (0.19) | 9.24a (0.21) | 8.11a (0.22) | 10.24a (0.19) |

For animals with BCS 2 or 3 there were significant differences between sexes in colour ($F_{1,128} = 61.44$, $p < 0.001$ and $F_{1,128} = 6.58$, $p = 0.01$ for BCS 2 and 3 respectively with the venison from does being preferred by consumers in each case (Figure 3.1). There was also a significant interaction between sex and BCS for rating of colour ($F_{1,336} = 6.01$, $p = 0.015$).

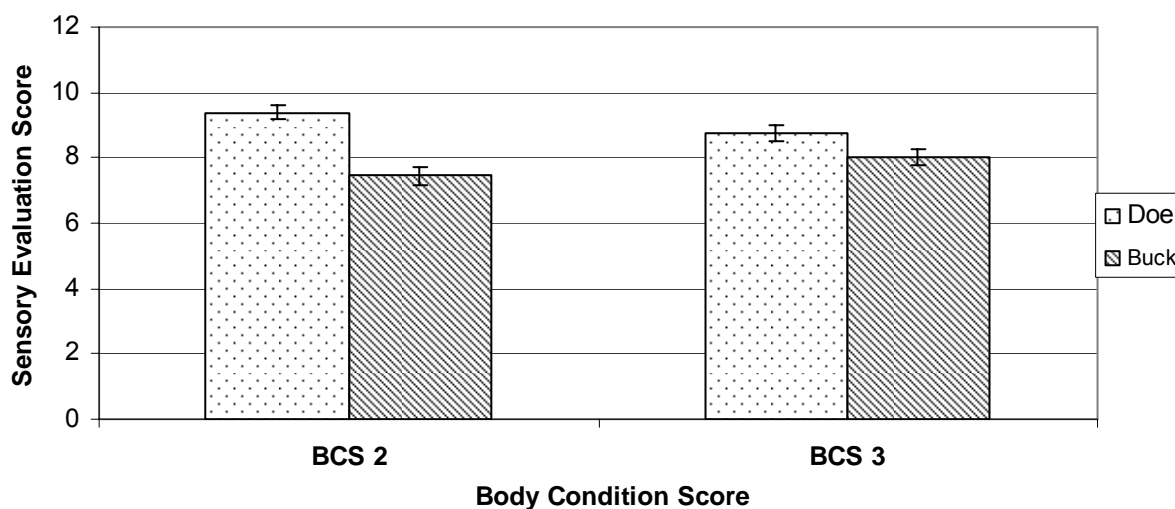


Figure 3.1 Mean (+/- SE) sensory panel scores on meat colour for venison from fallow deer bucks and does with body condition scores of 2 and 3.

When the data were analysed for differences in consumer evaluation of venison from carcasses hung by either pelvic suspension or Achilles tendon (table 3.3) the pelvic suspension method scored significantly higher for tenderness ($F_{1,336} = 8.46$, $p = 0.004$) and juiciness ($F_{1,336} = 6.53$, $p = 0.011$). There were no significant differences between factors for other sensory parameters measured.

Table 3.3 Mean (+/- SE) sensory evaluation scores for venison from fallow deer bucks and does hung by either the Achilles tendon or by pelvic suspension (n=20 of each)

| Suspension Method | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tender-ness | Juici-ness | Overall Liking* |
|-------------------|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|------------------|
| Achilles tendon | 8.74a (0.18) | 8.39a (0.16) | 7.80a (0.17) | 9.74a (0.16) | 8.52a (0.16) | 6.71a (0.20) | 8.82a (0.21) | 7.64a (0.21) | 9.92a (0.18) |
| Pelvic suspension | 8.09b (0.19) | 8.80a (0.15) | 7.46a (0.18) | 9.91a (0.19) | 8.25a (0.17) | 6.75a (0.21) | 9.64b (0.19) | 8.39b (0.21) | 10.38a (0.20) |

Measurements in columns with the same letter are not significantly different

There was a significant interaction between BCS and method of carcass hanging. If BCS was 2 there was no difference between the sexes in rating of overall likeness. However, if BCS was 3 then venison from carcasses hung by pelvic suspension was rated more acceptable than venison from carcasses hung by the Achilles tendon ($F_{1,170} = 7.266$, $p = 0.008$) (Figure 3.2).

