Feeding soy or fish meal to Alaskan reindeer (*Rangifer tarandus tarandus*) – effects on animal performance and meat quality

Greg Finstad[1], Eva Wiklund[1,2*], Kristy Long[3], Phillip J. Rincker[4], Alexandra C. M. Oliveira[5] & Peter J. Bechtel[6]

[1] Reindeer Research Program, University of Alaska Fairbanks (UAF), P.O. Box 757200, Fairbanks, AK 99775-7200, USA.
[2] AgReserch MIRINZ, Ruakura Research Centre, East Street, Private Bag 3123, Hamilton 3240, New Zealand.
[3] Co-operative Extension Service, UAF, Food Product Development, Fairbanks, AK 99775-6180, USA.
[4] Department of Animal Sciences, University of Illinois, Urbana, IL 61801, USA.
[5] Fishery Industrial Technology Center, UAF, Kodiak, AK 99615-7401, USA.
[6] USDA-ARS, Subarctic Agricultural Research Unit, UAF, Fairbanks, AK 99775-7220, USA.
*Corresponding author: ffemw2@uaf.edu

Abstract: Fourteen reindeer (8 steers and 6 females) were used to compare the effects of two different reindeer diets (a feed mix based on barley, brome hay and soybean meal (SBM) or fishmeal (WFM) as protein source) on animal growth performance, feed conversion efficiency and ultimate meat quality. Samples from free-ranging reindeer (n=4; 2 steers and 2 females) on the Seward Peninsula were included to provide comparisons with the traditional reindeer meat produced in Alaska. No significant difference was observed in overall weight gain between the WFM and SBM animals or between females and steers; however, the feed conversion efficiency was significantly higher for the reindeer fed the WFM mix. Carcass dressing percentage from the SBM group was higher compared with the WFM animals. No differences were found in live weight, carcass characteristics, meat pH, temperature decline, shear force, meat color or cooking loss when comparing the treatment groups. The meat samples (*M. longissimus*) from the free-range group had the highest amount of omega-3 fatty acids and also the highest amount of polyunsaturated fatty acids (PUFA). Meat from the animals fed SBM was significantly higher in triglyceride content and lower in phospholipid content compared with the two other groups. No significant differences were found when the trained panel compared the sensory attributes of the meat. Off-flavor attributes related to "wild' or "gamey" flavor was reported by consumers for samples from the WFM and free-range reindeer (15 and 24 per cent of the consumers, respectively). No "fish-related" flavor was reported. In conclusion, no negative effects in either animal performance or meat quality characteristics by using fish meal as opposed to soybean meal as a protein supplement in a milled reindeer diet were found.

Key words: commercial feed mixtures, feed conversion efficiency, lipid composition, natural grazing, reindeer meat, sensory evaluation.

Rangifer, 27 (1): 59-75

Introduction

Reindeer (*Rangifer tarandus tarandus*) is one of Alaska's primary livestock species with annual population numbers surpassing that of cattle and swine combined (Alaska Agriculture Statistics, 1990-2005). Reindeer production in Alaska now uses an extensive management system where animals are allowed to free-range over large designated grazing ranges on the Seward Peninsula, St Lawrence and Nunivak Islands and the Aleutian Chain (Fig. 1). Most of these ranges are large and remote with no or limited availability of slaughtering, processing and transportation infrastructure. These limitations prevent the reindeer industry from meeting the market demands of a continuous supply of high quality, inspected reindeer meat.

Fig. 1. Reindeer grazing ranges in Alaska; Seward Peninsula, St Lawrence and Nunivak Islands and the Aleutian Chain.

Some reindeer producers want to shift the management and location of their operations to more intensively managed farms in Interior Alaska to utilize cereal grain and forage production, inspected slaughtering facilities, and transportation and distribution networks. A large effort by the state of Alaska in the 1980s to expand agriculture resulted in the development of cereal grain and forage production in Interior Alaska. Barley *(Hordeum vulgare)* grows well in high-latitude regions and many varieties have been developed specifically for high yield in Alaska (Taylor, 1985), but these barley varieties have different fiber and nutritional profiles from one another (Wooding & Knight, 1973). Using barley as the main energy source in a diet for reindeer in Alaska is desirable due to its relatively low cost and high availability. Smooth brome grass (*Bromus inermis*) is the dominant perennial forage species grown on rotational croplands in Alaska and is commonly produced as hay. Chopping the hay and mixing with a barley diet will moderate intake of the concentrate, increase rumination, and reduce the possibility of high fermentation rate and acidosis. Utilizing the locally abundant supply of cereal grains and forages to meet the high demand for reindeer meat is a favorable scenario for both Interior Alaskan farmers and reindeer producers.

Nutritional requirements of reindeer vary seasonally (Suttie & Webster, 1995) and the composition of a summer diet needed to support growth and lactation should contain relatively high crude protein (CP, >15%) and mineral concentrations (Ryg & Jacobsen, 1982; White, 1992). Barley and brome can supply the energy and fiber requirements of farmed reindeer, but they do not contain sufficient CP to meet the summer nutritional requirements of reindeer. Soybean meal is often used as a protein supplement; however, soybeans cannot be grown in Alaska and meal must be shipped into the state. Fishmeal is used in the beef and dairy industry as a protein source and supplement to increase animal performance (Hussein & Jordan, 1991). The Alaska fishing industry commonly produces over 2 million metric tons of fish for human consumption and over 70 000 metric tons of fishmeal from the by-products (Crapo & Bechtel, 2003). In Alaska, fishmeal can often be priced competitively with soybean meal on a unit-protein basis and is readily available. Fishmeal is an excellent source of rumen non-degradable protein (Hussein & Jordan, 1991), is generally recognized as being very digestible, and useful as a protein supplement in high production settings for cattle (Carroll *et al*., 1994). The effect of fishmeal on the performance of reindeer is unknown.

Scandinavian studies have reported that reindeer meat has a good nutritional profile with low fat content, favorable fatty acid composition and high content of vitamin E. However, these studies found that different diets affected the composition of the meat, as well as its flavor attributes (Wiklund *et al*., 2001; 2003a; Sampels *et al*., 2004). Fishmeal as an ingredient in reindeer feed is currently not used in Sweden, Norway or Finland; however, it has previously been used in one of the Norwegian commercial reindeer feed mixtures (RF-80). No reports are available on the effects of fishmeal on the sensory quality attributes of reindeer meat.

Therefore the purpose of this study was to compare the effects of using two different reindeer diets (a feed mix based on barley, brome hay and soybean meal or fish meal as protein source) on animal growth performance, feed conversion efficiency and meat quality. In the evaluation of meat quality, samples from free-ranging reindeer on the Seward Peninsula were included to provide comparisons with the traditional reindeer meat produced in Alaska. In addition, the chemical composition of raw and cooked reindeer meat was also evaluated.

Material and methods

Animals

Eight reindeer steers (castrated bulls) and 6 females, all 13 months of age, were included in the performance trial to simulate current intensive production settings in Alaska. The reindeer were raised and fed together at the University of Alaska Fairbanks (UAF) Reindeer Farm for 8 weeks after which only the steers were slaughtered. One steer was removed from the performance part of the experiment when he sustained a severe leg laceration that required individual handling and treatment with antibiotics. However, this animal was fed the WFM diet through the whole experiment period, and was sent to slaughter with the other steers and included in the meat quality

data. A total of twelve reindeer (10 steers and 2 females, of which 8 were the steers from the performance trial and 4 were free-ranging animals) were included in the study of meat quality parameters.

The feed mixtures used were developed by the Reindeer Research Program at UAF and were based on barley, smooth brome hay and either fishmeal (WFM) or soybean meal (SBM) as the supplemental protein source. The main composition of the feed mixtures is described in Tables 1 and 2. Further description of the feeding procedure follows.

The reindeer raised at UAF were transported for about 2 hrs (158 km) to a USDA approved slaughter facility (Delta Meats, Delta Junction, Alaska). At slaughter these animals were stunned with a captive bolt. Following the normal slaughter procedure, the weights of the carcasses were registered before they entered the chilling room. Temperature in *M. longissimus* (LD, at the last rib) was measured at 1, 2, 3, 4, 5, 6, 7, 8, 10, 12 and 24 h *post mortem*. At 1 day *post mortem* the carcasses were butchered and the saddles (both LDs with bone) were collected, packaged and frozen until analysis.

The free-ranging reindeer ($n=4$ adult reindeer; 2 steers and 2 females, ages 3-5 years) were brought through a handling corral (Duck Creek, Teller, Alaska) and were slaughtered outside the corral. The saddles were removed from the warm carcasses immediately after gutting and dressing, stored in insulated boxes to keep them from freezing immediately and transported at approximately 6 h post-slaughter from the field to an indoor facility for pH measurements, packaging and freezing.

Ultimate pH in LD (at the last rib) was measured in all twelve carcasses at approximately 24 h *post mortem*. Meat samples for analysis of shear force, color, cooking loss, proximate analysis, cholesterol content, fatty acid, and lipid class composition were collected in connection with the sensory evaluation. Proximate analysis, determination of cholesterol content, fatty acid and lipid class composition was performed on both raw and cooked meat samples.

