

SIMILARITIES AND DIFFERENCES IN COMPOSITION AND SELECTED SENSORY ATTRIBUTES OF REINDEER, CARIBOU AND BEEF

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ABSTRACT

The longissimus from caribou (n = 6), reindeer (n = 6) and beef (n = 6) were evaluated to determine differences in composition, color and sensory properties. Caribou contained the least fat followed by reindeer, and then beef (P < 0.05). Both venison sources contained more heme pigment and had a higher glycolytic potential than beef (P < 0.05). A trained sensory panel found both sources of venison to be more tender than beef (P < 0.05); however, Warner–Bratzler shear force yielded no significant differences. The sensory panel scored both reindeer and caribou as having a more intense off-flavor (livery) and less intense meat-flavor than beef (P < 0.05). Venison was darker than beef as determined by Minolta L values (P < 0.05). No differences (P > 0.05) were found in ultimate pH or juiciness (sensory panel) among any of the products. Results from this study indicate that reindeer and caribou are a low-fat source of protein with desirable sensory characteristics.*

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INTRODUCTION

Rangifer, the genus that encompasses both caribou and reindeer, are an integral part of the food chain throughout much of the world. In Alaska, both domestic reindeer and wild caribou are present. Reindeer were introduced to Alaska in the late 1890s from Russia. Currently, the Alaskan reindeer industry is found predominately on the Seward Peninsula, where reindeer are extensively herded over large tundra ranges (Stern *et al.* 1980). During the 1920s and 1930s, up to 600,000 reindeer were distributed across Alaska, implying high potential for commercial production of reindeer (Stern *et al.* 1980). In 2002, the USDA identified approximately 15,000 domestic reindeer being farmed in Alaska. This translated into total sales of approximately \$453,000, with sales from meat accounting for \$251,000 (Benz *et al.* 2003). The world population of caribou is approximately 5,000,000, with Alaska accounting for 950,000, or almost 20% of the total. Additionally, Alaskan hunters harvest about 20,000 wild caribou annually for food (Valkenburg 1994). *Rangifer* are important, both economically and nutritionally, in parts of rural Alaska.

It is anticipated that more meat from Alaska's reindeer will be marketed to upscale restaurants, where questions about meat quality and sensory attributes of beef versus wild caribou will arise. A limited amount of research has been conducted concerning quality and sensory attributes of reindeer and caribou. There is even less literature comparing these species to more common animal protein sources such as beef. Because red deer is more abundant and more aggressively marketed throughout much of the world, more research involving the red deer has been conducted. Attributes commonly measured in studies concerning red deer include ultimate pH (pH_u), objective color and sensory properties. The objectives of the current study were to determine differences and similarities among reindeer, caribou and beef as they relate to appearance, chemical composition and sensory attributes.

MATERIALS AND METHODS

Animals

Reindeer and caribou were harvested on the Seward Peninsula near Nome, Alaska. A total of 18 animals were utilized for this study. These 18 animals consisted of 6 wild caribou, 6 domestic reindeer and 6 domestic beef cattle from the midwestern United States. The reindeer and caribou were harvested for normal consumption purposes, indicating that they would rep-

resent typical animals for this purpose: however, samples were removed for evaluation. Reindeer and caribou were harvested by a sharpshooter with a rifle from close proximity. Kill shots were placed either in the neck or shoulder and the animals did not run after the initial shot. A portable tripod was taken to the carcass to suspend it for skinning and evisceration. The total number of samples of caribou ($n = 6$) and reindeer ($n = 6$) was selected based on funding available for the study. Beef samples were purchased to equal the number of reindeer and caribou samples acquired.

The free-ranging (however, still farmed) reindeer were harvested at an outdoor slaughter facility on snow as is typical for this industry. All 6 reindeer utilized were castrated males that ranged in age from 3 to 6 years. They were harvested on two separate days at -3.9C (both days) with wind chills of -10.6 and -7.2C , respectively. Immediately following harvest, bone-in-loin sections were excised and wrapped in plastic. Times and temperatures were recorded from the moment of wrapping until the samples were frozen. Samples were stored at -19.5C .

Caribou are wild animals that migrate in and out of the reindeer herd, causing major management problems. Intact male caribou were identified by the herders and harvested in the field. Five of the caribou were estimated to be 3 years old and one animal was estimated to be 1 year old as determined by antler size and long bone length. The caribou were also harvested on two separate dates at -5.0 and -0.5C with wind chills of -12.8 and -7.2C , respectively. As with the reindeer, the samples were excised immediately following harvest and time and temperature were recorded until freezing.

