# Relationships between carcass characteristics, meat quality, age and sex of free-ranging Alaskan reindeer: a pilot study

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*Abstract:* Twenty-four reindeer (*Rangifer tarandus*) carcasses from male and female animals that ranged in age from calves to adults were purchased from Bering Sea Reindeer Products (BSRP), Nunivak Island, Alaska, USA. Preslaughter and abattoir procedures were observed and evaluated. Carcasses were split in half, weighed, and broke into wholesale primal cuts of chuck, rib, loin, and hindquarter. Each primal cut was weighed, boxed, and frozen. Each half carcass of primal cuts was later dissected into lean tissue, bone, and the three compartments of fat: subcutaneous, intermuscular, and peritoneal. A portion of the loin was collected from each animal in order to obtain data on pH and shear force. Sensory panel analysis was performed on loin steaks. Due to management and environmental effects, pH values were high and the meat was dark in colour. Carcasses from adult male reindeer contained significantly lower levels of fat than carcasses of adult females. Data indicated that yearling reindeer are of greatest economic value for meat production.

**Key words:** carcass composition, grading, *Rangifer tarandus*, slaughter.

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## Introduction

The natural patterns of cervid growth and weight loss are important criteria in the decision of optimal slaughter age. Reindeer (*Rangifer tarandus*), like wapiti (*Cervus elaphus*) (Renecker & Hudson, 1993), moose (*Alces alces*) (Renecker & Hudson, 1986), and red deer (Fennessy, 1982) have seasonal growth cycles that are important functions in determination of the optimal time and age of commercial slaughter (Drew, 1991a). These cycles are entrained by factors such as photoperiod, temperature, and plant growth that show rapid growth in spring and summer followed by stasis and weight loss in late autumn and winter (Nieminen, 1994; Schwartz & Renecker, 1997). As male reindeer enter the 2-year-old cohort, weight loss during the autumn rut and subsequent winter will increase in comparison to calves and yearling bulls. Female reindeer do not incur the severe weight loss in autumn as a result of inappetance during rut (Leader-Williams, 1988) but instead are probably more metabolically efficient, like moose (Renecker, 1987; Schwartz & Renecker, 1998) and other large northern ungulates (Hudson & Christopherson, 1988; Renecker & Samuel, 1990).

The sequence of fat depot growth and mobilization is still not well understood although it is clear that there are marked differences between species at equal fatness (Kempster, 1980). Due to the harsh environment and annual metabolic cycle of reindeer, the deposition and subsequent utilization of fat is paramount from both a survival and commercial production perspective. Nieminen & Maijala (2001) found that reindeer fed concentrates had higher carcass weights, protein content of the meat, and fat content of the meat that varied seasonally and with animal age and sex (castrates *vs.* intact). While there have been some studies on *Rangifer tarandus* regarding the deposition and utilization of fat (Engebretsen, 1975), information is limited on the differential growth of muscle, bone, and fat of the reindeer from commercial operations.

Variation in pH can affect meat quality and may change with time of slaughter, animal age and condition, and sex. Most meat has an ultimate pH between 5.4 and 5.7 (Wookey *et al.*, 1970; Wiklund, *et al.*, 1995; Drew, 1996; Renecker *et al.*, 2001a) with values over 5.9 considered dark cutting. The phenomena known as dark cutting or DFD (dark, firm, and dry) meat is a major economic problem in the slaughter industry effecting an estimated 3% of beef, pork, and lamb slaughtered in North America (Hedrick *et al.*, 1994). DFD meat is associated with animals that undergo *ante mortem* stress thus depleting glycogen stores required to facilitate proper conversion of muscle to meat. The resultant meat has high pH values effecting proper colour change, providing an optimal environment for bacteria growth, and produces tissue that is dry or sticky in texture and has high water binding capacity meat (Schaefer *et al.*, 2001).

In 1993, a pilot project was initiated to assess meat quality and carcass composition (meat yield, cutability, and quality) of inspected reindeer meat from animals of various age and sex cohorts that were raised on open range on Nunivak Island, Alaska. The primary objective of this study was to obtain quality and quantity data in order to determine the optimal age and sex cohorts for commercial slaughter of reindeer on Nunivak Island and to identify meat parameters requiring further investigation that are associated with market desirability and demand. As with the domestic livestock industry, the development of a basic grading system is paramount for the reindeer industry to develop a niche in the specialty meat market of urban North America. Market success is dependent foremost upon the production of a standardized quality product that is consistent with North American consumer preferences.

## Study area and reindeer population

Nunivak Island is located in the Bering Sea at 50°23'N and 165°10'W approx 1025 km west of Anchorage, Alaska (Fig. 1). The Island is 113 km long and 80 km wide and contains a total area of 440 297 ha. The coastline includes sea cliffs, sandy


Fig. 1. Nunivak Island in relation to other reindeer herds in the State of Alaska, USA.

beaches backed by sand dunes, saltwater lagoons, and rocky shores with numerous coves and bays. The interior of the island is dominated by arctic tundra (Fries, 1977; Calista, 1986). The village of Mekoryuk is located on the north side of the island and is the site of Bering Sea Reindeer Products' (BSRP) office and abattoir. The subarctic climate is moderated by the Bering Sea and has a mean annual temperature of -7.0 °C, however, severe storms and blizzards occur throughout the year and periods of extended cloudiness with dense fog are common. Cold temperatures, heavy snow falls, high winds, and often freezing rain accompany winters (Calista, 1986). Annual snowfall averages 137 cm and has been reported in all but two months of the year.

The reindeer on the Island are a hybrid of reindeer originally introduced in the 1920s from the Seward Peninsula of Alaska (*R. t. tarandus*) and montane caribou (*R. t. granti*) bulls from the Kokrines area of the Yukon River that were introduced in 1925. The Bureau of Biological Survey worked with the cooperation of the Lomen Reindeer Corporation to begin caribou x reindeer cross-breeding experiments (Lomen, 1954). Today, the Nunivak herd is free-ranging and slaughtered for both commercial and village use.

## Material and methods

In January 1993, twenty-four reindeer carcasses were purchased from Bering Sea Reindeer Products (BSRP) during the scheduled Nunivak Island reindeer slaughter. No modifications to BSRP pre-slaughter protocol or abattoir procedures were made during the collection of these carcasses. The project attempted to obtain an equal number of carcasses from each age (calf, yearling, and adult) and sex cohort. The male cohort was to contain only intact (non castrated) males. BSRP, the current custodians of the Nunivak Island reindeer herd, has a minimal management policy pertaining to animal identification, herd health, population distribution, and herd dynamics. Due to the free-range nature and lack of a herd management strategy, the project was unable to obtain numbers of carcasses from the age and sex cohorts as planned. At the time of kill, age and sex were estimated from a distance with the assistance of binoculars, using body size, body development, and antler size as the primary criteria. To obtain more precise age determinations, tooth wear and eruption patterns were assessed and the lower jaws were collected from each of the twenty-four animals killed. Tooth extraction and cementum annuli aging was subsequently performed by Matson Labs (P.O. Box 308, 7600 Zaug Dr., Milltown, MT 59851 USA).