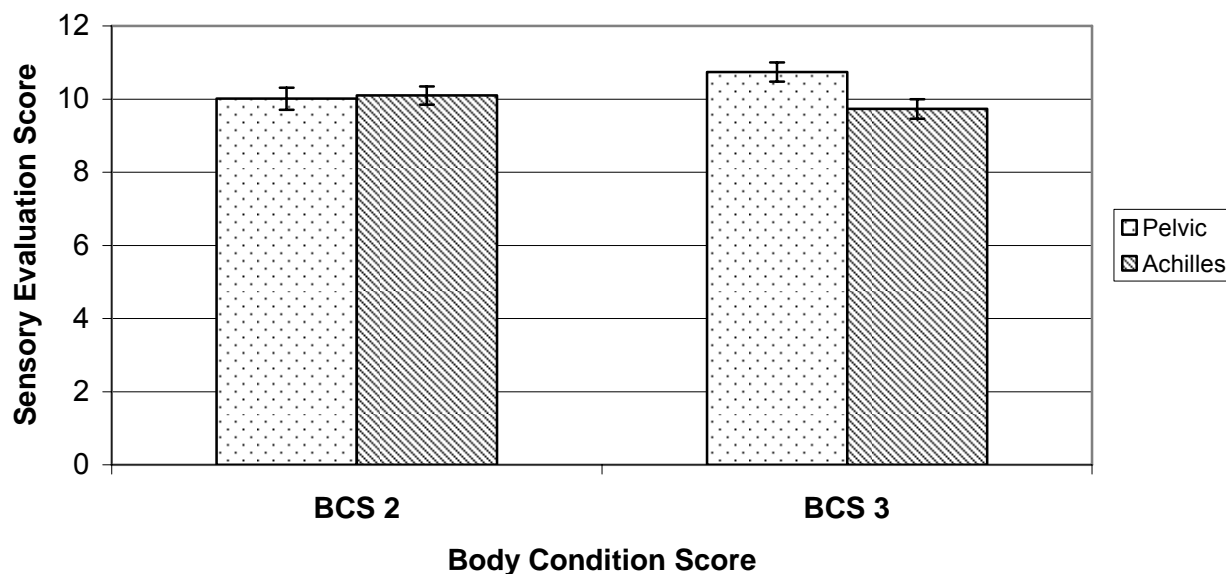


Figure 3.2 Mean (+/- SE) sensory panel scores on overall liking of venison from fallow deer with body condition scores of 2 and 3. Carcasses were hung by the Achilles tendon or by pelvic suspension.

Discussion

From this set of experiments there were a number of key findings. Does were generally more tender than bucks, even at older ages, and had a high overall liking rating by consumers even though the meat was significantly darker and had a stronger flavour. This general acceptance of venison from older does is quite important as farmers can now consider early culling of does that are not performing in the breeding herd, without losing carcass value. This practice will only be effective if wholesalers also accept the consumer ratings from sensory tests, and don't superimpose values held for other domestic meats on venison. According to Sims (2004) similar studies on cattle have shown heifers to be significantly more tender than steers and bulls which corroborates the present findings for deer. The data indicate no overall difference in liking for BCS 2-3 animals, whether bucks or does. This is also important given that most fallow deer presented for slaughter fall into this BCS range.

Consumers clearly distinguished their overall liking for venison derived from carcasses treated with pelvic suspension post-slaughter, with the important quality characteristics of tenderness and juiciness improved by this technique. This finding is consistent with the data in chapters 1 and 2, and indicates that the technique of pelvic suspension should be adopted by the deer industry to produce venison that consumers have an increased preference for. There was a significant interaction between BCS and method of hanging between the sexes in rating of overall liking, whereby consumers were unable to differentiate between venison hanging techniques at BCS 2, but had a definite preference for venison from carcasses hung by the pelvis at BCS 3. This increased rating for venison of higher BCS is further investigated later in this chapter.