Beef samples were obtained from a commercial slaughter facility in the midwestern United States. No gender or genetic background information was available. Six select strip loins were purchased and shipped to the University of Illinois Meat Science Laboratory where they were frozen immediately upon arrival at 8 days postmortem.

Meat Preparation

Product was evaluated at the University of Illinois Meat Science Laboratory over a period of 3 days. Two *longissimus* sections from each species were evaluated on each day. Samples were removed from the freezer and placed in a cooler at 4C for a period of 48 h to thaw. Upon thawing, the *longissimus dorsi* was removed from the bone-in-loin section. Measurements on boneless samples included ultimate pH (pH_u) and Minolta L^* , a^* and b^* color measurements. Steaks 2.5 cm thick were cut for use in proximate analysis, glycolytic potential, total pigment determination, shear force and sensory evaluation.

Ultimate pH Determination

The pH_u of each sample was determined utilizing the SFK star probe (SFK Technologies, Cedar Rapids, IA) calibrated with two buffers of pH 4.0 and 7.0.

Color Determination

Objective color was determined with a Minolta Chromameter CR-300 using a D65 illuminant and a 0° observer (Minolta Camera Co., Osaka, Japan). A 0.5-cm slice was removed to expose a fresh surface to air and the sample was allowed to bloom for 15 min prior to its color measurement being taken.

Proximate Analysis

A sample for proximate analysis was collected from each specimen and trimmed of all external fat and connective tissue prior to being homogenized in a food processor (Black and Decker, Shelton, CT). Proximate analysis for determination of moisture and fat content were conducted in duplicate following procedures described by Novakofski *et al.* (1989). Moisture content was determined by drying in an oven at 110C for 48 h. Lipid content was determined through extraction with a 4:1 chloroform : methanol solution.

Glycolytic Potential

Determination of glycolytic potential was conducted as described by Bidner (1999). A 2-g muscle sample was utilized to determine concentrations of glycogen, glucose, glucose-6-phosphate (G-6-P) and lactic acid. Glycolytic potential (GP) was determined using the equation: $\text{GP} = 2 \times ([\text{glycogen}] + [\text{glucose}] + [\text{G-6-P}] + [\text{lactate}])$.

Total Heme Pigment

Myoglobin concentration was determined using a modified version of the total pigment assay performed by Warriss (1979). A 2.00-g muscle sample was homogenized in a 15-mL centrifuge tube with sodium phosphate buffer for a total volume of 10 mL (Ultra-Turrex T8, IKA WRKE; GMBH & Co., Hanan, Germany). The pigment was extracted at 4C for 1 h while samples were rotating (Labquake shaker, Labindustries, Inc., Berkley, CA) before being centrifuged at 4000 rpm for 10 min at 4C (Eppendorf Centrifuge 5810R, Hamburg, Germany). The sample was filtered through a glass wool to remove excess lipid and centrifuged again. One mL of the supernatant and 500 μL of Drabkin's reagent were placed in a 1.5-mL microcentrifuge tube and held on ice for 10 min prior to being centrifuged at 14,000 rpm for 30 min at 4C

(Eppendorf Centrifuge 5810R). The myoglobin concentration was determined by spectrophotometry (model DU-640, Beckman Instruments, Inc., Fullerton, CA) at 540 μm against a standard curve prepared from myoglobin in phosphate-buffered saline.

Shear Force

Warner–Bratzler shear force was determined on 2.5-cm steaks. Two steaks were cut from each individual animal and were cooked to end-point temperatures of 65 and 75C on an open hearth Farberware grill (model 455N, Walter Kiddle, Bronx, NY). Internal temperature was monitored with copper-constantan thermocouples (Type T, Omega Engineering, Stamford, CT) and a Barnant scanning digital thermometer (model 692-0000, Barnant Co., Barington, IL). Steaks were cooled to 25C prior to removal of 1.3-cm cores parallel to the orientation of the muscle fibers. Cores were sheared using an Instron universal testing machine (model 112, Instron Corporation, Norwood, MA) set with a 10-kg load cell and a 200 mm per minute chart drive and crosshead speed. A total of three cores per chop were utilized and the values were averaged.

