Carcass composition and yield of Alaskan reindeer (Rangifer tarandus tarandus) steers and effects of electrical stimulation applied during field slaughter on meat quality

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Received 19 February 2007; received in revised form 1 June 2007; accepted 2 June 2007

Abstract

Twenty six adult reindeer steers (>3 years old) were used in a study to evaluate the effect of electrical stimulation (ES) on the quality of hot-boned, rapidly frozen shoulder meat and of the striploin (M. longissimus, LD) from carcasses held at +3 °C for 48 h. Carcass yield and composition was determined from the left carcass half from which the shoulder meat was not removed. The shoulder meat was processed frozen into cubed, sliced or ground products. Proximate composition of the LD, meat color and water-holding capacity were very similar for the ES (n = 15) and non-electrical stimulation (NES; n = 11) groups. Ultimate pH and shear force values were significantly lower in the ES meat (LD), however a trained sensory panel could not detect differences between the two groups in any of the measured sensory attributes. Consumer preference tests demonstrated that ES increased tenderness in the cubed and sliced products made from field slaughtered reindeer shoulder meat. ES in combination with hot boning and processing of boneless frozen meat can be used in field slaughter systems for reindeer to improve meat quality and to increase the potential value of the carcass.

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Keywords: Meat quality; Low voltage stimulation; Carcass composition; Shear force; Trained sensory panel; Consumer test

1. Introduction

Alaska has a small red meat industry but given its large grazing and forage crop base the potential economic output could be significant. The Alaskan reindeer industry has produced meat for subsistence and local use and at times has been an important export commodity (Stern, Arobio, Naylor, & Thomas, 1980). Currently, the reindeer industry uses both a typical USDA inspected system for a small number of animals slaughtered annually and a state-regulated field slaughter system for the majority of reindeer slaughtered in Alaska. The field slaughtered reindeer meat can be marketed locally provided animals are slaughtered on snow when ambient temperature is below 0 °C, carcasses are allowed to freeze in the field and the meat is not thawed until in the hands of the consumer (Alaska Department of Environmental Conservation, 2003). Ambient air temperatures during field slaughtering are usually below −10 °C so instant chilling and freezing of the carcasses inevitably occurs. The requirement to keep the field slaughtered reindeer meat frozen (Alaska Department of Environmental Conservation, 2003) limit the diversity of techniques available for value added processing due to the presence of bone in the frozen carcass. However, if the bones are removed prior to freezing the meat can be
sliced, cubed and ground while still frozen. Potential problems include compromised meat quality due to the rapid freezing of pre-rigor meat.

Electrical stimulation accelerates post-mortem glycolysis and rigor onset, so that rapid cooling or freezing of carcases may be carried out soon after slaughter without risk of the muscles cold shortening (Davey & Chrystall, 1980). This technique has also been adopted in commercial slaughtering as a method of meat tenderisation in beef, lamb and goat carcases (Chrystall & Hagyard, 1976; Davey, Gilbert, & Carse, 1976; Geesink, van Laak, Barnier, & Smulders, 1994; Savell, Smith, Dutson, Carpenter, & Suter, 1977). Studies on red deer (Cervus elaphus) demonstrated that electrical stimulation applied to the carcases accelerated the rate of tenderisation (Chrystall & Devine, 1983; Drew, Crobie, Forss, Manley, & Pearse, 1988; Wiklund, Stevenson-Barry, Duncan, & Littlejohn, 2001) and had no negative effects on water-holding capacity of the meat (Wiklund et al., 2001). Reindeer meat (M. longissimus) has been found to be extremely tender regardless of ultimate pH and to reach optimal tenderness without ageing (Wiklund, Barnier, Smulders, Lundström, & Malmfors, 1997). As early as 3 days post-mortem, shear force values in the reindeer meat samples were only 2–3 kg/cm², which was very low compared with measured shear force values in beef (values around 10 kg/cm²) after the same ageing time (Barnier, Wiklund, van Dijk, Smulders, & Malmfors, 1999). No reports are available on the effects of electrical stimulation on mechanical or sensory tenderness or other meat quality attributes in reindeer meat.