3.2 Fallow Deer - Impact of Supplementary Feeding

Introduction

Body condition score is a useful tool in assessment of animal well-being, and a frequently used descriptor in the buying and selling of livestock for slaughter. The BCS of an animal can be altered by the presence or absence of supplementary feeds, and meat production systems for beef, pork and chicken frequently utilise supplementary feeding to increase feed conversion efficiency and to produce carcasses that consistently meet market specifications. Market specifications are often established according to the amount of subcutaneous fat coverage on the live animal and scales of reference have been established that allow accurate prediction of carcass characteristics from live animal BCS assessments in fallow (Flesch et al 2002) and red deer (Tuckwell 2003). Feeding red deer and reindeer commercial feed mixtures (grain-based) pellets) for 8-10 weeks prior to slaughter has been demonstrated to significantly change the flavour of venison compared with control groups of animals grazing natural pasture before slaughter (Wiklund et al 2003b, 2001). In the quest to meet market specifications for various deer species, it is of great interest to also study the effects of supplementary feeding of fallow deer on venison flavour. Although cooking methods are usually implicated in changes to odour and taste of meat the food eaten by other domesticated meat animals (beef and sheep in particular) immediately prior to slaughter has been shown to alter the taste (Lawrie 1991), with the same author indicating that the degree of fatness of the carcass can also change perceptions of flavour.

In the current study it was evident that slaughter-aged (12-24 months) fallow deer are usually in the 2-3 BCS range, though older animals can reach BCS 4-5 seasonally or when fed concentrates. In beef animals flavour intensity becomes greater as carcass maturity and marbling increases (Aberle et al 2001; MSA 2001). It is important to know if increased carcass fatness associated with concentrate feeding of deer alters venison characteristics to the extent that consumers can detect a difference in flavour compared with deer fed on pasture only, and if so is the change in flavour appreciated or not. This trial investigated the influence of supplementary feeding on the eating quality characteristics of venison from fallow deer.

Methods

Twenty four fallow does, three years old, were slaughtered as part of a supplementary feed trial. Twelve of these does were grazed on kikuyu pasture over-sown with ryegrass and oats in winter. The remaining animals were fed *ad libitum* barley and lucerne hay. Animals were slaughtered in two groups; Group 1 after 135 days and Group 2 after 170 days of feeding. Samples were analysed to ascertain the effects of feeding on meat quality. This trial also provided BCS 4 animals for establishing relationships between BCS and eating quality.

Results

The only difference in sensory attributes detected by panellists was a difference in flavour strength between animals fed grain compared with animals fed only pasture prior to slaughter, with venison from grain-fed animals deemed to have a stronger flavour (table 3.4). There was no interaction between BCS and feed for all sensory parameters measured. Therefore data were averaged over BCS for analysis of differences between feed and averaged over feed for analysis of difference between BCS for all sensory parameters measured except for flavour strength (table 3.5). Analysis of variance for averaged data shows no significant differences between BCS and feed for all sensory parameters analysed. However, there was a significant interaction between BCS and feed for flavour strength ($F_{1, 199} = 4.69, p=0.03$). When deer BCS was 3, barley fed animals scored significantly higher than pasture fed animals ($F_{1,79} = 4.76, p=0.03$) but when the deer BCS was 4 there was no significant difference between the feeds (figure 3.7).

Table 3.4 Mean (+/- SE) sensory evaluation scores for fallow deer does fed on either pasture or grain prior to slaughter (n=12 per group)

| Feed Treatment | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tenderness | Juiciness | Overall Liking |
|----------------|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|------------------|-----------------|------------------|
| Pasture | 8.56a (2.35) | 8.34a (2.41) | 7.88a (2.51) | 9.49a (2.18) | 8.08a (2.13) | 6.99a (2.81) | 9.74a (2.39) | 8.34a (2.81) | 10.13a (2.38) |
| Grain | 8.21a (2.48) | 8.14a (2.32) | 8.03a (2.63) | 9.97a (1.95) | 8.52b (1.84) | 7.29a (2.67) | 10.03a (2.16) | 8.39a (2.72) | 10.55a (1.90) |