Sensory Evaluation

Sensory evaluation was performed by a six-member trained sensory panel. Panelists were selected based on previous experience conducting trained sensory evaluation and trained for tenderness and juiciness that used boiled hotdogs and cold water-added ham as respective standards. Training for off-flavor (livery or gamey) was conducted using *longissimus* samples from white-tailed deer harvested in Illinois. Because the reindeer and caribou samples were being evaluated against beef samples, this gamey flavor was considered an off-flavor for the purpose of this study. There were however, no spoilage or oxidized flavors associated with any of the samples. Two 2.5-cm steaks from each animal were cooked to an internal temperature of 65 and 75C in the same manner as the shear force steaks. Samples (1 by 1 cm) were presented to panelists under fluorescent lighting. Water and unsalted crackers were made available to panelists for palate cleansing between samples. A 15-cm unstructured line scale was utilized to evaluate tenderness, juiciness, meat-flavor intensity and off-flavor (livery or gamey) intensity (0 = extremely tough, extremely dry, no meat-flavor and no off-flavor; 15 = extremely tender, extremely juicy, intense meat-flavor and intense off-flavor, respectively).

Statistical Analysis

Statistical analysis was carried out using the mixed procedure of SAS (SAS Institute, Inc. 1999, version 8.2) utilizing the animal as the experimental

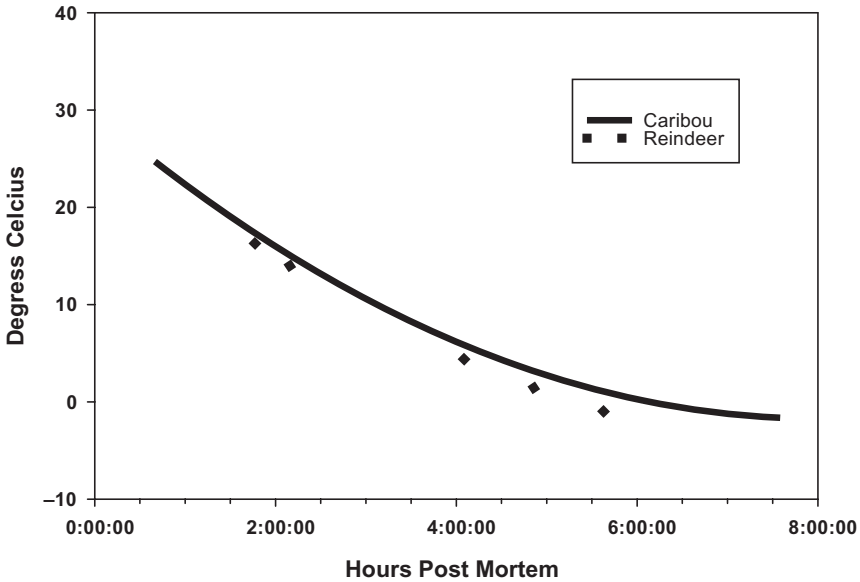


FIG. 1. AVERAGE OF REINDEER ($N = 6$) AND CARIBOU ($N = 6$) TEMPERATURE DECLINES

unit with the model including species, degree of doneness and any significant interactions. Significance was determined at the $P < 0.05$ level.

RESULTS AND DISCUSSION

Temperature Decline

The time–temperature decline curves for the reindeer and caribou reveal a rapid rate of cooling. Figure 1 demonstrates that the samples had reached freezing temperatures by about 6 h postmortem. Ohene-Adjei (1999) reported an average temperature for conventionally chilled porcine carcasses at 4.25-h postmortem to be 16.5C for the loin and 26.7C for the ham. The rapid cooling rates for the current study are attributable, in part, to the samples being immediately excised after slaughter and having the skin removed, thus allowing them to cool more quickly. Also, the process of harvesting the animals at an outdoor slaughter facility on days when the temperatures and wind chills are below freezing would accelerate temperature decline by allowing the carcass the opportunity to start cooling immediately after exsanguination rather than when it is placed into a cooler.