### *Slaughter procedures and events*

BSRP slaughters were scheduled during winter months when temperatures were below freezing and the possibility of meat spoilage was minimal. This protocol complied with the Alaska Food Code for the retail sale of Alaskan reindeer meat. Reindeer were killed in the field (as opposed to the abattoir) minimizing infrastructure demands and maintenance. Two to four days prior to slaughter, Mekoryuk villagers used snowmobiles to locate and round-up a large group of reindeer. The animals were herded slowly to a central kill site over two to three days (some dispersal occurred during the night and reindeer were often regathered each morning).

The kill site was located approximately 1.5 km from the abattoir and encompassed an area of approximately 1 km by 0.5 km. This site was open at one end with the ocean providing a natural barrier of sea ice and the remaining two sides were enclosed by snow fence. On the date of slaughter, reindeer were herded into the kill area and allowed to settle for approximately one to two hours. During this time, the reindeer separated into small groups of 15-25 animals and were allowed to disburse along the snow fence. When the animals seem settled, a shooter, using a .22-270 rifle equipped with a scope, drove a snowmobile out to the reindeer, stopped approximately 30 to 60 m from a group of animals. Reindeer were then selected by the shooter and killed with a shot to the head. The number of animals killed at one time varied and depended upon the current status of the slaughter plant, the number of animals allotted for village use, and the reaction of the animals. The sequential kill ended when the group of reindeer became agitated and moved away from the shooter. The shooter then waited for the animals to settle or moved to another group of reindeer.

When the shooting was discontinued, dead reindeer were dragged by snowmobile to a central area for processing. Animals were not bled. The time period between shooting and decapitation varied greatly. The animals destined for the abattoir were decapitated, the esophagus was tied, and they were loaded onto a sled and pulled approximately 1.5 km to the abattoir. Many bodies laid in the field for over an hour before transport to the abattoir.

Each body was tagged for identification before being hauled to the abattoir. At the abattoir, decapitated carcasses were piled outside to wait further processing. This wait ranged from immediate to two hours before being hauled into the abattoir via a chute and pulley system. Once in the abattoir, reindeer were placed in a cradle and the hooves and hide removed. Carcasses were then suspended by the hind legs from an overhead rail, eviscerated, washed, singed with a propane torch to remove hair, and split longitudinally along the spinal column, and moved to the chill room. The state inspector examined the internal organs, lymph nodes, and carcasses of each animal and routinely collected a vacutainer sample of blood from each animal to test for the presence of brucellosis (*Brucella suis* and *B. bovis*).

*Carcass analysis*

To avoid interference with abattoir staff, carcasses were not weighed during BSRP slaughter procedures but weights were obtained after the carcasses entered the chill room. Carcasses were allowed to chill for 24 hours and then cut dorsally in half. Each carcass half was cut into wholesale primal cuts (chuck, rib, loin, and hindquarter), boxed, frozen, and shipped to Fairbanks, Alaska. Fabrication of the wholesale primal cuts followed the diagram in Fig. 2 (location of cuts followed the U.S. National Live Stock and Meat Board recommendation for beef cattle) (Hedrick *et al.*, 1994). The chuck primal consisted of the neck, shoulder, and fore shank/brisket and was removed from the side by a cut between the 5$^{th}$ and 6$^{th}$ ribs and perpendicular to the back. The primal rib (in this study consisted of the rib and plate) was separated from the loin between the 12$^{th}$ and 13$^{th}$ ribs (normally this is the separation point between the fore and hindquarters). The wholesale loin consisted of both the loin and flank and was separated from the round primal by cutting on a line between the last sacral and the first coccygeal vertebrae and about 3.5 cm anterior to the aitch bone. The hindquarter was composed of the rump, round, sirloin, and hind shank subprimals. Each of the four wholesale primals from one-half of the carcass was dissected into lean muscle tissue, bone, and each of three compartments of fat (subcutaneous, intermuscular, and peritoneal). The fat depots were defined as: a) subqutaneous fat under the skin of the animal; b) intermuscular fat between muscle groups (sometimes called seam fat); and c) peritoneal fat was body cavity fat. Muscle and fat samples were collected at the time of dissection for later chemical and fatty acid analyses in a companion study. At the same time, the second half of each carcass was cut into retail cuts for the deter-

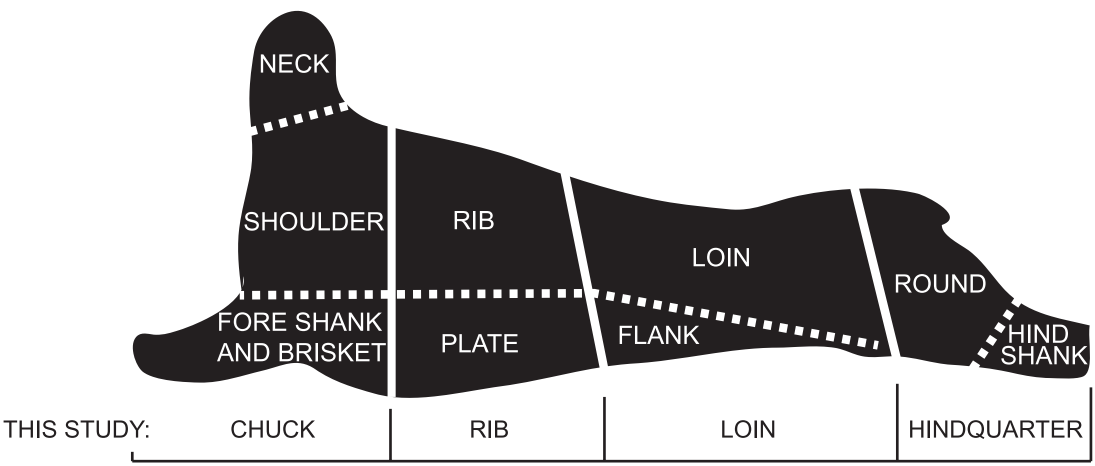


Fig. 2. Wholesale primal cuts of reindeer and the location of each of these in the carcass. A solid or dash line indicates a division between wholesale primal cuts for beef according to the U.S. National Live Stock and Meat Board (Hedrick *et al.*, 1994). The solid lines also indicate where actual cuts were made in this study.

mination of meat yield (yield test) in a companion study (Renecker *et al.*, 2001b) and loins collected for sensory panel and shear force analyses (Department of Food Science, University of Missouri, Columbia, Missouri, 65211 USA). Muscle pH was taken after the frozen loins arrived at the University of Missouri laboratory.