Measurements with the same letter in columns are not significantly different

Table 3.5 Mean (+/- SE) sensory evaluation scores for fallow deer does with BCS ranging from 2 to 4

| BCS | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tenderness | Juiciness | Overall Liking |
|-----|-----------------|-----------------|-----------------|-----------------|------------------|-----------------|------------------|-----------------|------------------|
| 2 | 8.49a (2.52) | 8.35a (2.52) | 7.82a (2.35) | 9.45a (2.19) | 7.97a (1.79) | 6.85a (2.77) | 10.03a (2.27) | 8.15a (2.97) | 10.08a (2.51) |
| 3 | 8.19a (2.43) | 8.17a (2.41) | 7.92a (2.64) | 9.77a (2.02) | 8.07a (2.25) | 6.97a (2.77) | 9.55a (2.42) | 8.11a (2.68) | 10.33a (2.02) |
| 4 | 8.60a (2.32) | 8.31a (2.28) | 8.02a (2.59) | 9.72a (2.14) | 8.59a (1.87) | 7.41a (2.72) | 10.08a (2.18) | 8.71a (2.74) | 10.38a (2.24) |

Measurements with the same letter in columns are not significantly different

For BCS 3 the flavour strength for pasture-fed animals was significantly lower (score=7.53 SE 0.37) than for barley (score= 8.60 (0.33)). When BCS was 4 there was no significant difference between pasture-fed and barley-fed animals (figure 3.3).

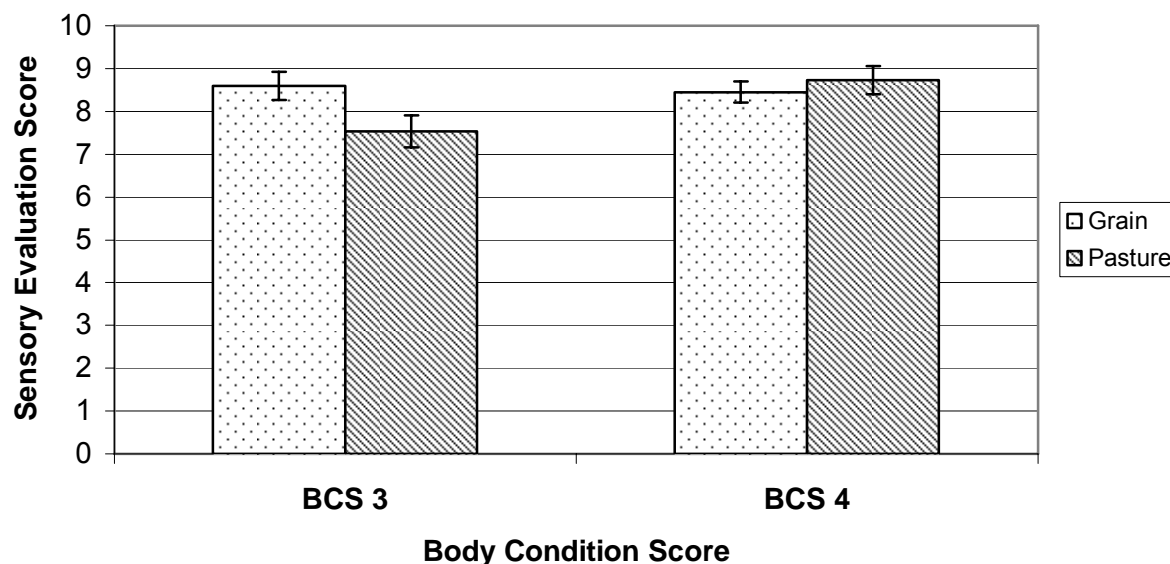


Figure 3.3 Mean (+/- SE) sensory panel scores for flavour strength of venison from fallow deer with body condition scores of 3 and 4, fed either pasture or barley prior to slaughter.