The rate of temperature decline is an important factor relating to meat quality. Several studies have indicated that pH decline at an elevated temperature can lead to protein denaturation and decreased meat quality (Bowker *et al.* 1999; Rathgeber *et al.* 1999). It has also been demonstrated that aggressive chilling early postmortem can result in cold shortening of muscle or freezing early postmortem could result in thaw rigor upon thawing. Either one of these conditions can result in shorter sarcomere lengths, which have been associated with less tender products with decreased water-holding capacity (Price and Schweigert 1987). Rathgeber *et al.* (1999) demonstrated how an accelerated chilling system could improve meat quality by slowing the rate of pH decline of poultry. They also reported that a more rapid chilling rate had small effects on the pH_u of a meat product. Utilizing standard immersion chilling of poultry carcasses at 20-min postmortem as a control and delayed chilling of carcasses at 110-min postmortem as the experiment, they were able to produce significant ($P < 0.05$) quality differences. The delayed chill resulted in breast meat that was lighter (increased L^*) ($P < 0.05$), had a lower pH_u ($P < 0.05$) and decreased ($P < 0.05$) protein extractability, which all indicate decreased meat quality (Rathgeber *et al.* 1999). Rapid chilling in beef has been evaluated by Aalhus *et al.* (2002) by exposing one side of a beef carcass to either -20 or -35C to be compared against the control side chilled at 2C for 24 h. The most aggressive treatment in this experiment resulted in *longissimus* temperatures approaching 0C between 7 and 8 h postmortem. This is not quite as fast as the reindeer and caribou approached 0C , which is probably because of the mass of the tissues. Results from this study indicated that the accelerated chilling did not negatively affect tenderness or cooler shrink, but the more aggressive treatments did have a negative impact on drip loss (Aalhus *et al.* 2002). This is in contrast to data reported by Van Moseke *et al.* (2001), in which the rapidly chilled beef (-25C for 5 h) underwent cold shortening as indicated by the sarcomeres of the rapidly chilled beef being 30% shorter and an increase in Warner-Bratzler shear force. Based on the temperature decline curves generated for the current study, protein denaturation because of temperature and pH interactions should have been minimized. There is the potential for tenderness issues, however, based upon what is known about rapid chilling or freezing of predominately red muscle early postmortem.

Ultimate pH

Several studies have revealed that the pH_u of venison ranges from 5.50 to 5.75 (MacDougall *et al.* 1979; Seman *et al.* 1988; Wiklund *et al.* 2000, 2001; Pollard *et al.* 2002). This pH range is similar to pH values obtained from other mammalian species. Average pH values for 1000 head of commercially harvested beef carcasses and almost 4000 commercially harvested pigs both

TABLE 1.
VALUES OF SELECTED TRAITS FROM BEEF, CARIBOU AND REINDEER

	Beef	Caribou	Reindeer	SEM
Glycogen + glucose + G-6-P ($\mu\text{mole/g}$)	18.07 ^a	58.93 ^b	49.29 ^c	2.70
Lactic acid ($\mu\text{mole/g}$)	82.96 ^a	62.83 ^b	64.37 ^b	2.12
Glycolytic potential ($\mu\text{mole/g}$)	119.10 ^a	180.69 ^b	162.96 ^c	5.61
Fat (%)	4.02 ^a	1.18 ^b	2.76 ^c	0.27
Moisture (%)	72.82 ^a	73.80 ^b	73.83 ^b	0.20
Myoglobin (mg/g)	7.29 ^a	8.59 ^{ab}	9.79 ^b	0.56
pH _u	5.48	5.61	5.60	0.07
Minolta <i>L</i> *	34.26 ^a	26.28 ^b	25.30 ^b	0.77
Minolta <i>a</i> *	22.29 ^a	18.08 ^b	17.07 ^b	0.70
Minolta <i>b</i> *	9.19 ^a	5.51 ^b	5.14 ^b	0.63

^{a,b,c} Means with different superscripts within the same row are different $P < 0.05$.
SEM, standard error of the least square means.

yielded values of 5.50 (Velarde *et al.* 2000; Page *et al.* 2001). The average pH values in this study for beef, reindeer and caribou were 5.48, 5.60 and 5.61, respectively (Table 1). The pH of a product will often affect the color of the meat because as the pH moves farther away from the isoelectric point of the muscle proteins (approximately 5.0) the water will be more tightly bound and less light will be reflected (Price and Schweigert 1987). However, in this particular study, no significant differences ($P < 0.05$) in pH among species were evident.

Color

The objective color values as determined by the Minolta chromameter revealed some dramatic differences. For all three Minolta values (*L**, *a** and *b**), reindeer and caribou were significantly different ($P < 0.05$) from beef, but not from each other (see Table 1). The values obtained in the current study correspond with those reported by MacDougall *et al.* (1979) and Pollard *et al.* (2002). Similar to these results, Pollard *et al.* (2002) reported Minolta *L**, *a** and *b** values that were significantly lower ($P < 0.05$) for venison than for beef with values for red deer ranging from 16 to 20. MacDougall *et al.* (1979) observed Hunter *L*-values ranging from 21 to 29 in farmed, young red deer. Page *et al.* (2001) reported an average Minolta *a** value of 25.05 on 1000 head of commercially slaughtered beef which is similar to the values obtained from beef samples in the present study. The lower *L**, *a** and *b** values of the venison indicate a product with a darker appearance, less red and yellow colors than beef.