Least squares curvilinear regression analysis was used (Axum, 1994) to evaluate the cost of growth (meat production) in relation to age (efficiency of growth in young *vs.* older animals) in order to address the question of "what slaughter age is optimal to provide the greatest returns for producer investment and delivers a consistently desirable product to the consumer"? Differences in carcass characteristics were determined with a linear glm model analysis of variance (S.A.S., 1993). Significance for all analysis was at the 5% level.

*Taste panel and meat quality analyses*

The loin samples from 23 (loins from 22 dissected animals plus a loin from one yearling male) reindeer were frozen and shipped to the Department of Food Science Laboratory, University of Missouri, where they were cut into steaks and held at -18 °C prior to analysis. Upon removal from the freezer, steaks were placed in refrigeration at 4 °C for a minimum of 24 hr. Care was taken to ensure that each package had adequate air circulation around it while in refrigeration. Residue from the packaging and thawed steaks were weighed. An iron-constantan micro thermocouple (TT-J36) was placed in the center of each oven to monitor temperature. Thermocouples were connected to an Omega multipoint digital thermometer (Model 2166A) and each oven was turned on and set at 170 °C one hr prior to use. Reindeer loin steaks were removed from refrigeration, a micro thermocouple inserted into the geometric center of each steak. As each steak was boneless, the micro thermocouple was in contact with only meat tissue. Two to three steaks were placed on a broiler pan in each oven and cooked until the steak's internal temperature reached 70 °C. After cooking, each steak was removed from the broiler pan, cut into 1 $cm^3$ pieces and a toothpick was inserted into the center of each cube. Cubes were immediately placed in coded beakers held in a hot sand bath at 53 °C and served to panelists seated in individual booths. Each booth was equipped with red incandescent light bulbs and ambient temperature was 20 °C.

Ten panelists evaluated all samples that were presented to them randomly. The protocol used in this sensory evaluation followed standard procedures established by the Department of Food Science and Human Nutrition, University of Missouri-Columbia (H. Heymann pers. commun., 1994). Each panelist had prior experience and training with meat sensory evaluation in beef. In order to train panelists in the sensory traits of reindeer, introductory analysis of reindeer loin were prepared and to each panelist prior to the trial test samples to allow each panelist to "calibrate" at the beginning of each session. This allowed panelists to evaluate the range of sensory characteristics that would be expected in reindeer meat rather than comparisons with conventional livestock loin such as beef. Each panelist evaluated one 1 $cm^3$ piece of sample steak. In each session, the panelists were served 6 samples. Samples were randomized across the following sequence. Panelists evaluated the cooked cubes of meat for juiciness, gamey flavor, tenderness, graininess, rancidity, and bloody after-taste on a 9 point scale. Acceptability of scores was a result of taste panel sensory evaluation. All samples were expectorated and water (Culligan, Columbia, Missouri) was used as a rinse between samples.

Raw steaks

Intact thawed raw steaks were placed on small plastic trays lined with white butcher paper. Trays were covered with a single layer of plastic wrap and coded with 3-digit codes. Each tray was placed in a MacBeth Lightbox (Model EBX-222) lighted with an Examolite daylight bulb (7400 K) prior to evaluation. Panelists evaluated each tray on the following attributes on a 9-point scale: intensity of purple colour; intensity of red colour; amount of black colour; amount of brick red colour; amount of purple colour; or amount of red colour.

Cooked steaks

Intact cooked steaks, cooked as described above, were placed on small plastic trays lined with white butcher paper. Trays were covered with a single layer of plastic wrap and coded with 3-digit codes. Each tray was placed in a MacBeth Lightbox (Model EBX-222) lighted with an Examolite daylight bulb (7400 K) prior to evaluation. Panelists evaluated each tray on the following attributes on a 9-point scale: Intensity of brown colour; amount of black colour; amount of brown colour; amount of marbling.

*pH analysis*

Due to study conditions, it was not possible to obtain pH measurements prior to carcass freezing. Meat pH was taken on each thawed loin steak using an Orion model 290A portable pH/concentration meter (Orion Research Inc. Laboratory Products Group, 529 Main St., Boston, MA 02129 USA) equipped with an Ingold model 406-M6 spear tipped electrode (Ingold electrodes Inc., 261 Ballardvale St., Wilmington, MA 01887 USA).

*Shear force analysis*

Core samples, measuring 1.27 cm in diameter were taken from randomly selected thawed reindeer loin steaks. Steaks were cooked as described above, cooled to room temperature and measured, prior to the shear force analysis. Shear force was determined using an Instron Universal Testing Machine. A modified Warner-Bratzler shear device was used to determine the shear force of reindeer loin cores. A crosshead speed of 25.4 cm/min and a load cell of 100 kg were used. Core samples were sheared perpendicular to the muscle fiber. The shear constant used for analysis was: gram force = 315.8 kg/cm$^2$ x peak height in cm.

Chi square analysis was applied to mean judge acceptance data from the sensory panel analysis. Data were analyzed with a glm analysis of variance (S.A.S., 1993). Duncan's multiple range test was used to identify significant differences at the 0.05 level of significance (S.A.S., 1993).

## Results

Carcass size of male and female reindeer differed between the three age cohorts. Generally, primal weights (mean in kg with standard error of the mean $s_{\bar{x}}$) tended to differ only between the three age groups with the exception of the loin that was significantly heavier in adult female (1.79, $s_{\bar{x}}$ = 0.10) than male reindeer (1.32, $s_{\bar{x}}$ = 0.10) (Table 1).
Reindeer carcasses from the adult female cohort had significantly more fat in all categories (subcuta-

Table 1. Mean (standard error of the mean $s_{\bar{x}}$) carcass, side and primal weights of male and female reindeer calves, yearlings, and adults slaughtered in January, 1993 on Nunivak Island, Alaska.