Discussion

Body condition score was increased by grain feeding young animals to achieve BCS 4, which was not achievable by pasture feeding alone. However, taste panels found a significantly stronger flavour in the venison from animals fed grain prior to slaughter, particularly in animals that remained at BCS 3. The stronger flavour in venison from grain-fed animals was not detected in animals of BCS 4. As there were no significant differences in other quality parameters between BCS 2, 3 and 4 animals, or between animals fed grain or pasture, there would appear to be no justification for fallow deer farmers to finish animals on grain prior to slaughter. The meat from all animals included in this supplementary feed study has also been evaluated for colour stability during display and after chilled storage up to 6 weeks in vacuum bags (Wiklund et al, 2005). It was concluded that venison from the fallow deer finished on pasture maintained the desired red meat colour for longer compared with venison from the grain-fed deer (Wiklund et al, 2005), which is another good reason for pasture based management systems from the perspective of consumer preference. In the previous section it was shown that flavour increased with increasing animal age, and these data show that flavour can be increased by grain feeding animals of the same age, compared with pasture-fed animals. This knowledge may be of some importance to deer farmers producing for particular market preferences.

3.3 Red Deer (pasture-fed) - Method of carcass suspension

Introduction

As mentioned previously product consistency is vitally important for growth of the domestic and export markets for Australian farmed venison. In Australia, and elsewhere red deer are being farmed in increasing numbers for venison production, and development of finesse in post-slaughter carcass treatment is likely to provide significant return on investment because the anticipated improvements to product quality will add significant value to the product. Venison from fallow deer carcasses hung by pelvic suspension has been shown (Sims et al 2004 and chapter 2 this study) to be consistently more tender than venison from carcasses hung by the Achilles tendon, and this improvement to product quality has been demonstrated across different sex and age classes of deer. The technique of pelvic suspension is now used commercially for carcasses from domestic species like beef and lamb, especially within quality control systems that guarantee a tender product. The effect of pelvic suspension as an alternative carcass suspension technique on meat quality has not been reported for red deer (*Cervus elaphus*) prior to this study, and results in chapter 1 demonstrate that meat tenderness has been increased for both raw and cooked venison by using this technique, as measured in the laboratory by using a Warner-Bratzler Shear. This section now investigates whether sensory evaluation panels can detect differences in venison quality from red deer carcasses treated differently post-slaughter.

Methods

The methods used for sensory evaluation are described in detail in the methods section, and the approach used with pannelists on the day of testing are as described for fallow deer (this section). Venison from 14 red deer stags was used for this work. Carcasses were split along the mid ventral axis, and each carcass side was randomly allotted to either Achilles tendon suspension (normal hanging technique) or to pelvic suspension. Using this experimental design, each animal was exposed to both treatments, and consumers could evaluate venison from the same animal by tasting venison from each of the treatments randomly. All meat samples tested were *M.gluteus medius* (rump).

Results

Carcasses hung by pelvic suspension were preferred by panellists for tenderness ($F_{1,166} = 23.39$, $p < 0.001$), juiciness ($F_{1,166} = 10.46$, $p = 0.001$) and overall likeness ($F_{1,166} = 7.382$, $p = 0.007$) (Table 3.6).

There were no significant differences between AT and TS carcasses for other sensory parameters measured. The differences between AT and TS carcasses as judged by the sensory panels are shown in figure 3.4.

Table 3.6 Mean (+/- SE) sensory evaluation scores for venison from carcasses of red deer stag hung by either the Achilles tendon or by pelvic suspension (n=14 of each)

| Suspension Method | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tenderness | Juiciness | Overall Liking |
|-------------------|------------------|------------------|------------------|-------------------|------------------|------------------|-------------------|-------------------|-------------------|
| Achilles | 8.37 a (0.27) | 8.98 a (0.24) | 7.52 a (0.27) | 9.97 a (0.25) | 8.01 a (0.24) | 6.58 a (0.31) | 8.87 a (0.33) | 8.90 a (0.29) | 10.37 a (0.28) |
| Pelvic | 7.93 a (0.29) | 8.90 a (0.24) | 7.46 a (0.28) | 10.36 a (0.25) | 8.22 a (0.24) | 6.57 a (0.30) | 10.85 b (0.24) | 10.22 b (0.29) | 11.38 b (0.24) |