Growth performance, feed conversion efficiency and feed analysis

The eight 13 month-old reindeer steers and six 13 month-old female reindeer raised at the UAF farm were randomly allocated to a control group (SBM diet) and a treatment group (WFM diet) and put in two 25 m x 25 m pens two weeks prior to the start of the study. Diets were gradually shifted to experimental diets over the two-week period to allow for rumen adjustment.

Diets consisting of 73 –77% concentrate (dry-rolled Albright barley), 10% ground brome hay and either soybean meal (SBM) or whitefish meal (WFM) were formulated to produce protein equivalent mixtures. Soybean meal contributed 3.5% and fishmeal 2.1% to the total dietary protein of these two feed mixtures. Minerals were added to the diet to obtain a concentration of 0.7% calcium, 0.5% phosphorus, and 0.7% potassium. Corn oil, molasses, and urea were used in the diet to provide readily available energy and nitrogen sources for maintenance of rumen microflora. Vitamins and other feed components were added to the diet to achieve a balanced ruminant diet (see Table 1). Diets were mixed every 5-7 days in a 250 kg capacity Davis feed mixer. Rations were fed in rubberized tubs fitted into wooden stands at a height of 50 cm distributed under a 8 m x 15 m shelter to allow free access to all tubs. From previous experiments (Moore, 2002) the approximate daily dry matter intake (DMI) was known, and enough feed was placed in feed tubs to ensure *ad libitum* feeding of each diet configuration.

All reindeer were given fresh feed daily between 10 am and 12 pm at a rate that was adjusted to leave approximately 10 percent weigh-back (orts). Daily rations were weighed to the nearest 0.1 kg. Random feed samples were taken from each 250 kg batch of feed mixture; 10 samples to determine dry matter correction values and 10 samples for nutritional analysis. All orts were removed daily from the feed tubs and weighed to the nearest 0.1 kg. Daily orts were pooled, thoroughly mixed, and 5 samples were randomly selected for dry matter correction values. The daily dry matter intake (DMI) of each diet was calculated by dividing total feed consumption (corrected for DM content) by number of animals in the pen to determine mean DMI /animal/day.

Animals were weighed at the start of the trial using a squeeze chute mounted on Tru-test MP 800 load bars (Tru-test Ltd., Auckland, New Zealand) and then twice weekly throughout the experiment. All weightings occurred at the same time of the day. Feed conversion efficiency was calculated from the average weekly weight gain of the animals in each treatment group (SBM and WFM) divided by the respective groups' average weekly feed consumption. Ten composite fecal samples were collected in each pen every week for nitrogen, fiber and mineral analysis. The pens were cleaned of all fecal material after samples were collected.

All feed and fecal samples were oven-dried for 48 h at 60 ºC (nutritional analysis) or for 48 h at 100 ºC (DM content) and ground through a 20 mesh screen in a Wiley Mill®. Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) concentrations were determined sequentially using an Ankom® fiber analyzer (Vogel *et al*., 1999). Hemi cellulose concentra-

Table 1. Nutritional values on a dry matter (DM) basis (least-squares means ± standard errors) for the two feed mixtures used in the study; soybean meal mixture (SBM; *n* =10 samples) and fishmeal mixture (WFM; *n*=7 samples).

	SBM mixture	WFM mixture	Degree of sign.[1]
Crude protein [2]	15.3 ± 0.2	14.9 ± 0.1	n.s.
Crude fat [2]	1.7 ± 0.05	2.3 ± 0.05	***
Metabolizable energy [3]	13.0 ± 0.07	13.0 ± 0.07	n.s.
Ash [2]	5.1 ± 0.1	5.1 ± 0.1	n.s.
In vitro total digestibility [2]	85.1 ± 0.3	84.6 ± 0.4	n.s.
Neutral detergent fibre [2]	25.8 ± 0.2	26.8 ± 0.4	*
Acid detergent fibre, [2]	9.6 ± 0.2	9.5 ± 0.2	n.s.
Lignin [2]	1.3 ± 0.06	1.4 ± 0.08	n.s.
Phosphorus (P) [2]	0.4 ± 0.01	0.4 ± 0.01	n.s.
Potassium (K) [2]	0.8 ± 0.02	0.7 ± 0.03	**
Calcium (Ca) [2]	0.6 ± 0.01	0.6 ± 0.02	n.s.
Magnesium (Mg) [2]	0.2 ± 0.004	0.1 ± 0.004	*
Sulfur (S) [2]	0.2 ± 0.004	0.2 ± 0.007	n.s
Sodium (Na) [4]	810.3 ± 52.5	1010.5 ± 72.8	*
Copper (Cu) [4]	22.2 ± 1.4	16.8 ± 0.4	*
Zinc (Zn) [4]	124.3 ± 1.6	121.4 ± 3.9	n.s.
Manganese (Mn) [4]	106.6 ± 2.9	115.3 ± 8.7	n.s
Iron (Fe) [4]	190.0 ± 4.3	177.9 ± 10.3	n.s.
Cobalt (Co) [4]	0.6 ± 0.02	0.6 ± 0.03	n.s.
Molybdenum (Mo) [4]	0.4 ± 0.02	0.1 ± 0.03	n.s.
Selenium (Se) [4]	0.2 ± 0.1	0.2 ± 0.1	n.s.

[1] n.s. = $P>0.05$; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$; [2] %; [3] MJ kg^{-1}; [4] ppm.

tions were obtained by subtraction of Ankom ADF from Ankom NDF values. Nitrogen (N) and mineral analysis (K, P, Ca, Mg, S, Na, Cu, Zn, Mn, Fe, Co, Mo, Se) were performed at the Plant and Soil Analysis Laboratory, University of Alaska, Palmer, Alaska. Samples were digested in a nitric-perchloric mixture prior to analysis in an ICP Optima 3000 XL analyzer (PerkinElmer, MA, USA). In-vitro true dry matter digestibility (IVTDMD) was done at the Institute of Arctic Biology Nutritional Laboratory, University of Alaska Fairbanks in Ankom bags using the method of Goering & Van Soest (1970) with the Tilley & Terry modification (1963). Rumen inoculum was obtained from two rumen-fistulated reindeer at the Large Animal Research Station, University of Alaska Fairbanks.

Amino acid composition of the protein supplements (fishmeal and soybean meal) was analyzed at the AAA Service Laboratory, Inc., Boring, Oregon, USA. Samples were hydrolyzed with 6N HCl and 2% phenol at 110 °C for 22 h. Amino acids were quantified using the Beckman 6300 sodium hydrolysate method with post column ninhydrin derivatization. Tryptophan and cysteine contents were not determined.

Temperature and pH measurements

For calibration of the pH equipment, buffers of pH 7.0 and 4.0 (Thermo Orion, Beverly, MA, USA) at room temperature (20 °C) were used. Temperature was measured with a digital thermometer (Comark, DT 300, Beaverton, OR, USA) and pH values were measured with a portable pH meter (Orion, model 290 A, Boston, MA, USA) equipped with a Orion KnipHe® electrode (Beverly, MA, USA). The pH meter was adjusted to muscle temperature at each measurement.

Tenderness, color and cooking loss

For tenderness, color and cooking loss measurements, the meat samples (boneless LD) were thawed overnight. 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 from the sample to expose a fresh surface to air and the slice was allowed to bloom for 15 min prior to color measurement. Then the samples were cut in to steaks (2.5 cm thick) and cooked on an open hearth Farberware grill (Model 455N, Walter Kiddle, Bronz, NY, USA) to an end temperature of 71 °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., Barington, IL, USA). Steaks were weighed before cooking and then after being cooled down to 25 °C to measure cooking loss, prior to 1.3 cm cores being removed parallel to the orientation of the muscle fibers. These cores were sheared at 4 °C using an Instron® universal testing machine (model 112, Instron Corporation, MA, USA) set with a 10 kg load scale and a 200 mm per minute chart drive and crosshead speed. A total of 3 cores per steak were utilized and the values were averaged.

Table 2. Amino acid composition (mean values; % of total identified amino acids) of the two protein supplements used in the study; soybean meal and fishmeal.

Amino acid	Soybean meal (n=2 samples)	Fishmeal (n=2 samples)
Hydroxyproline (HPRO)	0	1.0
Aspartic acid (ASP)	11.8	9.5
Threonine (THR)	4.1	4.5
Serine (SER)	5.3	4.7
Glutamic acid (GLU)	18.1	14.3
Proline (PRO)	5.4	5.0
Glycine (GLY)	4.5	7.1
Alanine (ALA)	4.4	6.2
Valine (VAL)	5.1	5.2
Methionine (MET)	1.5	3.1
Isoleucine (ILE)	4.8	4.5
Leucine (LEU)	8.4	7.9
Tyrosine (TYR)	2.9	4.0
Phenylalanine (PHE)	5.5	4.4
Histidine (HIS)	2.7	2.1
Lysine (LYS)	7.0	8.2
Arginine (ARG)	8.6	8.1

Proximate analysis and lipid extraction

Protein (AOAC 968.06, 1990), moisture (AOAC 952.08, 1990), ash (AOAC 938.08, 1990) and lipid (Folch *et al*., 1957) content were determined in triplicate for each meat sample (LD). After lipid extraction, the solvent was removed at 49 °C on a rotary evaporator (Büchi Rotavapor R-205, Westbury, NY) and the lipids transferred into a pre-weighed 10ml amber screw top vial. The remaining solvent was removed under a N_2 gas stream until a constant weight was achieved and the percent lipids were then calculated. Extracted lipids were stored in chloroform containing 0.01% BHT at -70 °C for fatty acid, cholesterol and lipid class analysis.