| Item | Mean ($s_{\bar{x}}$) weight in kg | | | | |
|---|---|---|---|---|---|
| | Male | | Female | | |
| | Calves (*n*=8) | Adults (*n*=4) | Calves (*n*=3) | Yearlings (n=3) | Adults (n=4) |
| Carcass | 18.59a[a] (1.40) | 34.86b (1.98) | 19.40a (2.28) | 23.90c (2.28) | 35.54b (1.98) |
| Side | 9.35a (0.67) | 17.25b (0.95) | 9.35a (1.10) | 11.80a (1.10) | 17.79b (0.95) |
| Chuck | 3.60a (0.27) | 6.84b (0.38) | 3.49a (0.44) | 4.27a (0.44) | 6.37b (0.38) |
| Rib | 1.17a (0.09) | 2.29b (0.13) | 1.21a (0.15) | 1.53a (0.15) | 2.49b (0.13) |
| Loin | 0.80a (0.07) | 1.32b (0.10) | 0.74a (0.12) | 1.05ab (0.12) | 1.79c (0.10) |
| Hindquarter | 3.78ac (0.27) | 6.80b (0.38) | 3.90acd (0.44) | 4.95cd (0.44) | 7.14b (0.38) |
| Lean | 6.48a (0.52) | 12.32b (0.74) | 6.57a (0.99) | 8.39a (0.99) | 11.82b (0.87) |
| Bone | 2.21acd (0.17) | 4.03b (0.24) | 2.43acde (0.28) | 2.62acde (0.28) | 3.15cde (0.24) |
| SQ Fat[b] | 0.02a (0.10) | 0.03a (0.15) | 0.04a (0.17) | 0.01a (0.17) | 0.84b (0.15) |
| Peritoneal Fat | 0.02a (0.02) | 0.04a (0.03) | 0.03a (0.03) | 0.02a (0.03) | 0.16b (0.03) |
| IM Fat[c] | 0.08a (0.05) | 0.17a (0.07) | 0.15a (0.09) | 0.07a (0.09) | 0.62b (0.07) |
| Fat: Bone | 0.06a (0.06) | 0.06a (0.08) | 0.09a (0.09) | 0.04a (0.09) | 0.52b (0.08) |
| Lean: Bone | 2.95abc (0.10) | 3.04abc (0.14) | 2.71ab (0.16) | 3.19ac (0.16) | 3.81d (0.14) |

[a] Means in the same row without a letter or bearing a common letter do not differ significantly ($P > 0.05$).
[b] SQ = subcutaneous fat.
[c] IM = intermuscular fat.

neous, intermuscular, and peritoneal) and exhibited a significantly higher fat to bone (0.52, $s_{\bar{x}}$ = 0.08) and lean to bone (3.81, $s_{\bar{x}}$ = 0.14) ratios than all other cohorts (Table 1).

Adult female reindeer had more of each fat depot on a relative primal basis for the carcass side than the other reindeer groups (Table 2), however, there was no difference in the relative amount of lean.

Table 2. Mean (standard error of the mean $s_{\bar{x}}$) lean, bone, and fat (subcutaneous, intermuscular, and peritoneal) tissues (g/kg of primal) of male and female reindeer calves, yearlings, and adults slaughtered in January, 1993 on Nunivak Island, Alaska.

| Item | Mean ($s_{\bar{x}}$) weight (g/kg of primal) | | | | |
|---|---|---|---|---|---|
| | Male | | Female | | |
| | Calves ($n$=8) | Adults ($n$=4) | Calves ($n$=3) | Yearlings ($n$=3) | Adults ($n$=4) |
| Chuck | | | | | |
| Lean | 664.3[a] (15.9) | 683.0 (22.6) | 691.3 (26.0) | 670.9 (26.0) | 678.7 (22.6) |
| Bone | 261.2ab (12.5) | 255.6abc (17.7) | 304.1ab (20.4) | 256.2abc (20.4) | 216.2bc (17.7) |
| SQ[b] fat | 1.37a (2.35) | 1.56a (3.33) | 2.46a (3.84) | 0.16a (3.84) | 14.35b (3.33) |
| Peritoneal fat | 1.37ab (0.94) | 2.99abc (1.33) | 1.48abc (1.53) | 0.88ab (1.53) | 5.47bc (1.33) |
| IM[c] fat | 12.11a (4.21) | 13.27a (5.97) | 21.52a (±6.88) | 9.64a (6.89) | 45.86b (5.97) |
| Rib | | | | | |
| Lean | 758.6 (30.9) | 754.7 (43.7) | 729.3 (50.5) | 809.5 (50.5) | 762.7 (43.7) |
| Bone | 286.7ab (15.0) | 251.3abc (21.2) | 300.9ab (24.4) | 278.6abc (24.4) | 227.0bc (21.2) |
| SQ fat | 1.35a (6.13) | 0.94a (8.67) | 1.67a (10.01) | 0.46a (10.01) | 53.81b (8.67) |
| Peritoneal fat | 3.16a (1.56) | 2.69a (2.22) | 5.29ab (2.56) | 2.05a (2.56) | 11.98b (2.22) |
| IM fat | 5.63.a (6.55) | 5.70a (9.27) | 10.51a (10.70) | 0.99a (10.70) | 57.02b (9.27) |
| Hindquarter | | | | | |
| Lean | 711.9 (15.6) | 728.2 (19.2) | 717.4 (22.1) | 735.8 (22.1) | 679.4 (19.2) |
| Bone | 207.2a (5.9) | 199.6a (8.4) | 214.5a (9.6) | 189.3a (9.6) | 141.9b (8.4) |
| SQ fat | 3.48a (5.50) | 2.27a (7.77) | 6.98a (8.97) | 1.80a (8.97) | 51.43b (7.77) |
| Peritoneal fat | 1.15a (±1.39) | 1.62a (1.97) | 2.90a (2.27) | 2.18a (2.27) | 9.17b (1.97) |
| IM fat | 8.37abc (2.02) | 10.32abc (2.86) | 13.56abd (3.30) | 3.99ac (3.30) | 20.54bd (2.86) |
| Loin | | | | | |
| Lean | 658.0ab (39.4) | 697.5ab (55.8) | 647.3ab (64.4) | 606.8abc (64.4) | 458.3bc (55.8) |
| Bone | 200.1abc (25.4) | 270.0ab (35.9) | 236.6ab (41.1) | 165.5abc (41.1) | 120.2ac (35.9) |
| SQ fat | 5.07a (15.67) | 0.50a (22.16) | 1.37a (25.59) | 0.0a (25.59) | 113.20b (22.16) |
| Peritoneal fat | 6.96 (2.24) | 4.27 (3.17) | 13.61 (3.66) | 3.98 (3.66) | 12.83 (3.17) |
| IM fat | 2.70ab (3.62) | 1.84ab (5.12) | 3.05ab (3.92) | 6.94abc (5.92) | 19.06bc (5.12) |
| Side | | | | | |
| Lean | 739.2 (9.6) | 741.2 (13.6) | 712.4 (15.7) | 753.9 (15.7) | 716.0 (13.6) |
| Bone | 250.5abc (5.4) | 243.6abc (7.6) | 261.1a (8.8) | 236.9ac (8.8) | 189.4d (7.6) |
| SQ fat | 2.69a (5.49) | 1.94a (7.76) | 4.23a (8.96) | 0.93a (8.97) | 48.41b (7.76) |
| Peritoneal fat | 2.10a (1.13) | 2.63a (1.60) | 3.61a (184) | 1.96a (1.84) | 9.11b (1.60) |
| IM fat | 9.54a (3.48) | 10.68a (4.93) | 15.61a (5.69) | 6.28a (5.69) | 37.07b (4.93) |