Numbers in columns with the same letter are not significantly different

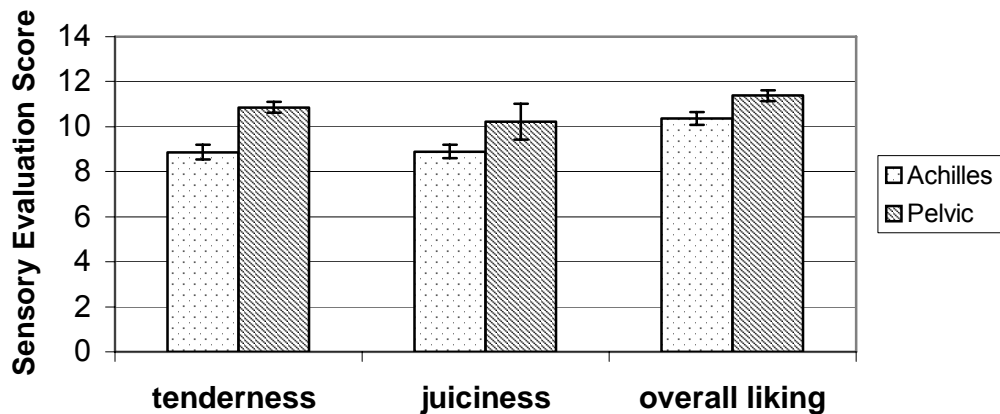


Figure 3.4 The mean (+/- SE) sensory panel scores for tenderness, juiciness and overall liking for red deer stags with BCS between 2 and 3 hung post-mortem by either the Achilles tendon or by pelvic suspension

Discussion

As for fallow deer, pelvic suspension of red deer carcasses produced venison that was significantly more juicy and tender than the venison from carcass hung by the Achilles tendon. The overall liking for venison from carcasses hung by pelvic suspension was significantly higher, and once again reinforced the data in chapters one and two on the advantages of the deer industry of employing this technique. Tenderness is consistently noted by consumers as the most important quality characteristic that they look for in meat, and the “tender stretch” technique has been shown in these experiments to be consistently noted by panellists to produce venison that is more tender and juicy.

3.4 Red Deer (pasture-fed) - Comparison of sensory acceptability for red deer stags with BCS of 2, 3 and 4

Introduction

As previously described the level of fatness in a carcass can be detected by using BCS as an indicator. At any given time there can be variation within and between farms in the BCS of animals due to differences in age, sex, management practices, disease status and climatic conditions, and venison quality will vary in response to pressures exerted by these variations. Quite often the only guide to whether an animal is suitable for slaughter is its live weight and general body condition, and for this reason it is important to know whether BCS *per se* is related to consumer preference in the case of red deer venison. This section explores consumer perception of differences in BCS for red deer stags. Biochemical analysis of the venison from these animals is provided in chapter 1 (table 1.10).

Methods

Venison from 26 red deer stags killed commercially and with BCS ranging between 2 and 4 was collected for this study (see table 10, chapter 1). The sensory evaluation techniques are as described for previous experiments.

All meat samples tested were *M.gluteus medius* (rump).

Results

There were significant differences in consumer preference between animals of different BCS when judging tenderness ($F_{2, 123} = 3.06, p=0.05$) (table 3.7). Ryan's Q test detected significant differences between BCS 2 and BCS 4, with panellists preferring venison from BCS 4 animals (figure 3.5). As BCS increased, consumer preference increased. However, there were no significant differences between BCS 2 and BCS 3, and between BCS 3 and BCS 4. There were no significant differences between BCS for other sensory parameters measured.

Table 3.7 Mean (+/- SE) sensory evaluation scores for red deer stags with BCS of 2, 3 or 4 (n=12, 6 and 8 respectively).

| BCS | Colour | Aroma | Aroma Strength | Flavour | Flavour Strength | Game Flavour | Tenderness | Juiciness | Overall Liking |
|-----|------------------|------------------|------------------|-------------------|------------------|------------------|-------------------|------------------|-------------------|
| 2 | 8.25 a (0.40) | 8.85 a (0.33) | 7.80 a (0.35) | 9.74 a (0.36) | 7.92 a (0.33) | 6.56 a (0.43) | 8.85 a (0.44) | 8.87 a (0.39) | 10.18 a (0.40) |
| 3 | 9.00 a (0.32) | 9.13 a (0.38) | 7.58 a (0.35) | 10.37 a (0.28) | 8.30 a (0.29) | 6.76 a (0.38) | 9.60 ab (0.40) | 9.86 a (0.36) | 11.31 a (0.30) |
| 4 | 8.85 a (0.31) | 9.28 a (0.41) | 7.57 a (0.36) | 10.07 a (0.36) | 8.74 a (0.29) | 7.08 a (0.42) | 10.27 b (0.38) | 9.31 a (0.41) | 10.81 a (0.40) |