Reindeer meat is a very exclusive product even in the countries where it is produced and is in high demand and often on the menu in the more luxurious restaurants but otherwise difficult to buy for the ordinary consumer. There are traditional ways of processing and preparing reindeer meat, i.e. in the Fennoscandian countries primal and lower quality cuts from the carcase are first separated and the lower quality cuts are then frozen and thin sliced to a stir-fry type product. In rural Alaska, the tradition is to cut up the whole carcase in cubes for “stew” meat, though ground meat products have become increasingly popular.

It is essential for reindeer meat producers, abattoir managers and wholesale distributors to have knowledge about carcase composition and the yield of primal and lower quality cuts to estimate the potential market value of a carcase to develop business strategies. Earlier work has described carcase composition and yield of reindeer bulls, cows and calves from Nunivak Island, Alaska (Renecker, Renecker, & Mallory, 2005). However, this study did not include castrated bulls (steers) which is the most common reindeer category destined for slaughter in Alaska.

The major purpose of the study was to evaluate the use of electrical stimulation and hot boning in a field slaughter setting and the further processing of frozen meat to improve the quality of less tender reindeer cuts (shoulder meat). In addition, the effect of electrical stimulation of reindeer carcases on sensory and mechanical tenderness as well as water-holding properties of the striploin (M. longissimus) was determined. Another purpose of this study was to determine carcase yield and composition to illustrate the proportion of primal and less valuable cuts in typical slaughter animals from the Seward Peninsula, Alaska.

2. Material and methods

2.1. Animals

A total of 26 castrated reindeer bulls (>3 years old) were included in the study. Reindeer were gathered just outside Nome on the Seward Peninsula, Alaska, and shot in the field. After bleeding, carcases were randomly allocated to either an electrical stimulation treatment (ES; n = 15) or a no electrical stimulation treatment (NES; n = 11). Electrical stimulation was applied within 5 min post-stunning/bleeding, followed by removal of the viscera and hide. Meat from the right shoulder was boned out from the warm carcases in the field at approximately 45 min post-slaughter, packed into individual plastic-lined cardboard boxes and left to freeze at ambient temperature. The ambient temperature during the field slaughter varied between −18.6 °C and −24 °C, and the meat in the boxes was frozen in the field after on average 8.2 h post-mortem (varying between 5.5 and 10 h post-mortem). The carcases minus the right side shoulder were immediately transported by truck (10 minutes transport at ambient temperature), to a meat processing facility in Nome and hung in a chilling room (+3 °C) to avoid freezing in the field (simulating an inspected slaughter). Temperature in M. longissimus (LD, at the last rib) and in M. biceps femoris (BF) was measured at 3, 4, 5, 6, 7, 8 and 48 h post-mortem. At 2 days post-slaughter carcases were boned and both the right and left loins (LD) were removed, loins from each side were randomly allotted for either sensory evaluation (one loin) or analysis consisting of determination of water-holding capacity, proximate analysis, meat color and tenderness measurements (one loin divided in five parts; four samples for water-holding capacity measurements and one sample for tenderness, color and proximate analysis. Samples were randomly allocated to each measurement). All samples were vacuum-packaged and frozen at −20 °C until analysis except those for determination of water-holding capacity. These samples were either frozen to measure freeze/thaw loss or vacuum-packaged and chilled (+3 °C) for 1, 2 and 3 weeks to measure drip loss (purge).

2.2. Electrical stimulation

Electrical stimulation of the 15 ES carcases was performed via a low voltage beef stimulator (Jarvis BV80, Jarvis®, Connecticut, USA) with the following specifications: rectangular pulses with 5 ms duration, 70 ms pulse period and an output of 80 V peak to peak. A 2500 W gas-powered generator at the field slaughter site powered the
stimulator. Carcasses were stimulated in a lying position on the snow and all of them were resting on their left side. The stimulation equipment was hooked up via battery clips attached to the nasal septum and a fleshy region of the skinned right rear hock. Current was applied for 20 s within 5 min post-stunning/bleeding.

2.3. Temperature and pH

Temperatures in the LD (at the last rib) and BF were measured with a digital thermometer (Comark, DT 300, Beaverton, OR, USA). Ultimate pH values were measured in the lab in connection with the proximate analysis by homogenizing 2 g of meat in 20 ml of room tempered deionized water. The pH values were registered on a Beckman 350 pH meter (Beckman Coulter Inc., Fullerton, CA, USA) equipped with a combination pH electrode (Beckman Futura 511080, Beckman Coulter Inc., Fullerton, CA, USA).