[a] Means in the same row without a letter or bearing a common letter do not differ significantly ($P > 0.05$).
[b] SQ = subcutanious fat.
[c] IM = intermuscular fat.

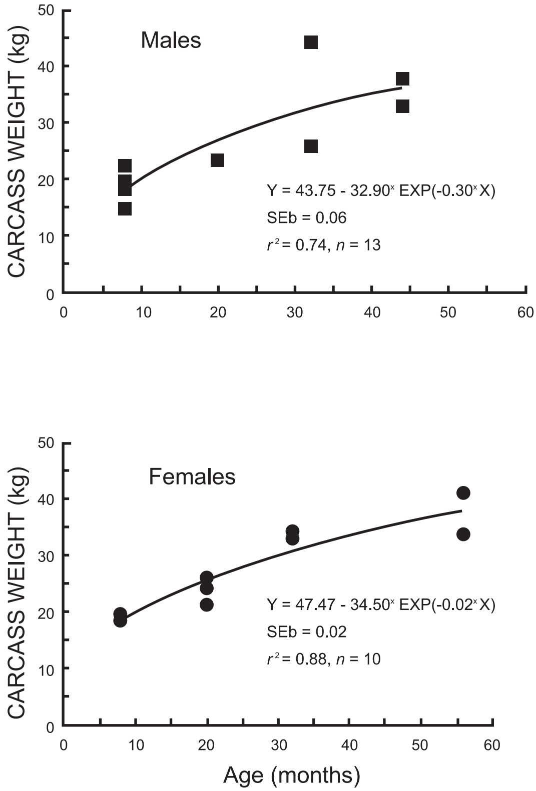


Fig. 3. Relationship between carcass weight and age (months) of free-ranging male and female reindeer from Nunivak Island, Alaska, January,

The composition of the side showed adult females had significantly less relative amount of bone than the other slaughtered groups of reindeer. There was no significant difference in the relative amount of lean dissected from the chuck and rib wholesale primal between all age and sex cohorts. However, adult females had more intermuscular and subcutaneous fat on a relative chuck and rib wholesale primal cuts than the other groups of reindeer. The adult females exhibited a higher relative proportion of peritoneal and subcutaneous fat and less bone in the hindquarter primal cut than the other slaughter groups. The loin lean primal tissue was similar in the adult and yearling females on a relative basis and all male age groups had significantly more lean than adult females (Table 2). In contrast, adult females had more fat in all depots in the wholesale loin primal on a relative basis than adult males.

Data from our study illustrates that adult females during mid winter maintain higher fat and lean tissue to bone ratios than all other groups of reindeer slaughtered. As a result, adult females slaughtered on Nunivak Island during mid winter may actually have a higher asymptotic carcass weight (47.47 kg) than adult males (43.75 kg) (Fig. 3).

Physical properties of the reindeer loin steaks used in the sensory panel analysis included residual weight at thawing or thaw loss (percent of primal) (loss of fluid after thawing), percent edible portion (bone, fat, and inedible portions removed), and cooking loss (fluid loss after cooking the loin steak as a percent of initial weight of steak before thawing/cooking). Excessive moisture residue loss was recorded from all age and sex cohort steaks upon thawing. Residue loss ranged from 6.2% to 8.7% of loin, while percent cooking loss ranged from 23.6% to 30.7%. Cooking loss was significantly higher in yearling females than both adult male and female reindeer. Residue loss at thawing and cooking loss both followed a trend of lower loss with increased animal age (Table 3). The edible portion after cooking was significantly higher in adult males in comparison to adult female reindeer.

Table 3. Mean (standard error of the mean, $s_{\bar{x}}$) physical characteristics of loin steaks of free-ranging reindeer slaughtered on Nunivak Island, Alaska, January, 1993.

| Item | Mean ($s_{\bar{x}}$) | | | | |
|---|---|---|---|---|---|
| | Male | | Female | | |
| | Calves (*n*=8) | Adults (*n*=4) | Calves (*n*=3) | Yearlings (*n*=3) | Adults (*n*=4) |
| Thaw loss (% primal) | 8.706[a] (1.378) | 7.304 (1.946) | 8.689 (2.247) | 6.162 (2.247) | 7.007 (1.946) |
| Cooking loss (%)[b] | 26.04abc (1.29) | 23.62ab (1.82) | 30.73ac (2.10) | 26.51abc (2.10) | 24.37ab (1.82) |
| Edible portion (% of before cooking wt.)[c] | 54.75abc (2.00) | 60.31ab (2.83) | 54.46abc (3.27) | 53.81abc (3.27) | 48.41ac (2.83) |

[a] Means in the same row without a letter or bearing a common letter do not differ significantly ($P > 0.05$).
[b] Cooking loss is loss of fluid after cooking the loin steak.
[c] Edible portion is cooked with the inedible portion (bone, fat, and inedible portion) removed after cooking.