Preparation of fatty acid methyl esters and gas chromatography analysis

Fatty acid methyl esters (FAME) were prepared using the Methanol/BF_3 method and C23:0 as internal standard (AOAC 969.33, 1990). FAMEs were transferred into 1.5 ml snap-cap amber GC vials (Agilent Technologies, Wilmington, DE, USA) and immediately analyzed. FAMEs were analysed in duplicate on a GC model 6850 (Agilent Technologies, Wilmington, DE, USA) fitted with a DB-23 (60 m x 0.25 mm id., 0.25 µm film) capillary column (Agilent Technologies, Wilmington, DE, USA) as previously described by Bechtel and Oliveira (2006). Data was collected and analysed using the GC ChemStation program (Rev. A.08.03 [847]; Agilent Technologies 1990-2000, Wilmington, DE, USA). Identification of peaks was performed using Supelco® (Bellefonte, PA, USA) standards Marine Oil #1, Marine Oil #3, Bacterial Acid Methyl Esters Mix and S-37 fatty acid methyl esters. Fatty acids were expressed as a percentage of the sum of identified fatty acids.

Lipid classes analysis

An Iatroscan™ TLC/FID Analyzer model MK-6s (Iatron Laboratories Inc., Tokyo, Japan) was used to determine the distribution of the main lipid classes in the extracted lipids according to Oliveira and Bechtel (2006). Seven standards obtained from Sigma (St. Louis, MO, USA) were used to identify the lipid classes and included cholesterol (ST), tripalmitin (TAG), palmitic acid (FFA), L-α phosphatidylcholine (PL), 1,2-dipalmitoyl-sn-glycerol (1,2-DAG), 1,3-dipalmitoyl-sn-glycerol (1,3-DAG) and DL-α-monopalmitoylglycerol (MAG). The solvent system was a mixture of hexane: ethyl ether: formic acid at the ratio of 80:25:1.2. In this system 1,3-DAG co-elutes with the sterol peak and is separated from the 1,2-DAG peak. Lipid classes were reported as percentage of total area of the triacylglycerides, free fatty acids and phospholipids. Peaks corresponding to monoglycerides and the combined percentages of sterols and 1,3-diacylglycerides were lower than 2.5 per cent of the total area and were not reported because integration of these small peaks is difficult and shows excessive variation.

Cholesterol analysis

Duplicate analyses were performed on the lipid extracts of the reindeer meat samples. The analysis followed the method of Kovacs *et al.* (1979) with modifications as described by Oliveira and Becthel (2006). Chromatography analysis was carried out on a GC 6850N (Agilent Technologies, Wilmington, DE) coupled to a FID and fitted with a DB-17 (30 m x 0.25 mm x 0.15 µm film) capillary column (Agilent Technologies, Wilmington, DE). Chromatographic conditions were as previously described (Oliveira & Bechtel, 2006). A five-point calibration curve was determined (R^2 = 0.99) using the peak area ratio of cholesterol (0.1-1 mg) and 5-α-cholestane (1 mg) versus the weight ratio of these compounds.

Sensory evaluation

Trained panel

Sensory evaluation was performed by a six-member trained sensory panel at the Department of Animal Sciences, University of Illinois, USA. Panelists were selected based on previous experience conducting trained sensory evaluation, and had also participated in an earlier study where meat from caribou and reindeer was compared with beef (Ricker *et al.*, 2006). One 2.5-cm steak (LD) from each animal was cooked to an internal temperature of 71 °C in the same manner as the shear force steaks. Samples (1 cm x 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).

Consumer preference test

The consumer test was performed in collaboration with the Cooperative Extension Service Research Kitchen (UAF, Fairbanks). One triangle test (Mielgaard *et al.*, 1999) was performed at UAF, which meant that most of the consumers participating were students and staff at the University.

The reindeer meat (LD) was cooked in a conventional oven in cooking bags to an internal temperature of 71 ºC one day prior to the test. The meat was cooled down and stored in a refrigerator (+ 3 ºC) overnight. On the day of the test, the meat was cut into cubes, placed in vacuum bags and heated in a water-bath (60 ºC) before it was served to the consumers (n = 59). The consumers were presented with a plate holding three sub samples, each coded with a random three digit number. Two of these samples originated from the free ranging reindeer (control group representing "normal" Alaskan reindeer meat) and one sample from the WFM animals. Together with the meat samples, a questionnaire was presented with the following instructions (from Mieldgaard *et al.* (1999); "Taste the samples on the plate in the order listed below (top to bottom). Two samples are the same; one sample is different. Select the different sample (just one) by placing an X in the box next to the code of the different sample. If you cannot detect any difference among the samples, you must

"guess"". Space was provided for the consumers to specify additional remarks on the meat samples.

Statistical analysis

The statistical analyses were carried out with the Statistical Analysis System (SAS Institute, 2003) and Systat (SPSS Inc., 1997) using the GLM and MIXED procedures. The model for comparing total weight gain, feed intake, feed conversion efficiency, meat ultimate pH, tenderness, color, cooking loss, chemical and fatty acid composition, lipid classes and cholesterol content 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. Statistical analysis of the data from the consumer test was performed by Creascience, Montreal, Canada.

Results

Growth performance and feed conversion efficiency

The fat content was significantly higher in the WFM mix compared with the SBM mix (Table 1). The fishmeal contained higher levels of the amino acids glycine, alanine, methionine, tyrosine and lysine than the soybean meal though no statistical comparison was conducted (n = 2 samples from each feed mix; Table 2). Soy meal had higher amino acid values for phenyalanine and glutamic acid. The animals consuming the SBM mix had higher nitrogen concentration in the feces than WFM animals (Table 3). The content of phosphorous excreted in the feces was similar for SBM and WFM groups.

The SBM animals had slightly higher body weights compared with the WFM group when the feeding trial started (average animal weights of the groups 82.2 kg and 78.3 kg, respectively). The plot of live weight over the feeding period (8 weeks) of the two treatment groups is shown in Fig. 2. There was no significant difference in overall weight gain between females and steers (P = 0.215), however a tendency towards higher weight gains (P = 0.068) in the WFM animals compared with the SBM animals (groups with combined weight gain from steers and females) was found (Table 4).

The variation in dry matter intake (DMI; g DM/day/kg body weight) for the two treatment groups is presented in Table 4. No statistical difference was found when comparing the average DMI for the WFM and SBM groups (30.1 g and 29.6 g, respectively, P = 0.407). Average feed conversion efficiency (kg weight gain per kg feed (DM) consumed) over the feeding period was significantly higher (P = 0.003) for the reindeer fed the WFM mix compared with the SBM animals (0.147 kg and 0.120 kg respectively, Table 4).

Carcass characteristics and meat quality attributes

There was a significantly higher (P = 0.03) dressing percentage of the carcasses from the SBM group compared with the WFM animals (Table 5). No other differences were found in carcass characteristics or ultimate pH in LD between the three treatment groups (SBM, WFM and free-range) (Table 5).

The carcasses from the SBM group seemed to cool down slightly slower than those from the WFM group, however the difference was not significant. At 6 h *post mortem*, there was a tendency (P = 0.1) towards higher temperatures in LD from the SBM group compared with the WFM animals (16.2 ± 2.1 °C and 10.5 ± 2.4 °C, respectively) (Fig. 3). Temperature decline was not measured in the carcasses from the free-ranging reindeer as these animals were slaughtered in the field.

No significant differences between the three treatment groups (SBM, WFM and free-range) were found when comparing values in LD for shear force, meat color and cooking loss (Table 5).

Proximate analysis

The chemical composition of meat (LD) from the three treatment groups was very similar, for both the raw and cooked meat samples. The raw SBM samples had higher fat content than samples from the free-range group (Table 6).

The effects of cooking on the chemical composition were analyzed within trait and treatment group (Table 6). Generally, the moisture content decreased significantly after cooking in samples from all treatment groups, at the same time as the protein content increased. The meat from the SBM and WFM groups had similar raw and cooked fat content; however, for the free-ranging animals an increase in fat content was observed. No significant difference in cholesterol content was found when comparing raw and cooked samples from the three treatments; however the WFM samples had significantly lower cholesterol content compared with the two other groups (Table 6).

Fatty acid composition

Three fatty acids constitute in excess of 75% of the total fatty acids which are C16:0, C18:0, and C18:1 n-9 (Table 7). There were many significant differences between the treatments for individual fatty acids, with many of the differences between the range and the other two groups. As expected, the long chain omega-3 fatty acids were found in small amounts in the raw and cooked reindeer meat with the free-range group having the largest concentration of C20:5 n-3 (EPA) at 0.9% of total identified fatty acids. WFM had the highest amount of C22:6 n-3 (DHA) at approximately 0.3%. The free-range group had the highest amount of

Table 3. Nutrient composition on a dry matter (DM) basis (least-squares means ± standard errors) in fecal samples from reindeer fed the two feed mixtures used in the study; soybean meal mixture (SBM, *n* = 7 samples) and fishmeal mixture (WFM, *n* = 8 samples).