Proximate Analysis

Muscle composition of beef, caribou and reindeer is presented in Table 1. The select-grade beef contained the highest ($P < 0.05$) percent lipid followed by the reindeer, then the caribou. This would be expected when beef cattle are fed on high-energy diets and selected for fat deposition. The reindeer are farmed, but the diets are not formulated to be as energy dense. Because the caribou are indeed wild, one would expect them to have the least amount of lipid present. Moisture content of reindeer and caribou were similar; however, beef had a slightly lower ($P < 0.05$) percent moisture value, which is consistent with its higher lipid content.

Typically, venison contains less fat, more protein and more water than the more common domestic species (Marchello *et al.* 1985). Authors have reported the fat content in the *longissimus dorsi* of red deer to range from 0.3 to 1.2% (Forss and Manley 1977; Aidoo and Haworth 1995). These numbers are similar to the lipid content of the caribou, but less than that extracted from the reindeer. The extraction of lipid in the previously mentioned experiments was conducted utilizing petroleum ether. Had the authors used a different solvent, the numbers may have been slightly higher. Research has demonstrated that extraction with an azeotropic mixture of chloroform and methanol, rather than ether, yields increased extraction of polar lipids. The increase, however, is generally less than 0.5% (Zhukov and Vereshchagin 1981; Novakofski *et al.* 1989).

Glycolytic Potential

The glycolytic potential of an animal will often influence the ultimate pH of a meat product. Bidner (1999) reported postrigor GP values for 34 (RN⁺rn⁺ 129.2 $\mu\text{mole/g}$) and 36 (RN⁻rn⁺; 207.5 $\mu\text{mole/g}$) pigs that resulted in ultimate pH values of 5.56 and 5.35, respectively. Lower pH values can lead to protein denaturation and loss of water-holding capacity. Very little information is available concerning the GP of venison.

Although the pH of the three species showed no differences ($P > 0.05$), there were significant differences ($P < 0.05$) between the GPs of the beef and the venison. Caribou had the highest ($P < 0.05$) overall GP (180.69 $\mu\text{mole/g}$) followed by reindeer (162.96 $\mu\text{mole/g}$), then beef (119.10 $\mu\text{mole/g}$). Caribou and reindeer samples had lower levels of lactic acid than beef ($P < 0.05$) even though they had a higher GP. Bidner (1999) reported RN⁻rn⁺ pigs to have GPs of 207.5 $\mu\text{mole/g}$ and lactic acid levels of 109.59 $\mu\text{mole/g}$. Although the reindeer and caribou had GP values similar to a RN⁻rn⁺ pig, the amount of lactic acid present was less than 65.0 $\mu\text{mole/g}$. This is consistent with post-mortem glycolysis being halted prior to all of the glycogen available being converted to lactic acid. If the sample was cooled and frozen quickly enough,

pH decline may have been halted prematurely. However, the pH_u of the venison in this study is similar to the pH_u previously reported by other investigators. The glycolytic profile of the reindeer and caribou indicate that cold shortening or thaw rigor may have been an issue with these samples. There were, however, no noticeable problems when the samples were thawed (i.e., noticeable shortening, excess purge). This lack of noticeable shortening could be attributed in part to the samples being bone-in-loin sections and thus held in place by structural components. Had boneless samples been removed, results may have been different.

Total Heme Pigment

The predominant pigment in muscle is myoglobin (Van Laack *et al.* 1996) and very limited data have been published concerning the myoglobin concentration of venison. MacDougall *et al.* (1979) reported a concentration of 6.36 mg of myoglobin per gram of wet tissue from a study of 27 farmed young red deer. Although myoglobin content will vary with species and increases with age, typical concentrations for pork, lamb and beef would be 1, 2.5 and 5 mg of myoglobin per gram of wet tissue, respectively (Price and Schweigert 1987). A significant difference ($P < 0.05$) in pigment concentration existed between the beef (7.29 mg/g) and the reindeer (9.71 mg/g) as shown in Table 1. Although the average value for the caribou was numerically higher (8.59 mg/g) than that of the beef, it was not statistically different ($P > 0.05$). The numbers are slightly higher than the average numbers reported by Price and Schweigert (1987). Other possible explanations for the differences in color between the species may involve mitochondrial numbers or fiber type differences. Further research in this area may be warranted.