Numbers in columns with the same letter are not significantly different

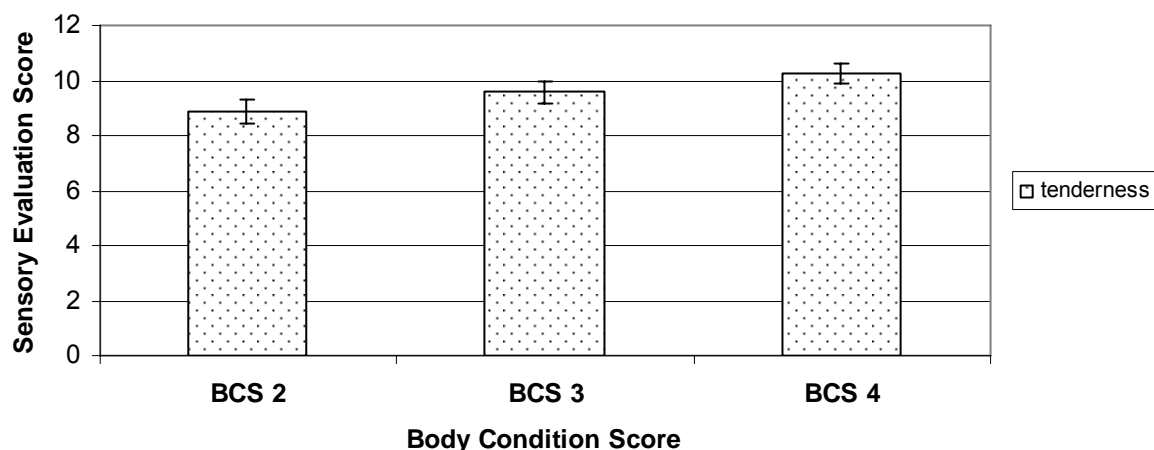


Figure 3.5 The mean (+/- SE) sensory panel scores for tenderness for red deer stags with BCS 2, 3 or 4.

Discussion

There was a gradual increase in tenderness of venison as BCS increased from 2 to 4. However, as seen in the previous section the result can be obtained by hanging carcasses differently after slaughter. As occurred in experiments with fallow deer there were no differences in the range of quality parameters measured across red deer carcasses ranging from BCS 2 to 4, except for a gentle increase in tenderness, and again this is a good result for red deer farmers and wholesalers. Animals ranging in BCS from 2 to 4 can be slaughtered without apparent affect on consumer preference, which allows for flexibility in the supply chain. Until now animals with low BCS (around BCS 2) have been considered to be largely unfit for the venison market, yet the results obtained in the current study show that consumers were reasonably happy with the meat. The current study does show a definite trend by consumers to prefer venison from animals with a BCS of either 3 or 4, compared with BCS 2, but this trend was not significant.

Conclusions

The hypothesis that changes in BCS would affect eating quality and consumer preference has not been proven in these experiments for either species of deer. The biochemical measurements taken (chapter 1) show little difference across the BCS range 2 to 4, except for a modest increase in tenderness in red deer with BCS 4 compared with BCS 2, (Chapter 3) and this lack of difference is further confirmed by the lack of differentiation between BCS 2-4 by taste panellists. It is apparent from data for both red and fallow deer that there was a trend for greater overall liking of venison from animals with BCS 3 and 4, compared with BCS 2, but this trend was not significantly different. It may be necessary to slaughter larger numbers of animals to prove beyond doubt that this trend is measurably significant.

An important finding in this study was the enhancement of tenderness and juiciness in all carcasses from red and fallow deer subjected to the pelvic suspension (tenderstretch) method of hanging carcasses as they cooled down and entered rigor mortis. The sensory evaluation scores for overall likeness were consistently higher for venison from the carcasses subjected to pelvic suspension, a further validation of the importance of tenderness and juiciness as favoured quality attributes of meat by consumers.