	SBM mixture	WFM mixture	Degree of sign.[1]
Crude protein [2]	16.8 ± 0.2	14.4 ± 0.2	***
Ash [2]	16.9 ± 0.9	22.5 ± 0.9	***
Neutral detergent fibre [2]	53.7 ± 0.6	57.9 ± 0.6	***
Acid detergent fibre [2]	27.0 ± 0.4	30.3 ± 0.4	***
Lignin [2]	5.0 ± 0.1	5.0 ± 0.1	n.s.
Phosphorus (P) [2]	0.7 ± 0.05	0.7 ± 0.04	n.s.
Potassium (K) [2]	0.3 ± 0.01	0.3 ± 0.01	n.s.
Calcium (Ca) [2]	1.9 ± 0.1	1.6 ± 0.1	n.s.
Magnesium (Mg) [2]	0.7 ± 0.02	0.6 ± 0.02	**
Sulfur (S) [2]	0.24 ± 0.01	0.20 ± 0.01	**
Sodium (Na) [3]	120.3 ± 6.1	107.0 ± 5.7	n.s.
Copper (Cu) [3]	71.5 ± 2.6	57.6 ± 2.4	**
Zinc (Zn) [3]	543.6 ± 16.4	485.1 ± 15.4	*
Manganese (Mn) [3]	488.4 ± 10.7	464.6 ± 10.0	n.s
Iron (Fe) [3]	2574.8 ± 281.9	4000.8 ± 263.7	**
Cobalt (Co) [3]	3.7 ± 0.1	4.4 ± 0.1	**
Molybdenum (Mo) [3]	1.22 ± 0.1	0.0 ± 0.1	***
Selenium (Se) [3]	0.1 ± 0.07	0.0 ± 0.06	n.s.

[1] n.s. = $P>0.05$; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$; [2] %; [3] ppm.

omega-3 fatty acids at 2.0% and also a tendency towards the highest amount of polyunsaturated fatty acids (PUFA) at 17.8% of total identified fatty acids. Most cooked samples had values for those fatty acids that were present in high concentrations and that were similar to those found in raw meat.

Lipid classes

Meat from the animals fed SBM was significantly higher in triacylglycerides (TAG) content and significantly lower in phospholipid (PL) content when compared with the meat from both WFM fed animals and free-ranging reindeer (Table 8). FFA content was significantly higher in free-ranging reindeer, but no significant difference was detected between SBM and WFM for this lipid class.

Comparing the raw and the cooked samples, FFA decreased significantly during cooking for all samples investigated (Table 8). In the WFM samples, the TAG content decreased and PL content increased when the samples were cooked; however for the other two treatments cooking did not lead to significant changes in PL and TAG.

Sensory evaluation

Trained panel

No significant differences between the three treatment groups (SBM, WFM and free-range) were found when comparing the sensory attributes of the meat. Sensory scores (least-squares means and standard errors) indicated that all samples were tender (values from 9.8 to 10.9 ± 0.7), juicy (values from 8.6 to 9.3 ± 0.3), had an intense meat flavor (values from 9.1 to 9.8 ± 0.3) and low off-flavor (0.6 to 1.8 ± 0.8).

Consumer test

Of the 59 consumers participating in the test, 29 could correctly identify the WFM meat as different from the free-range meat, indicating a significant difference between the samples (P = 0.008). When summarizing the written comments from the consumers, various off-flavor attributes were mentioned (*e.g.* "gamey", "after taste", "strong", "robust", "liver", "more flavor", "iron", "not like caribou") from 9 of the consumers on the WFM samples and from 14 of the consumers for the free-range samples. No comments were registered on any "fish-related" flavor attribute.

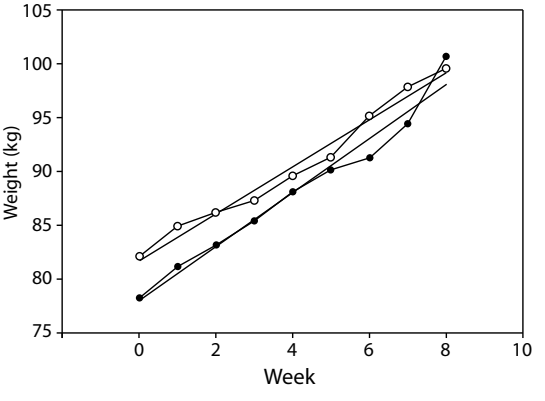

Fig. 2. Weekly live weight gain (mean values and fitted regression lines) for reindeer steers and females from two different feeding treatments; SBM (feed mixture based on soybean meal protein; n=7, 3 females and 4 steers) and WFM (feed mixture based on fish meal protein; n=6, 3 females and 3 steers).

Table 4. Weight gain, dry matter intake and feed conversion efficiency (least-squares means ± standard errors) for reindeer steers and females from two different feeding treatments; SBM (feed mixture based on soybean meal protein) and WFM (feed mixture based on fishmeal protein) during the 8 weeks performance trial.

Trait	SBM group	WFM group	Degree of sign.[1]
Weight gain, (kg)			
Females	14.8 ± 1.0 (n=3)	21.5 ± 3.1 (n=3)	n.s.
Steers	19.5 ± 1.9 (n=4)	23.5 ± 3.5 (n=3)	n.s.
Dry matter intake (DMI), (g DM/day/kg body weight)			
Females + steers	29.6 ± 0.1 (n=7)	30.1 ± 0.1 (n=6)	n.s.
Feed conversion efficiency, (g weight gain/kg feed consumed)			
Females + steers	120 ± 6.0 (n=7)	147 ± 5.0 (n=6)	**

[1] n.s. = P>0.05; ** = P≤0.01.

Discussion

The supplementation of a milled reindeer diet with processed fishmeal (WFM) in Alaska is attractive because it is readily available at a relatively low cost when compared with other imported protein supplements. Another advantage of using fishmeal in feed mixtures for farmed reindeer is its chemical composition. WFM is an excellent source of high quality protein and has a well-balanced amino acid profile, as in the present study demonstrated by high levels of amino acids like lysine, methionine, tyrosine and threonine (Table 2).

Reindeer have high dietary protein requirements during summer to support muscle, antler and hair growth (Klein, 1970). The main sources of metabolizable protein for the ruminant animal are microbial protein synthesized in the rumen and feed protein escaping rumen degradation. Fishmeal is considered a low rumen-degradable protein and has produced higher weight gains and feed efficiencies when replacing soybean meal (SBM) in ruminant diets (Orskov *et al*, 1970; Oldham *et al*., 1985). Approximately 60 –70% of WFM protein has been estimated to escape rumen degradation compared with only 30 – 35% of SBM protein (NRC, 1996). The reindeer (both steers and females) fed the feed mixture including WFM showed a trend towards higher weight gain and significantly improved feed conversion efficiency compared with animals fed the SBM mixture, suggesting that WFM can be used in reindeer diets across sex classes in a production setting with no negative effect on performance.

The WFM had no apparent effect on palatability of the diet as indicated by no significant difference in feed intake (DMI) between the two treatment groups. The two diets in the present study were equivalent in protein and mineral content, however it has been demonstrated that cattle fed a WFM-based diet as opposed to a SBM diet had a more complete amino acid profile of digesta flow reaching the small intestine (Korhonen *et al*., 2002). Amino acid profiles of digesta

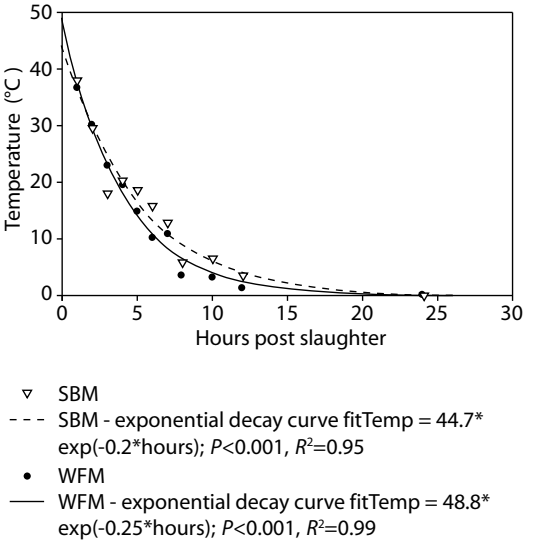

Fig. 3. Temperature decline (mean values and fitted regression curves) in *M. longissimus* (LD) from reindeer from two feeding treatments; SBM (feed mixture based on soybean meal protein; $n=4$) and WFM (feed mixture based on fish meal protein; $n=4$) included in the study, measured at 1, 2, 3, 4, 5, 6, 7, 8, 10, 12 and 24 h *post mortem*.