Table 4. Effect of sex and age cohort (calves, yearlings and adults) on mean (standard error of the mean, $s_{\bar{x}}$) flavour and colour profiles of loin steaks of free-ranging reindeer slaughtered on Nunivak Island, Alaska, January, 1993.

| Item | Mean ($s_{\bar{x}}$) judge panel acceptance | | | | |
|---|---|---|---|---|---|
| | Male | | Female | | |
| | Calves (*n*=8) | Adults (*n*=4) | Calves (*n*=3) | Yearlings (*n*=3) | Adults (*n*=4) |
| Flavour | | | | | |
| Juiciness | 5.25[a] (0.41) | 4.73 (0.58) | 4.03 (0.67) | 4.50 (0.67) | 5.40 (0.58) |
| Gamey | 4.71 (0.28) | 4.78 (0.39) | 4.60 (0.45) | 4.70 (0.45) | 4.90 (0.39) |
| Tenderness | 6.63ac (0.51) | 3.95bc (0.72) | 3.77bc (0.84) | 4.10bc (0.84) | 5.13abc (0.72) |
| Graininess | 4.35ac (0.27) | 3.30bc (0.39) | 2.93bc (0.45) | 2.50bc (0.45) | 3.40abc (0.39) |
| Rancidity | 2.11 (0.10) | 1.90 (0.15) | 1.87 (0.17) | 1.83 (0.17) | 1.83 (0.15) |
| Bloody after taste | 3.58 (0.16) | 3.70 (0.23) | 3.27 (0.26) | 3.53 (0.26) | 3.33 (0.23) |
| Appearance | | | | | |
| *Raw colour* | | | | | |
| Intensity of raw brick/red | 4.84ab (0.15) | 4.91abc (0.21) | 4.67ab (0.24) | 4.57ab (0.24) | 5.41bc (0.21) |
| Intensity of raw purple/red | 5.23 (0.36) | 6.26 (0.51) | 5.83 (.59) | 6.10 (0.59) | 5.84 (0.51) |
| Amount of raw black | 2.92ac (0.26) | 3.98bc (.37) | 2.63ac (0.43) | 3.47abc (0.43) | 2.61ac (0.37) |
| Amount of raw brick/red | 4.57 (0.30) | 4.22 (0.42) | 4.53 (0.50) | 3.87 (0.50) | 4.61 (0.42) |
| Amount of raw purple/red | 5.02 (0.34) | 5.24 (0.48) | 5.20 (0.56) | 5.67 (0.56) | 5.52 (0.48) |
| *Cooked colour* | | | | | |
| Intensity of brown | 5.83 (0.22) | 5.80 (0.31) | 5.83 (0.36) | 5.80 (0.36) | 6.48 (0.31) |
| Amount of black | 2.63 (0.28) | 2.76 (0.40) | 2.24 (0.46) | 2.40 (0.46) | 3.11 (0.40) |
| Amount of brown | 6.58 (0.14) | 6.50 (0.20) | 6.80 (0.23) | 7.03 (0.23) | 7.01 (0.20) |
| Amount of marbling | 2.40ab (0.16) | 2.48abc (0.23) | 2.27ab (0.26) | 2.0ab (0.26) | 3.03bc (0.23) |

[a] Means in the same row without a letter or bearing a common letter do not differ significantly ($P > 0.05$). Values show mean rank (1= low intensity or amount to 9 = highest intensity or amount).

There was no significant difference between age and sex cohorts for either juiciness or gamey flavour of loin steaks (Table 4). Female calves and yearlings received the lowest ranking for juiciness and the calves were again ranked most undesirable for gamey flavour (Table 4). Male calves and adult females were found to be statistically similar and most acceptable for tenderness (mean scores 6.63, $s_{\bar{x}}$ = 0.51 and 5.13, $s_{\bar{x}}$ = 0.72, respectively) and graininess (mean scores 4.35, $s_{\bar{x}}$ = 0.27 and 5.13, $s_{\bar{x}}$ = 0.72, respectively), respectively (Table 4). However, all loin sample scores for graininess were below an acceptable score of 4.5. All cohorts were found to have an unacceptable flavour for rancidity and bloody after-taste with no significant difference between groups.

The raw appearance of the loin steaks for intensity of raw brick/red colour showed a similar and the highest incidence of the trait in adult male and female groups (Table 4). All groups were similar and acceptable in the intensity of raw purple/red and amount of raw purple red colour. There was no difference in the amount of brick/red colour, however, the scores were marginal for acceptability. Differences occurred groups in the amount of raw black colour, however, all scores showed a high incidence of the colour.

There was no difference among groups in the intensity of brown, amount of black, and amount of brown cooked colour of loin steaks (Table 4). However, the amount of black cooked colour was highly unacceptable while intensity and amount of

Table 5. Effect of sex and age cohort (calves, yearlings, and adults) on mean (standard error of the mean $s_{\bar{x}}$) muscle pH and shear force values (g/cm$^2$) of loin steaks of free-ranging reindeer slaughtered on Nunivak Island, Alaska, January, 1993.

| Item | Mean ($s_{\bar{x}}$) | | | | |
|---|---|---|---|---|---|
| | Male | | Female | | |
| | Calves ($n$=8) | Adults ($n$=4) | Calves ($n$=3) | Yearlings ($n$=3) | Adults ($n$=4) |
| Muscle pH | 6.19[a] (0.12) | 5.84 (0.17) | 5.93 (0.24)[b] | 5.90 (0..19) | 5.78 (0.17) |
| Shear force (g/cm$^2$) | 2129ac (291) | 3178bc (411) | 389bc (475) | 3131abc (475) | 2605abc (411) |

[a] Means in the same row without a letter or bearing a common letter do not differ significantly ($P > 0.05$).

[b] $n$=2 for mean muscle pH of female calves.

brown cooked colour was highly acceptable. Loin samples from adult females (mean score 3.03, $s_{\bar{x}}$ = 0.23) and males (mean score 2.48, $s_{\bar{x}}$ = 0.23) had similar and the highest incidence of acceptable amount of cooked marbling, however, all groups had highly unacceptable scores for this trait.

The mean ultimate pH values were high with no difference between slaughtered groups and ranged from 5.78, $s_{\bar{x}}$ = 0.17 to 6.19, $s_{\bar{x}}$ = 0.12, indicative of dark cutting (Table 5). Shear force values were similar among male calves, female yearlings, and female (Table 5). The female calves exhibited the highest average shear force. Thirty percent of the study reindeer were considered to be dark cutters based on pH ≥ 6.0, and although Warner Bratzler shear force values were low, nearly half of all individuals had a moderately high mean pH value between 5.8 and 6.0 acquiring the highest shear values (Fig. 4). The relationship of muscle pH on shear force value had a significant correlation coefficient of $r^2$ = 0.31.

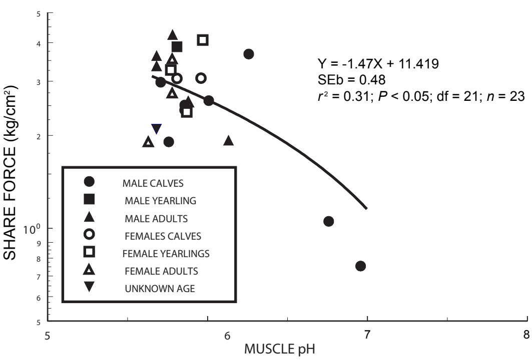


Fig. 4. Relationship between shear force (kg/cm$^2$) applied to loin steak and muscle pH pf reindeer loin steaks from Nunivak Island, Alaska, January, 1993.