The need to adopt the post-slaughter practice of pelvic suspension of carcasses of all ages, sexes and body condition scores is unequivocal if enhanced tenderness of venison is desirable. The sensory panels in this study validated the biochemical tests that indicated increased tenderness and juiciness of venison from carcasses subjected to pelvic suspension compared with venison from carcasses hung by the Achilles tendon in all trials where the pelvic suspension technique was employed.

The technique of pelvic suspension can be easily installed as routine practice in abattoirs once adopted, by altering the mechanics of how a carcass is added to and removed from the meat rail into and out of the chiller. Carcasses can be re-hung by the Achilles tendon for ease of transportation to the meat boning room of wholesale and retail butchers so that retail cut shape of the meat is maintained, because the process of tenderstretching carcasses is only effective while they are cooling down to a deep core temperature of 4-7°C during the first 12-24 hours post-slaughter. There are no mechanical reasons preventing the adoption of this valuable technique to enhance meat quality, though uptake of this technology will require cultural changes in the abattoir sector to alter traditional work practices.

Flavour is another key quality attribute evaluated by consumers and in this study flavour was shown to increase as animals got older, and if they were fed grain prior to slaughter. The trend for meat flavour to increase as animal age increases has been shown in a number of studies and in a range of domestic species (Aberle et al 2001), and is referred to anecdotally in reference to wild-shot deer (Whitehead, 1993). The detection by taste of panellists of stronger flavours in venison from deer fed grain prior to slaughter was more surprising and this finding could be used by the deer industry to satisfy market preference for stronger flavours, or could be a warning to restrict the feeding of grain prior to slaughter if stronger flavours are not desirable.

Interestingly, the stronger flavours in grain-fed deer were only detected in the lower BCS range, and were not detected when BCS was 4. Perhaps higher carcass fat levels in BCS 4 animals masked the flavour changes.

Although the present study did not specifically set out to determine differences in consumer preference for venison from bucks versus does the data for 'overall liking' from the sensory testing indicates consumer preference for venison from does.

This is useful information for the deer industry, especially with reference to slaughter of fallow deer, because fallow deer bucks are very aggressive toward each other during the breeding season and at this time of year, causing carcass bruising and dehydration. Venison quality can remain high by slaughtering cull female stock at this time of year.

Overall this study has shown that venison is a high quality product with biochemical parameters similar to or more desirable than other domestic meats. Sensory evaluation showed the product to be strongly appreciated by men and women between the ages of 25 to 55, and differences in 'overall liking' between red and fallow deer venison were not detected in the study.

Recommendations for Industry

- Deer with BCS ranging from 2 to 4 can be slaughtered for venison with no significant loss of quality.
- Carcasses from all deer slaughtered should be subjected to pelvic suspension hanging post-mortem to increase tenderness, juiciness and overall liking of the meat
- Venison from pasture-fed deer has greater colour stability, and therefore greater display life when sold as fresh or chilled product.
- Flavour strength increased in venison from deer fed concentrates for greater than 100 days prior to slaughter, and this may be useful information for wholesalers sending product into selected markets.
- Venison from female deer had a higher 'overall liking' rating by consumers, compared with venison from male deer.
- There was no apparent difference in sensory scores for 'overall liking' between red and fallow deer.

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Appendix 1

Sensory Evaluation of Venison

Please rate the sample for the following characteristics by marking on the line scale where it best describes your impressions.

Date: _____ Time: _____ Name: _____

Sample Code: _____

1. Please do not taste yet! Please look at the sample and rate its colour

COLOUR

Extremely Pale

Extremely Dark

2. Please smell the sample and rate its aroma

AROMA

Dislike Extremely

Neither Like nor dislike

Like Extremely

AROMA STRENGTH

None

Extremely Strong

3. Now taste the sample of venison and rate the following characteristics:

FLAVOUR

Dislike Extremely

Neither like nor dislike

Like Extremely

FLAVOUR STRENGTH

None

Extremely Strong

GAME FLAVOUR

None

Extremely Strong

TENDERNESS

Extremely Tough

Extremely Tender

JUICINESS

Extremely Dry

Extremely Juicy

OVERALL LIKING

Dislike Extremely

Neither like nor dislike

Like Extremely