Table 5. Carcass and meat quality characteristics in *M. longissimus* (LD) in reindeer from three different feeding treatments; SBM (feed mixture based on soybean meal protein), WFM (feed mixture based on fishmeal protein) and grazing free ranging animals included in the study (least-squares means and standard errors).

Trait	SBM group ($n=4$)	WFM group ($n=4$)	Range group ($n=4$)	Degree of sign.[1]
Live weight, (kg)	103.0 ± 5.8	108.9 ± 5.8	n.d.[2]	n.s.
Carcass weight, (kg)	58.4 ± 3.5	59.5 ± 3.5	n.d.	n.s.
Dressing, (%)	56.7 ± 0.5	54.6 ± 0.5	n.d.	*
Ultimate pH (LD)	5.61 ± 0.02	5.60 ± 0.02	5.58 ± 0.02	n.s.
Shear force, (kg)	2.4 ± 0.4	3.3 ± 0.4	2.3 ± 0.4	n.s.
Cooking loss, (%)	23.2 ± 1.5	22.1 ± 1.5	21.6 ± 1.5	n.s.
Color L-value	22.4 ± 1.8	19.6 ± 1.8	19.3 ± 1.8	n.s.
Color a-value	9.6 ± 0.8	11.4 ± 0.8	10.3 ± 0.8	n.s.
Color b-value	11.6 ± 1.2	12.1 ± 1.2	13.3 ± 1.2	n.s.

[1] n.s. = $P>0.05$; * = $P\leq0.05$. [2] n.d. = not determined.

reaching the small intestine were not determined in the present study. An average of 74% of the total nitrogen content in ruminant feces is of rumen bacterial origin but is also influenced by various dietary characteristics (Merchen *et al*., 1988). Fecal nitrogen concentration was higher for animals fed SBM than animals fed WFM in the present study. A lower protein excretion in feces from reindeer in the WFM group may indicate a better protein absorption of the WFM compared with the SBM feed mix.

The SBM fed reindeer had a significantly higher carcass dressing percentage than WFM fed animals. No measurements of fat depots in the carcasses (subcutaneous fat, kidney fat or fat around the digestive tract) were registered in this study, however the higher intra muscular fat content in the SBM group compared with the two other groups (Table 6) indicated animals in better physical condition. An increased subcutaneous fat layer in the SBM carcasses could have increased the dressing percentage and also contributed to the slightly slower cooling rate of these carcasses (Fig. 3). Protein and mineral nutrition is known to affect antler (Asleson *et al*., 1996; Moen *et al*., 1998) and most likely hair growth in cervids. Antler or hide weights were not measured after slaughter in this study but it can be speculated that lower carcass dressing percentage in the WFM animals could have been a result of an increased antler and hair growth.

The nutritional status and physical condition of reindeer has been demonstrated to have a considerable effect on muscle glycogen content and meat ultimate pH values (Wiklund *et al*., 1996). The meat pH values of the reindeer in the present study therefore indicated that the animals from all three groups (WFM, SBM and free-range) were in good physical condition. The other meat quality attributes measured; tenderness, cooking loss and color were all very similar comparing the three groups of reindeer. Earlier studies have reported equally low shear force (high tenderness) values for reindeer meat (Wiklund *et al*., 1997; Rincker *et al*., 2006) as well as cooking loss values in the same range as the present results (Wiklund *et al*., 1997). The present Minolta color L^* and a^* values were slightly lower and b^* values higher compared with a previous study of reindeer meat (Rincker *et al*., 2006).

Table 6. Chemical composition of raw and cooked *M. longissimus* (LD) in reindeer from three different feeding treatments; SBM (feed mixture based on soybean meal protein), WFM (feed mixture based on fish meal protein) and grazing free ranging animals included in the study (least-squares means and standard errors).

Trait	SBM group (n=4)	WFM group (n=4)	Range group (n=4)	Degree of sign.[1]
Moisture [2]				
Raw meat	71.7±0.9	71.8±0.8	71.4±0.9	n.s.
Cooked meat	66.4±1.1	67.6±0.9	64.0±0.9	n.s.
Degree of sign.[3]	**	**	***	
Ash [2]				
Raw meat	1.1±0.1	1.3±0.1	1.5±0.1	n.s.
Cooked meat	1.2±0.2	1.3±0.2	1.1±0.2	n.s.
	n.s.	n.s.	n.s.	
Protein [2]				
Raw meat	26.0±1.0	26.2±0.9	25.7±1.0	n.s.
Cooked meat	30.3±1.2	30.5±1.0	31.9±1.0	n.s.
	*	**	***	
Fat [2]				
Raw meat	5.1^{a}±0.7	3.7^{ab}±0.7	2.6^{b}±0.7	*
Cooked meat	5.2±0.8	3.4±0.7	4.8±0.7	n.s.
	n.s.	n.s.	*	
Cholesterol [4]				
Raw meat	2.42^{a}±0.3	1.26^{b}±0.3	2.62^{a}±0.3	*
Cooked meat	2.71^{a}±0.2	1.57^{b}±0.2	2.04^{b}±0.2	**
	n.s.	n.s.	n.s.	

[1] n.s.= P>0.05; * = P≤0.05. Comparisons between treatment groups, common letters in a row indicate no significant difference at P>0.05.

[2] %.

[3] n.s. = P>0.05; * = P≤0.05; ** =P≤0.01; *** =P≤0.001. Comparisons between raw and cooked samples within trait and treatment group (columns).

[4] Expressed as a fraction (g /100g) of total lipid content, n=3 for all treatments except raw SBM and cooked Range where n=2.

Table 7. Fatty acid composition (% of total identified fatty acids) of raw and cooked *M. longissimus* (LD) in reindeer from three different feeding treatments; SBM (feed mixture based on soybean meal protein; *n*=4), WFM (feed mixture based on fish meal protein; *n*=4) and grazing free ranging animals (*n*=4) included in the study (least-squares means and standard errors).

Fatty acid		SBM group	WFM group	Range group	Degree of sign.[1]
C14:0	Raw	1.2^{ab} ± 0.1	1.5^{a} ± 0.1	1.0^{b} ± 0.1	n.s
	Cooked	1.5 ± 0.3	1.0 ± 0.3	1.1 ± 0.3	n.s
Degree of sign.[2]			*		
C16:0	Raw	24.6^{a} ± 0.8	24.7^{a} ± 0.8	21.6^{b} ± 1.1	*
	Cooked	25.8 ± 1.1	24.4 ± 1.1	24.0 ± 1.1	n.s
C16:1 n-7	Raw	1.1 ± 0.1	1.2 ± 0.1	0.9 ± 0.1	n.s.
	Cooked	1.2 ± 0.06	1.0 ± 0.06	1.1 ± 0.06	n.s.
C17:0	Raw	0.6^{a} ± 0.05	0.6^{a} ± 0.05	0.8^{b} ± 0.05	n.s.
	Cooked	0.7^{a} ± 0.04	0.5^{a} ± 0.04	0.8^{b} ± 0.04	**
C18:0	Raw	18.3 ± 0.5	19.0 ± 0.5	19.3 ± 0.5	n.s.
	Cooked	18.4 ± 0.8	19.2 ± 0.8	20.3 ± 0.8	n.s.
C18:1 n-9 cis	Raw	37.3 ± 1.8	35.6 ± 1.8	32.1 ± 1.8	n.s.
	Cooked	38.9^{a} ± 2.0	32.5^{ab} ± 2.0	31.8^{b} ± 2.0	n.s.
C18:2 n-6 cis	Raw	7.3 ± 1.4	7.3 ± 1.4	9.4 ± 1.4	n.s.
	Cooked	5.9^{a} ± 0.8	10.4^{b} ± 0.8	9.4^{b} ± 0.8	**
C18:3 n-3	Raw	0.3^{a} ± 0.08	0.3^{a} ± 0.08	1.0^{b} ± 0.08	***
	Cooked	0.2^{a} ± 0.05	0.3^{a} ± 0.05	0.9^{b} ± 0.05	***
C20:0	Raw	0.18^{a} ± 0.01	0.21^{a} ± 0.01	0.25^{b} ± 0.01	**
	Cooked	0.15^{a} ± 0.02	0.19^{ab} ± 0.02	0.24^{b} ± 0.02	*
C20:2 n-6	Raw	0.18^{a} ± 0.05	0.21^{a} ± 0.05	0.42^{b} ± 0.02	*
	Cooked	0.16^{a} ± 0.02	0.28^{b} ± 0.02	0.35^{b} ± 0.02	***
C20:3 n-6	Raw	0.22 ± 0.07	0.27 ± 0.07	0.40 ± 0.07	n.s.
	Cooked	0.17^{a} ± 0.03	0.33^{b} ± 0.03	0.32^{b} ± 0.03	**
C20:4 n-6	Raw	2.6 ± 0.8	2.8 ± 0.8	4.7 ± 0.8	n.s.
	Cooked	1.9^{a} ± 0.4	3.5^{b} ± 0.4	3.1^{b} ± 0.4	*
C20:5 n-3	Raw	0.22^{a} ± 0.1	0.24^{a} ± 0.1	0.89^{b} ± 0.1	**
	Cooked	0.08^{a} ± 0.04	0.30^{b} ± 0.04	0.61^{c} ± 0.04	***
C24:0	Raw	0.52^{a} ± 0.3	0.63^{a} ± 0.3	2.03^{b} ± 0.3	**
	Cooked	0.35^{a} ± 0.1	0.70^{a} ± 0.1	1.31^{b} ± 0.1	***
C22:6 n-3	Raw	0.12 ± 0.1	0.27 ± 0.1	0 ± 0.1	n.s.
	Cooked	0^{a} ± 0.07	0.33^{b} ± 0.07	0^{a} ± 0.07	*
SFA[3]	Raw	47.9 ± 1.0	49.2 ± 1.0	47.4 ± 1.0	n.s.
	Cooked	49.2 ± 2.2	48.5 ± 2.2	50.1 ± 2.2	n.s.
MUFA	Raw	40.4 ± 1.9	38.8 ± 1.9	34.8 ± 1.9	n.s
	Cooked	42.0^{a} ± 2.2	35.3^{ab} ± 2.2	34.4^{b} ± 2.2	n.s.
PUFA	Raw	11.6 ± 2.8	12.0 ± 2.8	17.8 ± 2.8	n.s.
	Cooked	8.8^{a} ± 1.4	16.2^{b} ± 1.4	15.5^{b} ± 1.4	**