2.4. Carcass yield and composition

Yield of commercial cuts utilized only the intact left carcass half and used a protocol developed for this study, based on earlier moose (Alces alces) and reindeer carcass studies (Hansson & Malmfors, 1978; Wiklund, Hansson, & Malmfors, 2000). Definitions of the cuts presented in Table 1 are as follows: semiboneless leg (major part of the hindquarter of the carcass without shank, pelvic bone, vertebral and flank muscles but including the M. gluteus medius, M. quadriceps femoris, M. biceps femoris, M. semitendinosus and M. semimembranosus); saddle (M. longissimus with bone); striploin (M. longissimus); tenderloin (M. psoas major); topside (M. semimembranosus); and forequarter (neck, chuck and shoulder including M. triceps brachii, M. supra spinatus and M. infra spinatus with bone and shank).

2.5. Shear force, color and drip loss

For shear force measurements steaks (2.5 cm thick) were cut from the loin samples and cooked on a George Foreman grill (Salton, Lake Forest, IL, USA) to a core temperature of 70 °C. Internal temperature was monitored with copper-constantan thermocouples (Type T, Omega Engineering, Stamford, CT, USA) and a Barnant scanning digital thermometer (Model 692-0000, Barnant Co., Bariington, IL, USA). Cores of 1.3 cm were cut parallel to the muscle fibers and these cores were sheared at 4 °C using a TAXT Plus texture analyzer (Texture Technologies, NY, USA) instrument equipped with a Warner-Bratzler blade attachment at a head speed of 3.5 mm/s. Tenderness values were registered as maximum shear force (peak height).

Objective color (L, a and b values) was determined with a Hunterlab Colorflex (CFLX-45, Hunter Associates Laboratory Inc., VA, USA). A 0.5-cm slice was removed from the sample to expose a fresh surface to air and the slice was allowed to bloom for 15 min prior to color measurement.

Drip loss (purge) and freeze/thaw loss was measured by the following procedure: (1) the combined weight of meat and vacuum pack 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. The combined dry bag (average weight of 25 empty vacuum bags) and drip-free meat weights were subtracted from the unopened package weight to obtain the total drip weight. Drip weight was then expressed as a proportion (%) of the original weight of meat packed.

2.6. Processing of frozen shoulder meat

The frozen and boxed shoulder meat was shipped to the University of Alaska, SFOS Fishery Industrial Technology Center located in Kodiak, Alaska. The frozen meat was removed from the boxes and tempered in a cold room (+2–4 °C) to a temperature of −3 °C before being either ground (Brio Grinder model G58643; Brio Manufacturing Company, Ohio, USA) though a plate with 4 mm diameter holes, sliced (Urschel Comitrol model 1700; Urschel Laboratories Inc., Indiana, USA) using the 0.75 inch head (giving slices of approx. 5 mm thickness) or cubed (Koch Dicer model SR-1; Koch Equipment, Missouri, USA) to approximately 1 cm × 0.75 cm cubes while still frozen. The ground, sliced and cubed meat samples were then vacuum-packaged and transported to Fairbanks and kept frozen until sensory evaluation.

2.7. Proximate analysis

Moisture content was determined using AOAC method 952.08, ash with AOAC method 938.08 (AOAC, 1990) and