Sensory Evaluation and Shear Force

The results of the trained panel sensory evaluation are shown in Table 2. Reindeer and caribou were both more tender than beef, but did not differ statistically from each other. Juiciness did not differ ($P > 0.05$) among the three species. Reindeer and caribou were scored consistently higher for off-flavor intensity than was beef. Because the samples were being compared directly to beef, off flavor was described as any flavor not associated with typical beef flavor. The panelists described the predominant off-flavor associated with the venison as livery or gamey. None of the samples contained rancid, oxidized or spoiled flavors, indicating that the off-flavors associated with the venison samples was the livery or gamey flavor. Sensory panel evaluation of meat-flavor intensity also differed ($P < 0.05$) with beef having a more intense meat-flavor than venison. One explanation for this is that the

TABLE 2.
SENSORY CHARACTERISTICS OF BEEF, CARIBOU
AND REINDEER

	Beef	Caribou	Reindeer	SEM
Juiciness	8.13	8.04	8.83	0.29
Tenderness	8.57 ^a	10.20 ^b	9.58 ^b	0.28
Meat-flavor intensity	7.12 ^a	5.90 ^b	6.03 ^b	0.23
Off-flavor intensity	0.76 ^a	3.21 ^b	2.75 ^b	0.36
Shear force (kg) at 65C	1.30	1.28	1.13	0.20
Shear force (kg) at 75C	1.52	1.18	1.30	0.16

^{a,b} Means with different superscripts within the same row are different $P < 0.05$.

SEM, standard error of the least square means.

off-flavor of the venison overpowered the meat-flavor for many panelists. Lipid content and composition of different meat sources may also play a role in the detection of meat-flavor. Venison sources for the current study contained fewer lipids than beef.

Surprisingly, the shear force values did not differ ($P > 0.05$) among the species. This was in contrast to the trained sensory panel evaluation of tenderness where reindeer and caribou were more tender than beef ($P < 0.05$). Shear force values for all samples were below 1.52 kg, indicating all samples, including the select beef, were very tender.

Most literature relating to sensory evaluation of venison suggests that venison is usually juicy and either tender or very tender. It does, however, also have a gamey taste, which is sometimes described as livery (Forss and Manley 1977; MacDougall *et al.* 1979; Brittin *et al.* 1982; Wiklund *et al.* 2000; Pollard *et al.* 2002). Wiklund *et al.* (2000) states that this gamey flavor can be intensified by both method and length of storage.

Cooking Temperature

The effect of cooking temperature on sensory properties of reindeer and caribou has not been previously evaluated. End-point cooking temperature did significantly affect the trained panel's perception of tenderness and juiciness as would be expected. Both tenderness and juiciness significantly decreased ($P < 0.05$) as the end-point cooking temperature increased from 65 to 75C. It did not, however, have any effect on meat-flavor or off-flavor intensity. Cooking temperature did not have a consistent effect on shear force values among the three species (Table 3). The shear force values for both beef and reindeer increased with cooking temperature, but decreased for caribou.

TABLE 3.
EFFECT OF COOKING TEMPERATURE ON SENSORY
CHARACTERISTICS OF BEEF, CARIBOU AND REINDEER

	65C	75C	SEM
Juiciness	8.77 ^a	7.91 ^b	0.24
Tenderness	9.81 ^a	9.08 ^b	0.23
Meat-flavor intensity	6.51	6.19	0.19
Off-flavor intensity	2.27	2.22	0.29
Shear force (kg)	1.24	1.33	0.10

^{a,b} Means with different superscripts are different $P < 0.05$.
SEM, standard error of the least square means.

Although the average shear force value for all species combined increased with cooking temperature, with the limited number of samples available, no differences could be detected.

CONCLUSIONS

Various aspects of venison from two different sources in Alaska, farmed reindeer and wild caribou, were compared to beef. The proximate analysis revealed that both sources of venison contained less fat and more water than beef. Venison was darker with regard to objective color (L^*), had a higher GP and a higher concentration of heme pigment than beef samples. The pH_u of the products did not differ. A trained sensory panel found venison to be more tender than beef, but no differences were observed in juiciness. Warner–Bratzler shear force values did not differ among the products. The panel also found the venison to have a less intense meat-flavor and a more intense off-flavor (livery or gamey) than the beef. Results from this study indicate that reindeer and caribou, although different from beef in some respects, are low-fat sources of protein with desirable sensory characteristics.

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