P/S ratio	Raw	0.25 ± 0.06	0.25 ± 0.06	0.38 ± 0.06	n.s.
	Cooked	0.18[a] ± 0.03	0.33[b] ± 0.03	0.31[b] ± 0.03	*
n-6 PUFA	Raw	10.9 ± 2.5	11.2 ± 2.5	15.8 ± 2.5	n.s.
	Cooked	8.5[a] ± 1.3	15.3[b] ± 1.3	13.9[b] ± 1.3	**
n-3 PUFA	Raw	0.70[a] ± 0.28	0.81[a] ± 0.28	1.97[b] ± 0.28	*
	Cooked	0.30[a] ± 0.15	0.99[b] ± 0.15	1.58[c] ± 0.15	***
n-6/n-3	Raw	19.7[a] ± 2.0	14.8[a] ± 2.0	8.0[b] ± 2.0	**
	Cooked	31.1[a] ± 3.3	17.8[b] ± 3.3	8.7[b] ± 3.3	**

[1]n.s.= $P>0.05$; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$. Comparisons between treatment groups, common letters in a row indicate no significant difference at $P>0.05$.

[2]* = $P\leq0.05$. Comparisons between raw and cooked samples within fatty acid and treatment group (columns).

[3]Abbreviations: SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.

Table 8. Lipid class composition (TAG=triglycerides, FFA=free fatty acids, PL=phospholipids) of raw and cooked *M. longissimus* (LD) in reindeer from three different feeding treatments; SBM (feed mixture based on soybean meal protein), WFM (feed mixture based on fish meal protein) and grazing free ranging animals included in the study (least-squares means and standard errors).

Trait	SBM group ($n=4$)	WFM group ($n=4$)	Range group ($n=4$)	Degree of sign.[1]
TAG [3]				
Raw meat	59.6[a] ± 5.3	44.4[ab] ± 5.3	32.4[b] ± 5.3	**
Cooked meat	59.2[a] ± 3.2	32.8[b] ± 3.2	33.8[b] ± 3.2	***
Degree of sign.[2]	n.s.	*	n.s.	
FFA [3]				
Raw meat	1.0[a] ± 0.3	1.0[a] ± 0.3	6.2[b] ± 0.3	***
Cooked meat	0.6[a] ± 0.1	0.8[b] ± 0.1	2.0[c] ± 0.1	***
	*	n.s.	***	
PL [3]				
Raw meat	38.1[a] ± 4.9	52.9[b] ± 4.9	58.7[b] ± 4.9	*
Cooked meat	38.9[a] ± 3.1	64.4[b] ± 3.1	62.1[b] ± 3.1	***
	n.s.	*	n.s.	

[1]n.s.= $P>0.05$; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$. Comparisons between treatment groups, common letters in a row indicate no significant difference at $p>0.05$.

[2]n.s.= $P>0.05$; * = $P\leq0.05$; ** = $P\leq0.01$; *** = $P\leq0.001$.Comparisons between raw and cooked samples within trait and treatment group (columns).

[3] percentage of total area of TAG, FFA and PL.

The proximate composition of the reindeer samples indicated that the meat from all three present treatments was lean with a maximum fat content of 5.1%. Meat from free-range animals had significantly lower fat contents with values averaging 2.6% while the soy treatment animals showed higher fat contents. In a previous study (Rincker *et al*., 2006), meat samples from free-range Alaska reindeer had a fat content of 2.8%, similar to the free-range value found in the present study. Other studies report values for fat content in Scandinavian reindeer meat within the range of those found in the present study, *i.e.* between 2.1 and 4.2% and in good agreement with the conclusion that meat from free-range animals had the lowest fat

content and reindeer fed grain-based feed mixtures had the highest fat content (Wiklund *et al*., 2001; Sampels *et al*., 2004; 2005). Additionally, it was observed that the amount of triacylglycerides (TAG) was significantly higher in the meat from the SBM animals, while the amount of phospholipid (PL) was lower than in samples from the other two groups. It has been observed that biological tissues rich in lipids tend to present most of its lipids in the form of TAG (storage lipids) and tissues with lower lipid content have proportionally higher PL (structural lipids) values (Whitsett *et al*., 1986; Oliveira & Bechtel, 2006). Further, it was interesting to note that the cooked SBM samples retained the high percent TAG and low percent PL lipid class values. The protein content of the samples in the present study ranged from 25.7 to 26.2% which reflects the precision of the analytical method with differences between SBM and WFM samples being smaller than 1 per cent. A similar phenomenon was observed for the moisture content of the raw meat samples.

There is no data that compares the proximate composition of raw and cooked reindeer meat. As a generality cooking reduced the moisture content in this study from values for the raw samples of 71.4 to 71.8 to values in the cooked samples of 64.0 to 67.6%. Similar moisture values have been reported for raw and cooked pork (Novaskofski *et al*., 1989). As the moisture content decreased the protein content increased in the cooked samples to 30.3 to 31.9%. Interestingly the fat and ash content of the cooked and raw samples were similar for the SBM and WFM treatments. This indicates that the cooking loss consisted predominantly of moisture, which was accompanied by concentration of the protein. The cholesterol values did not differ between raw and cooked samples when expressed as a fraction (g/100g) of total lipid content (Table 6). Overall the cholesterol content of raw and cooked samples in the present study were similar to the range of values found for meat and meat products reported by USDA (2002) for a 3 oz. serving (approximately 84 g). As an example, oven roasted lean beef (fat content 4.0%) contained 59 mg cholesterol/serving (USDA, 2002) and pot roasted lean beef (fat content 7.0%) contained 82 mg cholesterol/serving (USDA, 2002). In comparison, expressing the present cholesterol results for reindeer meat using the same units as in the USDA publication, values of 119 mg cholesterol/serving for SBM samples and 45 mg cholesterol/serving for WFM samples were found.

Studies performed on cattle, sheep, red deer, reindeer and free-living ruminants have indicated that the fatty acid composition of meat changed in response to diets (Crawford *et al*., 1970; Manley *et al*., 1979; Wachira *et al*., 1999; Wiklund *et al*., 2001; Wood *et al*., 2003). Generally, a higher proportion of long, unsaturated fatty acids were found in meat from grazing animals compared with animals fed a grain based diet. Changes in fat content and fatty acid composition influence various aspects of meat quality, particularly meat and fat firmness, shelf life and flavor (Wood *et al*., 2003). The range of volatile flavor precursors deriving from different amounts of unsaturated fatty acids contributes to the taste of cooked meat (Wood & Enser, 1997; Mottram, 1998). In addition, unsaturated fatty acids are more prone to oxidation compared with saturated fats (Mottram, 1998; Morressey *et al*., 1998). This sensitivity to oxidation increases with increasing unsaturation, for example the oxidizability of the fatty acid 22:6 n-3 is much higher than that of 18:2 n-6 (Cosgrove *et al*., 1987). So higher levels of polyunsaturated fatty acids (PUFA) lead to increased oxidation, which in turn can reduce sensory quality, but also meat color stability and thereby shelf life, as a relationship between lipid oxidation and myoglobin oxidation have been reported (Kanner, 1994; Juncher *et al*., 2001). Taugbøl and Mathiesen (1999) found the PUFA 22:5 n-3 in intramuscular fat in reindeer meat (*M. psoas minor*) after grazing an old meadow or fed a commercial reindeer feed (RF-80). In the same study the PUFA 22:6 n-3 was found, but only in meat from animals fed RF-80, which contained fish by-products. However, no evaluation of sensory quality attributes of the meat was performed in the mentioned Norwegian study (Taugbøl & Mathiesen, 1999). A high content of the fatty acids 16:0, 18:0 and 18:1 n-9 was found in the reindeer meat samples from the present study and similar values have been observed for Scandinavian reindeer meat by other researchers (Sampels *et al*., 2004; 2006). The present study showed fatty acid profiles similar for all treatment groups; however, the P/S ratio was largest for the free-range group (0.38) and smaller for SBM and WFM (0.25). The total omega-3 levels in meat from the free-range reindeer were 2.0% of total identified fatty acids, which was much higher that the values for the SBM and WFM groups (0.7% and 0.8%, respectively). These results were probably related to the fatty acid content in the free-range diet and to the lower fat content in the meat samples from the reindeer in this treatment group. The most abundant fatty acids in the samples were similar between treatments and between raw and cooked samples. However, the amount of DHA (22:6 n-3) was highest in the samples from the WFM group. WFM is made from cold-water marine fish byproducts which contain high levels of both DHA and EPA (20:5 n-3) and therefore it was not surprising to see elevated levels of DHA in the meat from this treatment group. It would be interesting to know what component of the free-range reindeers' diet contributed

the EPA, resulting in levels higher than present in either the WFM or SBM groups. Sampels *et al.* (2006) could not find EPA in two varieties of grain-based reindeer pellets, however this fatty acid was present in four different species of lichen (*Cladina mitis, Cladina stellaris, Cladina arbuscula* and *Cretaria islandica*) which are important plants included in free-range reindeers' winter diet.