<table>
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<th>Trait</th>
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<tr>
<td>Live weight, kg</td>
<td>104 ± 11.2</td>
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<tr>
<td>Carcass weight (Cw), kg</td>
<td>56.9 ± 6.6</td>
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<tr>
<td>Dressing (%)</td>
<td>54.7 ± 2.4</td>
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<tr>
<td>Hindquarter, kg</td>
<td>21.8 ± 2.4</td>
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<tr>
<td>Hindquarter, % of Cw</td>
<td>38.5 ± 1.7</td>
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<tr>
<td>Forequarter, kg</td>
<td>22.7 ± 3.0</td>
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<tr>
<td>Forequarter, % of Cw</td>
<td>39.8 ± 1.9</td>
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<tr>
<td>Semiboneless leg, kg</td>
<td>15.4 ± 1.8</td>
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<tr>
<td>Semiboneless leg, % of Cw</td>
<td>27.2 ± 1.3</td>
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<tr>
<td>Saddle, kg</td>
<td>7.6 ± 1.1</td>
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</tr>
<tr>
<td>Saddle, % of Cw</td>
<td>13.4 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>Topside, kg</td>
<td>3.6 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Topside, % of Cw</td>
<td>6.3 ± 0.4</td>
<td></td>
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<tr>
<td>Striploin, kg</td>
<td>1.9 ± 0.3</td>
<td></td>
</tr>
<tr>
<td>Striploin, % of Cw</td>
<td>3.4 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Tenderloin, kg</td>
<td>0.8 ± 0.1</td>
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</tr>
<tr>
<td>Tenderloin, % of Cw</td>
<td>1.4 ± 0.1</td>
<td></td>
</tr>
<tr>
<td>Bone, kg</td>
<td>17.3 ± 2.4</td>
<td></td>
</tr>
<tr>
<td>Bone, % of Cw</td>
<td>30.2 ± 2.7</td>
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</table>
lipid content according to Folch, Lees, and Stanley (1957). The nitrogen content was determined in triplicate using the Leco FP-2000 Nitrogen Analyzer (LECO Corporation, St. Joseph, MI, USA). The protein content was calculated as percent nitrogen × 6.25.

2.8. Sensory evaluation

2.8.1. Trained panel

The work was performed at the Cooperative Extension Service, Food Product Development Kitchen (University of Alaska Fairbanks). A descriptive test, conventional profiling (ISO 6564, 1985), was carried out by a selected and trained sensory panel (ISO 8586-1, 1993) consisting of seven members. The panel members were trained in sessions where reindeer meat samples from animals in both treatment groups (ES and NES) and from different meat cuts from the carcasses were presented. The meat cuts were selected to represent the typical variation in sensory attributes (particularly tenderness) in reindeer meat and originated from the shoulder (M. infraspinatus), the stiploin (M. longissimus), the topside (M. semimembranosus) and the outside (M. biceps femoris). The sensory training was performed in accordance with ISO 6564 (1985). All assessments were carried out in a sensory laboratory with separate booths equipped with Compusense® five, an automated data collection system (Compusense Inc., 2004) and under normal white light (ISO 8589, 1988).

Upon thawing, the loin samples were put in a refrigerator at +3 °C for 17 h. The meat was cooked in a conventional oven at 150 °C to a core temperature of 70 °C. Internal temperature in each loin was monitored with copper–constantan thermocouples (Type T, Omega Engineering, Stamford, CT, USA) and a Barnant scanning digital thermometer (Model 692-0000, Barnant Co., Barington, IL, USA). At every session, the panel members were served meat samples from 7 to 9 animals at the same time, each sample consisting of one slice of meat. Samples were placed in plastic cups coded with three-digit numbers and were served to the panel members in randomised order, at room temperature and in two replicates. The following attributes were selected and unanimously agreed upon during panel training; tenderness, juiciness, bloody flavor, gamey flavor and sweet flavor. An unstructured continuous line scale from 0 (low intensity) to 10 (high intensity) was used.

2.8.2. Consumer preference tests

Three paired-comparison consumer tests (cubed meat, sliced meat and ground shoulder meat from ES vs. NES carcasses) were performed in collaboration with the Cooperative Extension Service (CES) on the UAF campus in Fairbanks using a total of 625 consumers to evaluate the cubed, sliced and ground shoulder meat. The cubed meat was cooked in the vacuum bags in a water bath to an end temperature of 74 °C. The slices and ground meat was roasted on an oven tray until well done (74 °C). All preparation of the meat samples took place on the day of each test and just prior to the tasting sessions.

At each of the test sessions the consumers were presented with two samples (meat from ES and NES carcasses), each coded with a random three-digit number. Together with the meat samples, a questionnaire was presented with the following instructions; “In front of you are two samples. Please test the samples from left to right and determine which sample is the most tender. Circle the corresponding number on the score sheet. You must make a choice, even if it is only a guess. You may re-taste the samples as often as you wish until they are consumed”. Space was provided for the consumers to specify additional remarks on the meat samples.