## Discussion

*Body condition and meat yield*

The purpose of this study was to determine the optimal age and sex cohort for commercial slaughter of reindeer on Nunivak Island and to identify meat parameters requiring further investigation. At the time of this study, reindeer bulls had completed the rut and cows had not yet entered the third trimester of pregnancy when they experience higher nutritional demands of a rapidly growing fetus. Therefore, cows had relatively large fat reserves in comparison to the bulls, which had depleted most fat stores during the rut. Based on dissection results, adult male and calf cohorts were most affected by the restricted food resources created by adverse icing conditions, which limited winter food during the winter of 1992-93. Reimers (1983) and Reimers & Ringberg (1983) observed comparable data in Svalbard reindeer and a similar scenario was noted by Flook (1970) in North American wapiti. These researchers concluded that calves with smaller autumn fat deposits and adult males with reduced fat reserves caused by the rut were more susceptible to mortality during severe winters than adult females. The greater fat stores in adult females is probably partially due to a seasonal decline in daily metabolic costs (from summer highs) in combination with more comfortable ambient conditions. As a result females continue to accumulate fat stores during the early autumn period.

All cohorts had significantly lower amounts of subcutaneous, peritoneal, and intermuscular fat in the side when compared to adult females. This may indicate increased mobilization of intermuscular fat by the male reindeer during the rut and by the smaller, female reindeer during early winter. Berg & Butterfield (1976) studying semi-starving steers observed that subcutaneous and intermuscular fat depots were lost during the first stages of starvation. Subsequently, they observed that subcutaneous fat was the last depot to be regained when the steers were put back on a higher primary nutritional regime. We assumed that subcutaneous fat is utilized first during periods of restricted food intake. In a study on the caribou of Coats Island, N.W.T., Adamczewski *et al.* (1987) concluded that fat depots varied in rate of maturation, but they were unable to determine the sequence of mobilization. Food deprivation will contribute to tissue energy depletion during periods of food shortage. Initially, the body will utilize glycogen stores from muscle and liver as immediate sources of energy. Subsequently, the process of energy mobilization requires that fat becomes lipolidic and move into the circulatory system, thus intramuscular fat (marbling) should be the most labile as it is closest to the circulatory system, followed by intermuscular and subcutaneous fat (A.L. Schaefer, R.G. White, and F.F. Mallory pers. comm., 2000). Berg & Butterfield (1976) noted that the order of fat depot utilization could only be verified if large numbers of animals are dissected throughout the entire weight loss process.

Carcass value is influenced by the development of muscle, bone and fat with the most valuable cuts of meat coming from the loin and hindquarters of the carcass. The amount of external, internal and intermuscular fat effects the economic value of carcasses more than any other factor (Hedrick *et al.,* 1994) as the highest commercial returns are realized from carcasses possessing the highest amount of lean tissue in comparison to bone and fat. The reindeer calves exhibited the lowest lean to bone ratio followed by the adult males, while yearling and adult females had the highest lean to bone ratio and were similar to data reported by Drew (1991b) for 26-month old New Zealand wapiti and 11-month-old wapiti/red deer hybrids. At the time of slaughter, the Nunivak Island reindeer calves were approximately 7-8 months of age. As bone growth occurs first in the young animal and is followed by increased muscular growth and ultimately fat deposition (Reimers, 1972; Berg & Butterfield, 1976; Hedrick *et al.,* 1994), calves had carcasses with higher proportions of bone when compared to the adult female cohort. Because body weight loss is not limited to the depletion of fat and also includes declines in muscle (Berg & Butterfield, 1976; Robbins, 1983) and to a lesser extent bone (Price, 1976, 1977), it is probable that the adult male reindeer were mobilizing lean tissue in conjunction to fat reserves. The adult male's larger skeletal frame may also account for significantly lower lean to bone and fat to bone ratios, while still achieving similar overall lean tissue when compared to the adult female cohort. The loins of the adult females were significantly smaller than adult males on a relative basis of lean tissue, however, adult females had entire loin primals, which weighed significantly more then those of the adult males. This difference was attributed to large amounts of subcutaneous fat deposited during late summer and early autumn over the loins and rump of females. Earlier research established that growth in mammals follows a centripetal pattern starting in the animal's extremities and converging along the back to the pelvis (Hammond, 1932; Palsson & Verges, 1952a, b). It is possible that this pattern is partly related to the mechanics of motion which would be least impacted by weight added on top of the pelvis where few muscles attach and added weight is centered over a large supporting structure (D. Freddy pers. comm., 2000). Hillis & Mallory (1996) found significantly greater adipose deposition around internal organs and the posterior part of the body in female wolves (*Canis lupus*) and concluded that this deposition was primarily related to reproduction and nurtural processes.

*Product quality and slaughter procedures*

Slaughter procedures at the Nunivak Island state inspected slaughter facility require improvement to elevate the overall quality of the final meat product. To date, no exsanguination procedure has been implemented even though it has been well documented in the domestic meat industry that improper exsanguination result in the creation of an optimal environment for bacterial growth and ecchymoses (small haemorrhages which occur in muscle). Blood makes up approximately 8% of an animals total live weight and is an optimal medium for the growth of bacteria (Petersen *et al.,* 1991). While proper exsanguination eliminates only about 50% of the total blood volume, the remainder being held in the vital organs, proper implementation of this procedure would result in a greater extension of product shelf life (Hedrick *et al.*, 1994). Ecchymoses, commonly referred to as "blood splash" or "streaking", occurs as a result of increased arterial blood pressure immediately after death and the resultant rupture of small capillaries in the muscle causing lesions (Petersen *et al.,* 1991). While ecchymoses occurs most commonly in the diaphragm and flank areas, it is aesthetically displeasing to the consumer and can result in devaluation of the product. Excessive blood residue upon thawing, as seen in this study, indicates improper exsanguination procedures and may predispose meat to excessive microbial growth and rapid spoilage (Hedrick *et al.*, 1994). Meat with the amount of residual blood found in the Nunivak reindeer would not be acceptable by consumers in continental United States (H. B. Hedrick pers. comm., 1994).

With the exception of four individuals, the study reindeer all had moderately high to very high pH values. Our findings are supported by the data of Petaja (1983) who found mean pH values for reindeer high and that these values increased from autumn to January and again to March when 100% of the reindeer evaluated had DFD meat.