Relative to other food groups, game meats offer high levels of protein and iron, and compared with beef, pork and lamb, lower levels of fat (Drew, 1991: Hoffman & Wiklund, 2006). Although game meat has characteristics that are distinct from domestic meat species, it is evaluated by consumers according to the same criteria as other meats, including color, texture, flavor, juiciness and price (Krieg, 1991). After 6 weeks of feeding reindeer various diets, a trained panel could not find any differences in the flavor of the meat (Wiklund *et al*., 2000). Flavor differences in the meat after 10 weeks of feeding either grass or pellets to red deer (*Cervus elaphus*) was reported, showing that the grass-fed animals produced meat with a more 'grassy' flavor and a tendency towards more 'gamey' flavor than the pellet fed deer ((Wiklund *et al*., 2003b). It has been suggested that natural grazing is an important contributor to the development of various 'wild' flavors in meat, possibly depending partly effects of the fatty acid composition (Wiklund *et al*., 2003a). In our present study, the trained panel did not find any differences in flavor attributes between the three treatment groups, however the consumers certainly commented on flavor variations in meat from WFM fed and grazing animals. The comments on 'wild' flavors in the meat samples were mainly related to the group of free-ranging grazing reindeer and were therefore in good agreement with previous research.

Conclusions

The results from this experiment suggest there are no negative effects in either animal performance or meat quality characteristics by using fish meal as opposed to soybean meal as a protein supplement in a milled reindeer diet.

Acknowledgements

The authors wish to thank the staff at Delta Meats, Delta Junction, the reindeer herder James Noyakuk, Teller and Robert van Buuren for all their assistance and co-operation in connection with the slaughter and collection of samples. We are also grateful to Robert Aikman and his staff for their help with animal management during feed and fecal sampling, feeding and weight registrations of the reindeer. During the consumer test the assistance of Suzanne Worker, Margo Kramer, Kamolluck Trateng and Heather Averett was greatly appreciated. We also thank Steve Coen (Fishery Industrial Technology Center, Kodiak) for his technical support during chemical and lipid analysis. Financial support for this work was provided by the United States Department of Agriculture (USDA), Cooperative State Research, Education and Extension Service Hatch Formula Funding accession no. 0178706 and by the Reindeer Research Program, University of Alaska Fairbanks.

References

Alaska Agriculture Statistics. 2005. *U.S. Department of Agriculture.* Palmer Alaska.

AOAC, Method 968.06. 1990. Official Methods of Analysis, 15th ed. *Association of Official Analytical Chemists*, Arlington, VA, USA.

AOAC, Method 952.08. 1990. Official Methods of Analysis, 15th ed. *Association of Official Analytical Chemists*, Arlington, VA, USA.

AOAC, Method 938.08. 1990. Official Methods of Analysis, 15th ed. *Association of Official Analytical Chemists*, Arlington, VA, USA.

AOAC, Method 969.33. 1990. Official Methods of Analysis, 15th ed. *Association of Official Analytical Chemists*, Arlington, VA, USA.

Asleson, M. A., Hellgren, E. C. & Varner, L. W. 1996. Nitrogen requirements for antler growth and maintenance in white-tailed deer. – *Journal of Wildlife Management* 60: 744-752.

Bechtel, P. J. & Oliveira, A. C. M. 2006. Chemical characterization of liver lipid and protein from cold water fish species. – *Journal of Food Science* 71: S480-S486.

Carroll, D. J., Hossain, F. R. & Keller, M. R. 1994. Effect of supplemental fish meal on the lactation and reproductive performance of dairy cows. – *Journal of Dairy Science* 77: 3058-3072.

Cosgrove, J. P., Church, D. F. & Pryor, W. A. 1987. The kinetics of the autoxidation of polyunsaturated fatty acids. – *Lipids* 22: 299-304.

Crapo, C. & Bechtel, P. J. 2003. Utilization of Alaska's seafood processing byproducts. – *In:* P. J. Bechtel (ed.). *Advances in Seafood Byproducts Conference Proceedings.* Alaska Sea Grant College Program, University of Alaska Fairbanks, pp. 109-121.

Crawford, M. A., Gale, M. M., Woodford, M. H. & Casped, N. M. 1970. Comparative studies on fatty acid composition of wild and domestic meats. – *International Journal of Biochemistry* 1: 295-305.

Drew, K. R. 1991. Carcass characteristics and optimal slaughter time in deer. – *In:* L. A. Renecker & R. J. Hudson (eds.). *Wildlife Production: Conservation and sustainable development.* AFES misc. pub. 91-6, University of Alaska, Fairbanks, USA, pp. 543-547.

Folch, J., Lees, M. & Sloane-Stanley, G. H. 1957. A simple method for the isolation and purification of total

lipids from animal tissues. – *Journal of Biological Chemistry* 226: 497-509.

Goering, H. K. & Van Soest, P. J. 1970. Forage fiber analyses. *ARS, USDA, Agricultural Handbook* No. 379, Washington DC, USA.

Hoffman, L. C. & Wiklund, E. 2006. Game and venison – meat for the modern consumer. – *Meat Science* 74: 197-208.

Hussein, H. S. & Jordan, R. M. 1991. Fish meal as a protein supplement in ruminant diets: a review. – *Journal of Animal Science* 69: 2147-2156.

Juncher, D., Ronn, B., Mortensen, E. T., Henckel, P., Karlsson, A., Skibsted, L. H. & Bertelsen, G. 2001. Effect of pre-slaughter physiological conditions on the oxidative stability of colour and lipid during chill storage of pork. – *Meat Science* 58: 347-357.

Kanner, J. 1994. Oxidative processes in meat and meat products – quality implications. – *Meat Science* 36: 169-189.

Klein, D. R. 1970. *Nutritive quality of Alaskan range forage and associated growth and welfare of reindeer and caribou. Completion report to the U. S. Department of the Interior*, Bureau of Land Management. 30 pp.

Korhonen, M., Vanhatalo, A. & Huhtanen, P. 2002. Effect of protein source on amino acid supply, milk production, and metabolism of plasma nutrients in dairy cows fed grass silage. – *Journal of Dairy Science* 85: 3336-3351.

Kovacs, M. I. P., Anderson, W. E. & Ackman, R. G. 1979. A simple method for the determination of cholesterol and some plant sterols in fishery-based food products. – *Journal of Food Science* 44: 1299-1305.

Krieg, K. L. 1991. Strategies for marketing game meats. – *In:* L. A. Renecker & R. J. Hudson (eds.). *Wildlife Production: Conservation and sustainable development.* AFES misc. pub. 91-6, University of Alaska, Fairbanks, USA, pp. 538-542.

Mielgaard, M., Civille, G. V. & Carr, B. T. 1999. *Sensory evaluation techniques, 3rd ed.* CRC Press New York, USA.

Merchen, N. R. 1988. Digestion, absorption and excretion in ruminants. – *In:* C. D. Church (ed.). *The Ruminant Animal: Digestive Physiology and Nutrition.* Waveland Press, Inc. Long Grove, Illinois, USA.

Moen, R., Pastor, J. & Pastor, A. 1998. A model to predict nutritional requirements for antler growth in moose. – *Alces* 34: 59-74.

Manley, T. R. & Forss, D. A. 1979. Fatty acids of meat lipids from young red deer (*Cervus elaphus*). – *Journal of the Science of Food and Agriculture* 30**:** 927-931.

Moore, K. 2002. *Determining differences of two barley-based diets on body mass and intake rates of pregnant captive reindeer.* Senior thesis. School of Agriculture and Land Resources Managemen, University of Alaska Fairbanks, USA.

Mottram, D. S. 1998. Flavour formation in meat and meat products: a review. – *Food Chemistry* 62: 415-424.

Morressey, P. A., Sheehy, P. J. A., Galvin, K., Kerry, J. P. & Buckley, D. J. 1998. Lipid stability in meat and meat products. – *Meat Science* 49: S73-S86.

National Research Council. 1996. *Nutrient requirements of beef cattle, 7th Revised Edition.* National Academy Press, Washington D.C., USA.