2.9. Statistical analysis

The statistical analyses were carried out with the Statistical Analysis System (SAS Institute, 2003) using the GLM

![Fig. 1. Temperature decline in M. longissimus (LD; 1a) and M. biceps femoris (BF; 1b) from reindeer from two treatments; electrically stimulated (ES; n = 15) or non-stimulated (NES; n = 11) included in the study (least-squares means), measured at 3, 4, 5, 6, 7, 8 and at boning (48 h post-mortem).](image-url)
and MIXED procedures. The model for comparing carcass characteristics and composition, meat ultimate pH, tenderness, color, drip loss, and chemical composition included the fixed effect of treatment group. Significance was defined as $P \leq 0.05$. For the trained panel work, the model included the random effects animal and panel member, as well as the fixed effect of treatment group. The consumer tests were set up as three separate paired comparisons (one-sided directional difference tests) with the null hypothesis being $H_0$: Tenderness ES samples $=$ Tenderness NES samples and the alternate hypothesis being $H_a$: Tenderness ES samples $>$ Tenderness NES samples (Mielgaard, Civille, & Carr, 1999).

3. Results

3.1. Carcass characteristics and composition, pH and temperature

The carcass characteristics, including yield and composition, for the reindeer steers are illustrated in Table 1. Temperature decline in $M$. longissimus (LD) and $M$. biceps femoris (BF) were very similar for both treatment groups (Fig. 1) indicating no effect of electrical stimulation on carcass cooling rate. The ES carcasses had significantly lower ultimate pH in LD compared with the NES carcasses although the difference was only 0.07 pH units (Table 2).

3.2. Color, shear force, drip loss and chemical composition

The LD from the ES carcasses was significantly more tender than LD from the NES carcasses when measured as shear force values (Table 2). No differences were found in meat color values, drip loss or freeze/thaw loss between the two treatment groups (Table 2).

The analysis of proximate composition (moisture, ash, fat and protein) showed no differences between the LD samples from the ES and NES groups (Table 3).

### Table 2

<table>
<thead>
<tr>
<th>Trait</th>
<th>ES group</th>
<th>NES group</th>
<th>Degree of sign.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate pH</td>
<td>5.58 ± 0.01</td>
<td>5.65 ± 0.01</td>
<td>***</td>
</tr>
<tr>
<td>Shear force (kg)</td>
<td>1.68 ± 0.05</td>
<td>1.84 ± 0.06</td>
<td>*</td>
</tr>
<tr>
<td>Color L-value</td>
<td>19.4 ± 0.3</td>
<td>18.8 ± 0.4</td>
<td>n.s.</td>
</tr>
<tr>
<td>Color a-value</td>
<td>15.7 ± 0.3</td>
<td>15.6 ± 0.4</td>
<td>n.s.</td>
</tr>
<tr>
<td>Color b-value</td>
<td>12.8 ± 0.2</td>
<td>12.3 ± 0.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>Drip loss (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 week</td>
<td>3.7 ± 0.5</td>
<td>4.1 ± 0.6</td>
<td>n.s.</td>
</tr>
<tr>
<td>2 weeks</td>
<td>4.9 ± 0.4</td>
<td>5.1 ± 0.5</td>
<td>n.s.</td>
</tr>
<tr>
<td>3 weeks</td>
<td>6.4 ± 0.6</td>
<td>5.2 ± 0.7</td>
<td>n.s.</td>
</tr>
<tr>
<td>Freeze/thaw</td>
<td>7.1 ± 0.6</td>
<td>7.6 ± 0.6</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Trait</th>
<th>ES group group</th>
<th>NES group group</th>
<th>Degree of sign.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>72.0 ± 0.6</td>
<td>71.8 ± 0.7</td>
<td>n.s.</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.2 ± 0.1</td>
<td>1.1 ± 0.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>23.6 ± 0.5</td>
<td>23.6 ± 0.6</td>
<td>n.s.</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>2.7 ± 0.3</td>
<td>2.8 ± 0.4</td>
<td>n.s.</td>
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</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Question</th>
<th>Which of these two samples is the most tender?</th>
</tr>
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<tbody>
<tr>
<td>Number participants</td>
<td>Preference ES</td>
</tr>
<tr>
<td>Cubed meat</td>
<td>203</td>
</tr>
<tr>
<td>Sliced meat</td>
<td>205</td>
</tr>
<tr>
<td>Ground meat</td>
<td>217</td>
</tr>
<tr>
<td>Total</td>
<td>625</td>
</tr>
</tbody>
</table>