The sensory panel found the Nunivak reindeer steaks to have unacceptable amounts of black colouration in both the raw and cooked product, to have unacceptable tenderness (except male calves and adult females), graininess, rancidity flavour, and bloody after taste. Game meat tends to be darker in colour than that of domestic species that may result from their higher iron content (Hamilton, 1994), a high ultimate pH (Wiklund, 1995; Renecker *et al.*, 2001b), or a combination of these and other factors yet to be determined. The dark colour of the Nunivak reindeer meat may be a combined effect of high pH and excessive amounts of residual blood. Wiklund *et al.* (1996) described a pungent odour, sickeningly sweet odour, sharp flavour and sickeningly sweet flavour all as attributes associated with the concept "stress-flavour". Brooks & Collins (1984) also reported an "undesirable" flavour from reindeer carcasses in poor condition and Rehbinder & Edqvist (1981) described a "stress-flavour" in meat when reindeer underwent intensive pre-slaughter handling. In our study, all sensory panelist's found the meat to have an unacceptable rancid flavour. As the meat had been chilled and frozen under State of Alaska inspection, the meat flavour described may be a consequence of stress as previously described by other researchers. There was high variability among judges in evaluation of the cohorts for juiciness and gamey flavour that may be due to a small sample size, individual animal and environmental variations, and judge training.

Reindeer meat is generally quite tender (Wiklund *et al.*, 1997) despite the reported high incidence of DFD meat (Petaja, 1983; Brooks & Collins, 1984; Wiklund, 1996). Wiklund *et al.* (1997) found reindeer *longissimus* muscles to be extremely tender regardless of ultimate pH and determined that further investigation was needed. In our study, all Warner Bratzler shear forces were low indicating the mechanical properties for tender meat, however, it is possible that the rating by judges for unacceptable tenderness could be due to an excessive amount of tenderness not normally found in beef and could also be confounded by other factors such as meat texture. With the exception of the adult female and male calf cohorts, that received a moderate rating, all other cohorts were judged to have low desirability for tenderness although this was not defined. Red deer venison with a pH of 7.15 was described by taste panel members as extremely dark and so tender that it was 'almost mushy' with a objectionable "off" flavour (Drew, 1996). Thirty percent of the study reindeer were considered to be dark cutters based on a pH ≥ 6.0 and had lower Warner Bratzler shear force values while nearly half of all individuals had a moderately high mean pH value between 5.8 and 6.0 acquiring the highest shear values (Fig. 4). This moderately high ultimate pH range is recognized to be associated with tough meat in beef carcasses (Jerimiah *et al.*, 1991; Wayne Robertson, pers. comm., 2000), sheep (*Ovis aries*) (Watanabe *et al.*, 1996), and red deer (*C. elaphus*) (Stevenson-Barry *et al.*, 1999) although how this occurs is not yet understood (Devine *et al.*, 1993). Harris and Shorthouse (1988) reported that the relationship between Warner Bratzler shear force and ultimate pH values in sheep muscle was curvilinear with the peak shear force values occurring close to a pH of 6.0. The normal range for muscle ultimate pH in domestic species is considered between pH 5.4-5.8 (Harris & Shorthouse, 1988). Unfortunately, few animals in our study had ultimate pH values in the normal range.

Nunivak reindeer carcasses are routinely subjected to long periods of time prior to entry into the abattoir. Due to this delay in processing, each carcass was subjected to large temperature fluctuations, which frequently resulted in a rapid loss of heat or too little heat dissipating from the carcass. These problems varied with speed of processing (hide removal and evisceration), environmental temperature, humidity, precipitation, wind conditions, and carcass fat cover and condition.

## Conclusions

The results of this study show that at the time of slaughter (January) on Nunivak Island the adult female reindeer have significantly more subcutaneous, intermuscular, and peritoneal fat than all other age and sex cohorts. In addition, adult males had significantly less intermuscular and subcutaneous fat on a relative basis than adult females in all primal cuts. The condition of adult males is much more precarious and susceptible to rapid weight loss as a result of extreme weather conditions during mid winter than adult females because of the energetic drain that results from the autumn rut.

Reindeer meat in this pilot study had high pH values, low shear force, dark colour, and excessive amounts of residual blood. The nature of these meat characteristics probably relate to dark-cutting and may be a function of *ante mortem* handling and stress (long round-up and holding time periods), nutritional status (meager winter food resources), and/or physical condition (body tissue stores entering winter). As a result, the reindeer meat was found to be unacceptable for rancidity flavour and graininess but generally acceptable for juiciness and gamey flavour. While the study showed that handling and slaughter procedures probably have an important effect on reindeer meat quality there is a need for further work with in this area to help quantify meat colour and pH while improving exsanguination procedures and slaughter techniques which are ultimately marketing strategies.

Our study found with the management regime and environment on Nunivak Island on a basis of carcass size, yearlings were probably the optimal candidates for annual commercial slaughters. We were unable to acquire yearling males in this study, however, yearling females yielded a significantly larger carcass than calves of the same sex. There is a US$ 42.97 economic advantage for slaughtering yearling females vs. calves as the optimal carcass size, however, this declines $US 27.23 as females mature into the adult cohort (Renecker *et al.,* 2001b). Because the lifestyle of male reindeer is more precarious then females during winter due to influence of autumn rut and breeding season's demand on fat stores, the selection strategy for slaughter should be to remove surplus yearling males from the population before death loss is incurred during winter. This would spare more over-winter resources for the breeding population and would capitalize on the economics of optimal carcass size. We suggest that future research should investigate the male yearling cohort in terms of carcass and meat quality characteristics (i.e. colour, ultimate pH, carcass temperature) in order to better evaluate the effects of stress and carcass handling on meat quality.

Our study provided scope of variability that can be expected in free-ranging reindeer carcass characteristics and quality. An understanding of this research is related to the long-term stability of this industry that is ultimately dependent upon increased meat quality and therefore sales. In turn, this will please meat processors and provide opportunities for better products, result in more customers, and ultimately better economics. Finally, the consumer will be pleased with the quality product and be a return customer. Government agencies are inclined to implement regulations to guarantee this quality, but they need criteria and guidelines. This research will begin to provide a basis for quality and tie together better economics and the private sector of the reindeer meat industry in order to produce a quality, healthy, lean meat product for consumers throughout North America.

Approximately 7500 reindeer were loosely-managed on Nunivak Island at the time of the study. Slaughter removed annually about 5-6% of the population (T. Moses, pers. comm., 1993). Since 1993 the reindeer population on Nunivak Island has declined due to wandering loss and winter mortality to about 4000 animals. The number of animals slaughtered at the abattoir has also declined probably partially due to administrative and regulatory issues (C. Rice, pers. comm., 1999).

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