Novaskofski, J., Park, S., Bechtel, P. J. & McKeith, F. K. 1989. Composition of cooked prok chops: Effect of removing subcutaneous fat before cooking. – *Journal of Food Science* 54: 15-17.

Oliveira, A. C. M. & Becthel, P. J. 2006. Lipid analysis of fillet from Giant Grenadier (*Albatrossia pectoralis*), Arrow Tooth Flounder (*Atherestes stomias*), Pacific Cod (*Gadus macrocephalus*) and Walleye Pollock (*Theragra chalcogramma*). – *Journal of Muscle Foods* 17: 20-33.

Oliveira, A. C. M. & Becthel, P. J. 2006. Protein and lipid composition of walleye pollock (*Theragra chalcogramma*) livers. – *Journal of Aquatic Food Product Technology* 15: 5-9.

Orskov, E. R., Fraser, C. & Corse, E. L. 1970. The effect on protein utilization of feeding different protein supplements via the rumen or via the abomasums in young growing sheep. – *British Journal of Nutrition* 24: 803-809.

Oldham, J. D., Napper, D. J., Smith, T. & Fulford, R. J. 1985. Performance of dairy cows offered isonitrogenous diets containing urea and fishmeal in early and midlactation. – *British Journal of Nutrition* 53: 337-345.

Rincker, P. J., Bechtel, P. J., Finstad, G., van Buuren, R. G. C., Killefer, J. & McKeith, F. K. 2006. Similarities and differences in composition and selected sensory attributes of reindeer, caribou and beef. – *Journal of Muscle Foods* 17: 65-78.

Ryg, M. & Jacobsen, E. 1982. Seasonal changes in growth rate, feed intake, growth hormone, and thyroid hormones in young male reindeer (*Rangifer tarandus tarandus*). – *Canadian Journal of Zoology* 60: 15-23.

Sampels, S., Pickova, J. & Wiklund, E. 2004. Fatty acids, antioxidants and oxidation stability of processed reindeer meat. – *Meat Science* 67: 523-532.

Sampels, S., Pickova, J. & Wiklund, E. 2005. Influence of production system, age and sex on carcass parameters and some biochemical characteristics of reindeer (*Rangifer tarandus tarandus* L) meat. – *Rangifer* 25: 85-96.

Sampels, S., Wiklund, E. & Pickova, J. 2006. Influence of diet on fatty acids and tocopherols in *M. longissimus dorsi* from reindeer. – *Lipids* 41: 463-472.

SAS Institute. 2003. *SAS System for Windows, release 9.1.* Cary NC: SAS Institute Inc.

SPSS Inc. 1997. *Systat 7.0: Statistics.* Chicago, Illinois. 751 pp.

Suttie, J. M. & Webster, J. R. 1995. Extreme seasonal growth in Arctic deer: comparisons and control mechanisms. – *American Zoology* 35: 215-221.

Taugbøl, O. & Mathiesen, S. D. 1999. Nutrient dependent composition of polyunsaturated fatty acids in *M. psoas minor* from reindeer. – *In*: R. E. Haugerud (ed.). Abstracts,

10th Arctic Ungulate Conference, University of Tromsø, Norway. – *Rangifer* Report No. 4: 55.

Taylor, R. L. 1985. Barley breeding in Alaska. – *Agroborealis* 2: 5-8.

Tilley, J. M. A. & Terry, R. A. 1963. A two stage technique for the in vitro digestion of forage crops. – *Journal of the British Grassland Society* 18: 104-111.

US Department of Agriculture. 2002. Nutritive values of foods. – *In:* S. E. Gebhardt & R. G. Thomas (eds.). *Home and garden bulletin*, Agricultural Research Service, Nutrient Data Laboratory, Beltsville, MD, USA, pp. 56-59.

Vogel, K. P., Pedersen, J. F. & Masterson, S. D. 1999. Toy JJ, Evaluation of a filter bag system for NDF, ADF, and IVDMD for analysis. – *Crop Science* 39: 276-279.

Wachira, A. M., Sinclair, L. A., Wilkinson, R. G., Demirel, G., Enser, M. & Wood, J. D. 1999. The effect of fat source and breed on the fatty acid composition of lamb muscle and adipose tissue. – *In: Proceedings British Society of Animal Science, Scarborough, UK*, p. 115.

White, R. G. 1992. Nutrition in relation to season, lactation, and growth of north temperate deer. – *In:* R. D. Brown (ed.). *The Biology of Deer.* Springer-Verlag, New York, USA, pp. 407-417.

Whitsett, J. F., Kennish, J. M., Kramer, D. E. & French, J. S. 1986. Fish oil analysis using combined thin-layer chromatography and flame ionization detection (TLC-FID). – *In: Proceedings International Symposium University of Alaska Sea Grant College Program, Fairbanks, Alaska, USA*, pp. 161-174.

Wiklund, E., Andersson, A., Malmfors, G. & Lundström, K. 1996. Muscle glycogen levels and blood metabolites in reindeer (*Rangifer tarandus tarandus* L) after transport and lairage. – *Meat Science* 42: 133-144.

Wiklund, E., Barnier, V. M. H., Smulders, F. J. M., Lundström, K. & Malmfors, G. 1997. Proteolysis and tenderisation in reindeer (*Rangifer tarandus tarandus* L) bull longissimus thoracis muscle of various ultimate pH. – *Meat Science* 46: 33-43.

Wiklund, E., Johansson, L. & Malmfors, G. 2003a. Sensory meat quality, ultimate pH values, blood parameters and carcass characteristics in reindeer (*Rangifer tarandus tarandus* L) grazed on natural pastures or fed a commercial feed mixture. – *Food Quality and Preference* 14: 573-581.

Wiklund, E., Manley, T. R., Littlejohn, R. P. & Stevenson-Barry, J. M. 2003b. Fatty acid composition and sensory quality of *M. longissimus* and carcass parameters in red deer (*Cervus elaphus*) grazed on natural pasture or fed a commercial feed mixture. – *Journal of the Science of Food and Agriculture* 83: 419-424.

Wiklund, E., Nilsson, A. & Åhman, B. 2000. Sensory meat quality, ultimate pH values, blood metabolites and carcass parameters in reindeer (*Rangifer tarandus tarandus* L) fed various diets. – *Rangifer* 20:9-16.

Wiklund, E., Pickova, J., Sampels, S. & Lundström, K. 2001. Fatty acid composition in *M. longissimus lumborum*, ultimate muscle pH values and carcass parameters in reindeer (*Rangifer tarandus tarandus* L) grazed on natural pasture or fed a commercial feed mixture. – *Meat Science* 58: 293-298.

Wood, J. D. & Enser, M. 1997. Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. – *British Journal of Nutrition* 78: S49-S60.

Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., Sheard, P. R. & Enser, M. 2003. Effects of fatty acids on meat quality: a review. – *Meat Science* 66: 21-32.

Wooding, F. J. & Knight, C. W. 1973. Barley yields on summer-fallowed and stubble land. – *Agroborealis* 5: 22.

Manuscript received 27 October, 2006
revision received 28 April, 2007
accepted 30 April, 2007

Utfodring av ren med soja- eller fiskmjöl - effekter på tillväxt, foderutnyttjande och köttkvalitet

Abstract in Swedish / Sammanfattning: I vår undersökning ingick 14 renar (8 kastrerade sarvar (härkar)och 6 vajor) för att jämföra effekter av två olika renfoder (baserade på korn, hö och soja- (SBM) eller fiskmjöl (WFM) som proteintillskott) med avseende på tillväxt, foderutnyttjande och köttkvalitet. Köttprover från naturbetande renar (n=4; 2 härkar och 2 vajor) från Seward Peninsula inkluderades i studien för att representera kvaliteten på traditionellt producerat renkött från Alaska. Inga signifikanta skillnader i tillväxt observerades, varken mellan SBM- och WFM-grupperna eller mellan härkar och vajor. Foderutnyttjandet var dock signifikant bättre hos WFM-renarna. Slaktutbytet var högst för renarna i SBM-gruppen, däremot rapporterades inga skillnader i levandevikt, slaktkroppsegenskaper, pH-värde och temperatur i ytterfilén, skärmotstånd, färg eller vattenhållande förmåga i köttet när de tre grupperna av renar jämfördes (SBM, WFM och naturbetande djur). Köttet från de naturbetande renarna hade det signifikant högsta innehållet av både omega-3-fettsyror och av fleromättade fettsyror. Kött från SBM-renarna hade det högsta innehållet av triglycerider och det lägsta innehållet av fosfolipider jämfört med de andra två grupperna. Den tränade smakpanelen kunde inte hitta några skillnader i sensoriska egenskaper hos köttet från renarna i de tre olika grupperna. I en konsumentundersökning rapporterades kommentarer om olika ”vilt-relaterade” bismaker i kött från naturbetande renar (24% av konsumenterna) och från WFM-gruppen (15% av konsumenterna), men inga ”fisk-liknande” bismaker i köttet kunde påvisas. Att byta ut sojamjöl mot fiskmjöl som proteintillskott i renfoder hade inga negativa effekter på renarnas tillväxt, foderutnyttjande eller på renköttets kvalitet.