3.3. Sensory evaluation

3.3.1. Trained panel

No significant differences between the two treatment groups (ES and NES) were found when comparing the sensory attributes of the meat (LD). Sensory scores (least-squares means and standard errors) indicated that all samples were tender (values from 6.2 to 6.6 ± 0.4), juicy (value 6.2 ± 0.3 for both groups), had low scores for game flavor (value 3.0 ± 0.4 for both groups), bloody flavor (values from 4.6 to 4.7 ± 0.6) and sweet flavor (3.1–3.3 ± 0.3).

3.3.2. Consumer tests

In the consumer tests of the cubed ($P < 0.05$) and sliced meat ($P < 0.001$), the ES meat was significantly more tender compared with the NES meat (Table 4). No significant difference was found when comparing the ground meat, however a tendency ($P < 0.10$) towards ES meat being most tender was observed (Table 4).

4. Discussion

Reindeer in Alaska originate from Chukotka in Russia where they were selected and used for meat production. Even though this sub species is the same as the Fennoscandian reindeer (Rangifer tarandus tarandus), the Alaskan animals are heavier and have a stockier body shape (Finstad & Prichard, 2000). Alaskan reindeer herders typically manage and slaughter adult steers (Alaska Agriculture Sta-
domestic species (Wiklund et al., 2000), results that were higher bone contents than red and fallow deer or domestic species (Wiklund et al., 2000). In the same study it was found that reindeer carcasses had lower fat contents than red deer and fallow deer (Renecker et al., 2005). The present data were in good agreement with a recent study of seasonal variation in live weights, carcass weights and carcass composition of adult reindeer bulls and steers from the Seward Peninsula (Wiklund, Finstad, & Bechétel, 2005).

Similar carcass composition values to those of the present study for reindeer have been reported for adult reindeer bulls by Wiklund et al. (2000). In the same study it was found that reindeer carcasses had lower fat contents and higher bone contents than red and fallow deer or domestic species (Wiklund et al., 2000), results that were in good agreement with those in the present study. Surgical and chemical castration of deer has been demonstrated to affect animal live weight gain and carcass composition, mainly fat content (Drew, Fennessey, & Greer, 1978; Freudenberger et al., 1991; Mulley & English, 1985), therefore further studies of carcass composition and meat quality attributes in Alaskan reindeer bulls and steers are being carried out. The variation in muscle/meat distribution between different deer species was described by Goosen, Fennessey, and Pearse (1999), where a hybrid animal (cross between red deer and Pére David’s deer (Elaphurus davidianus)) was demonstrated to have relatively more meat in the hind leg primal cut compared with red deer. Generally, the most valuable cuts from a carcass originate from the striploin, tenderloin and hindquarter. To illustrate the species differences in hindquarter composition, literature values for the three main cuts from the hindquarter (topside; M. semimembranosus, silverside; M. biceps femoris and M. semitendinosus and knuckle; M. quadriceps femoris) from reindeer, moose, and beef are compared in Fig. 2. Rusa deer had a very high percent of meat in the hindquarter (21.5%), silverside 25.4% and knuckle 18.7% compared with the other species (Sookhareea, Taylor, Dryden, & Woodford, 2001). As shown in Fig. 2 the topside of the reindeer hindquarters was the largest cut (16.4% of the hindquarter), while in moose the largest cut was the knuckle (15.3%) and in beef the silverside (14.4%). The hindquarters and forequarters in the present study represented approximately equal proportions of the whole carcass (hindquarter 38.8%; forequarter 40.2%). The economical value of the reindeer carcass would increase considerably if value could be added to the forequarter. This is challenging in the field slaughter situation where the carcasses have to be frozen in the field and cannot be thawed before purchase by the consumer.

High ultimate pH values in meat from ruminants (beef cattle, reindeer, red deer and fallow deer (Dama dama)) have been related to pre-slaughter handling stress (Malmfors, Lundström, & Fabiansson, 1983; Pollard, Stevenson-Barry, & Littlejohn, 1999; Warriss, 1990; Wiklund, Andersson, Malmfors, & Lundström, 1996) and poor nutritional status of the animals (Gregory, 1996; Pollard et al., 2002; Wiklund et al., 1996). The reindeer in the present study were shot in the field after a minimum of pre-slaughter handling and the measured meat pH values thus indicated that all animals were exposed to a stress-free slaughter and that they were in good physical condition.

When carcasses are cooled quickly, they have the potential to be affected by cold-induced shortening and/or toughening (Savell, Mueller, & Baird, 2005). Muscle temperature and pH relationships at the moment of rigor onset have been proposed to determine the degree of cold shortening (Hannula & Puolanne, 2004). The susceptibility to cold shortening has been demonstrated to vary between different types of muscle fibers (Bendall, 1973) and consequently beef, lamb and deer meat (where most muscles are dominated by red muscle fibers) was thought to be more sensitive to cold shortening than pork (Savell et al., 2005). There are economic advantages for rapid carcass chilling, which include reduced cooling time, increased carcass processing rate and decreased shrink and drip losses; however rapid chilling may reduce meat tenderness (Aalhus, Janz, Tong, Jones, & Robertson, 2001). Using treatments like electrical stimulation and pelvic suspension (i.e., hanging the carcass from the obturator foramen) offer meat processors the opportunity to counteract most or all the effects of cold shortening (Savell et al., 2005). The combination of electrical stimulation and rapid/blast chilling has been recommended as
a means to reduce chilling times and shrink losses while producing meat of as good or slightly superior quality compared with conventionally cooled beef carcasses (Aalhus et al., 2001; Li et al., 2006). Meat from bison (Bison bison bison) carcasses exposed to conventional chilling (0–2 °C for 24 h) and blast chilling (−20 °C and 3 m/s air velocity for 2 h) with or without ES was significantly more tender after ES compared to the NES treatment (Janz, Aalhus, & Price, 2001). The present reindeer LD samples were all very tender regardless of ES or NES treatment, though ES samples were significantly more tender than NES samples. Earlier studies have reported equally low shear force (high tenderness) values for reindeer meat (Rincker et al., 2006; Wiklund et al., 1997).

The present results support earlier conclusions that reindeer meat (LD) does not require a period of ageing to be tender (Barnier et al., 1999; Wiklund et al., 1997) and consequently electrical stimulation would not practically increase the rate of meat tenderization in primal cuts like the striploin. The potential positive effects of ES on tenderness in tougher reindeer meat cuts (like shoulder meat) must therefore be balanced against the risk of ‘over-tenderizing’ the already very tender primal cuts. The fact that individual muscles exhibit different pre-rigor behaviours was highlighted in a study of hot-boned ES treated beef (White, O’Sullivan, Troy, & O’Neill, 2006). In this study (White et al., 2006) it was concluded that mechanisms other than the prevention of shortening could be involved in the ES induced tenderization of meat and that a variation in fiber type composition and physical dimensions of the muscles might impact on the ES regimes.

The procedure of hot boning was developed to remove meat cuts from the carcass before chilling or freezing. However, excised muscle removed pre-rigor is more susceptible to shortening due to the loss of muscle–bone attachment and rapid freezing would enhance the likelihood of cold shortening (Savell et al., 2005). When meat freezes before the onset of rigor then, on thawing, the muscle shortens severely and becomes very tough after cooking, a phenomenon called thaw rigor (Warriss, 2000). If thaw rigor occurred in the processed reindeer meat samples in the present study that would have happened just before cooking the meat, as the meat samples were frozen until cooking. The effects of shortening/contraction would probably have been less in the processed samples, where the meat structure was mechanically broken compared with the effects whole pieces of meat. Further, it has been suggested that the effects of thaw rigor might be reduced during frozen storage of meat (Warriss, 2000). Results from the consumer test in the present study suggest application of low voltage ES may have ameliorated the effects of any shortening/toughening of hot-boned reindeer meat.

Values for drip loss (purge) during storage of fresh chilled reindeer meat have not been reported. However, purge values of 0.6–3.7% for red deer LD samples after 3 weeks of storage (Wiklund, Sampels, Manley, Pickova, & Littlejohn, 2006; Wiklund et al., 2001) and fallow deer and lamb meat (LD) purge values of 2.0–2.6% after 3 weeks of storage (Wiklund, Mulley, Hutchison, & Littlejohn, 2004) were lower than the purge values of 5.2 and 6.4% after 3 weeks of storage found in the present study. It should be noted that the red deer studies (Wiklund et al., 2006; Wiklund et al., 2001) were performed within the practices of the New Zealand venison industry where fresh meat is stored and transported at −1.5 °C while in the fallow deer/lamb study (Wiklund et al., 2004) and in the present study samples were stored at +2–3 °C.

Objective color values as determined by the Hunter chromameter were not different (p > 0.05) between ES and NES samples for L, a, and b values. The Hunter L values in the present study of 18.8 and 19.4 were slightly lower than values reported by McDougall, Shaw, Nute, & Rhodes (1979) for venison from farmed young red deer. The lower Hunter L, a, and b values of the reindeer meat are consistent with a product that is darker in appearance, and has less red and yellow color than beef (Rincker et al., 2006). Other investigators have compared the effects of ES on Minolta L, a, and b meat color values and reported ES beef to be paler (higher L values) and also redder (higher a values) than NES beef (Eikelenboom, Smulders, & Rüdérus, 1985; Hector, Brew-Graves, Hassen, & Ledward, 1992). ES treatment was associated with some loss of color stability during retail display of red deer meat (Wiklund et al., 2001), although this effect of ES was shown to be neutralized by manipulation of rigor temperature (Bekhit, Farouk, Cassidy, & Gilbert, 2007).

The significant difference in mechanical tenderness (shear force) between the two treatment groups showed that the ES treated meat (LD) was slightly more tender than the NES meat (Table 2), however with all shear force values being below 2 kg the marginal difference between the groups could not be picked up by the trained panel. Sensory scores for tenderness and juiciness in reindeer meat (LD) have been reported to be high (Renecker et al., 2005; Rincker et al., 2006; Wiklund, Johansson, & Malmfors, 2003), and the present results are in agreement with previous studies. In the present experiment three different products were prepared (thin sliced, cubed and ground meat) from field slaughtered lower quality cuts (shoulder meat) and the consumers confirmed ES treatment to increase tenderness in the cubed and sliced meat products (Table 4). These results are somewhat in contrast to the study by Toohey & Hopkins (2006) who concluded that ES was not sufficient to ensure eating quality of hot-boned/rapidly frozen sheep meat.

5. Conclusions

Results from this study demonstrate that ES increased tenderness in hot-boned cubed and sliced products made from field slaughtered reindeer shoulder meat. Loins from carcasses conditioned for 48 h prior to boning and freezing were similar in color and tenderness although ES did result...
in slightly lower shear force values. The ES technique in combination with the right processing methods can be used in field slaughter systems for reindeer to significantly increase the quality and potential value of e.g. forequarter meat.

Acknowledgements

The authors wish to thank the Davis’ family of Nome, Heikki Muhonen and Chuck Stites for all their assistance and cooperation in connection with the slaughter, butchering and collection of samples. We are also grateful to Heather Averett for laboratory analysis and Kamolluck Trateng for her invaluable assistance during the sensory sessions with the trained panel. During the consumer tests the help of Suzanne Worker, Margo Kramer and Becky Knight was greatly appreciated. Financial support for this work was provided by the United States Department of Agriculture (USDA; New Crops Opportunities IV, grant no. G00001355) and by the Reindeer Research Program, University of Alaska Fairbanks.

References


Alaska Department of Environmental Conservation. (2003). Regulations for reindeer slaughtering and processing (18 AAC 32.600) and regulations for reindeer for retail sale to or at a market (18 AAC 31.820), State of Alaska, USA.


Barnier, V. M. H., Wiklund, E., van Dijk, A., Smulders, F. J. M., & University of Alaska Fairbanks. Agriculture (USDA; New Crops Opportunities IV, grant work was provided by the United States Department of Agriculture (E), Geveve, Switzerland.


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