



Product Yield and Fatty Acid Content of North Dakota Mule Deer, Elk, and Moose

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Abstract: The objective of this study was to determine and document proportion of edible lean from harvested big game species (mule deer, elk, and moose), analyze nutritive value of *longissimus muscle* (LM) tissue, and discuss the implications of shot damage on loss of edible lean. Twenty-nine mule deer (*Odocoileus hemionus*; MUL), 22 moose (*Alces alces*), and 21 elk (*Cervus canadensis*) were harvested from the field and processed at the North Dakota State University Meat Science Laboratory. Fatty acid analysis was conducted for each species. Field harvested animal yield data were collected and compared across species to include edible lean availability and tissue loss (trimming) associated with bullet damage (shot loss). Larger species had heavier whole body (WB), field dressed (FD), carcass (CARC), and lean (LN) yield, whereas the smaller species (MUL) had the highest FD expressed as a percentage of WB (77.19%). Shot loss expressed as a percentage of total lean tissue was greatest for elk (16.59%, $P = 0.02$), then MUL (13.24%), and moose (12.32%). The most edible lean (332.53 kg) was obtained from moose whereas MUL tended to yield more lean as a percentage of WB (42.07%, $P = 0.06$). Moose had the least crude fat on a DM basis, the least total kcals/100 g of loin sample, and least total cholesterol (mg/100 g of loin sample). Mule deer and elk exhibited a greater percentage of oleic acid (24.1 and 29.7%, respectively, expressed as a percentage of LM crude fat content) than moose (14.5%, $P < 0.01$). Mule deer had the highest stearic acid content (24.7%) compared to elk (12.83%) and moose (21.62%). This research found that elk and MUL have more desirable MUFA and SFA of total fat content than moose which possess the highest lean yield percentage.

Keywords: consumer, hunting, nutritional analysis, wild game

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Introduction

Hunting provides opportunities for procurement of a variety of muscle foods. Different species provides the hunter with a different pursuit challenge that culminates with the harvest of game meat which provides an alternative source of protein that possesses a unique flavor profile. The average and range of live weights are readily available for many species of wild game; however, there are few documented sources reporting the edible, whole-muscle yield of many species harvested by hunters (Goguen et al., 2018; Kay, 1970; Kudrnáčová et al., 2018; Serrano et al., 2019). Further, information on the extent of shot loss (loss of

edible tissue as a result of bullet damage) and ante-mortem stress in wild game is limited. Hoffman and Wiklund (2006) indicated that wild harvested, free range game are being imported into Europe and the United States from South Africa to fill the desire for consumers seeking low impact production-sourced, high quality protein foods. Cordain et al. (2002) went so far as to suggest that the progression of chronic disease in human populations was a result of an evolutionary decline in the consumption of lean and fat tissue from wild grazing ruminants, in favor of commercial industrial animal farming. Finally, the harvest of game animals is an important tool in conservation and serves as a means for promoting animal biodiversity (Goguen et al., 2018).

Hoffman and Wiklund (2006) suggested that consumers perceive lean tissue produced by free roaming animals as nutritionally superior to meat from animals raised under intensive management conditions. However, there are limited data available to consumers that would allow for side-by-side comparisons of wild vs. domesticated meat species (Kudrnáčová et al., 2018). Previous research (Marchello et al., 1985) on the cutability and nutrient content of North Dakota whitetail deer is available, yet data from other large game species were not included. Furthermore, information on the extent of shot loss due to bullet damage in field harvested wild game is limited. The objective of this study was to determine and document proportion of edible lean from harvested big game species (mule deer [MUL], elk, and moose), analyze nutritive value, and discuss the implications of shot loss of edible lean.

Materials and Methods

Harvesting process

Hunters, in collaboration with wildlife clubs and the North Dakota Game and Fish Department, were recruited to deliver their field harvested game animals to the North Dakota State University (NDSU; Fargo, ND) meat laboratory for processing. Twenty-nine MUL, 32 moose, and 21 elk were received for analysis. The animals were harvested using bow, rifle, or muzzleloader as regulated by the North Dakota Game and Fish licensing laws. Hunters were provided with a contractor grade, heavy duty plastic bag to retain the entrails to accompany the field dressed carcass to the NDSU meat laboratory.

Lean processing

All carcasses were field dressed (FD; viscera and blood removed) by the licensed hunter. Field dressed carcasses and the entrails were weighed and recorded at the NDSU meat laboratory. The summation of FD and entrails served as whole body weight (WB) and was used in place of live weight due to the inability of methods to account for blood loss in the field. Carcasses were skinned (CARC) and weighed, then lean tissue (LN) was separated and weighed. The progression of cutout weights obtained were WB, FD, CARC, LN, and shot loss (SHOT; weight of tissue discarded due to bullet damage or other causes which rendered the lean inedible). Differences in post-harvest carcass dehydration (shrink) were considered random.

The carcasses were kept in a 3°C cooler until processing (1 to 3 d). The boneless lean was denuded of visible fat and processed into portions according to the hunter's specification. One *longissimus* muscle (LM) sample (approx. 454 g) was taken adjacent the 12th and 13th thoracic vertebra from each carcass for proximate analysis. Each individual muscle sample was frozen, lyophilized, and stored at -18°C.

Proximate analysis

Longissimus samples were trimmed of excess fat thoroughly homogenized and pulverized in a food processor (Cuisinart, East Windsor, NJ) and stored at -20°C. Dry matter was determined on lyophilized samples by oven drying at 105°C, protein was determined by the macro-Kjeldahl method (Kjeldahl, 1883) and the total fat content by the Foss-Let procedure (AOAC, 1980) whereby total lipids were extracted gravimetrically with chloroform-methanol mixture (2:1) as described by Folch et al. (1957). Gross energy was determined by bomb calorimetry as described in the Parr 1241 Oxygen Bomb Calorimeter Manual (Parr Instrument Company, Moline, IL). Cholesterol from lipid extracts was analyzed by an acetic anhydride-sulfuric acid colorimetric method (Stadtman, 1957). A portion of each lyophilized *longissimus* sample was sent to the USDA Grand Forks Human Nutrition Research Center (Grand Forks ND) for fatty acid analysis based on AOAC #996.06.

Statistical analysis

Data were analyzed as a completely randomized design using the mixed procedure in SAS (v. 9.2, SAS Inst. Inc., Cary, NC). The fixed effects included MUL, moose, and elk with harvest data (WB, FD, CARC, LN, and SHOT) as dependent variables, and nutrient composition moisture, protein, fat, ash, energy, cholesterol, and fatty acid) as random variables. The least squared means (LSMEAN) were calculated using the LSMEANS statement and differences were defined at $P < 0.05$.

Results

Hunter harvest and yield data

Carcass yield and percentages are presented in Table 1. The 3 species evaluated in the present study significantly differed ($P < 0.001$) from each another in

Table 1. Least square means (\pm SE) and *P*-value for processing yield of mule deer, elk, and moose harvested in North Dakota

Item	Mule deer (<i>Odocoileus hemionus</i>)	Elk (<i>Cervus canadensis</i>)	Moose (<i>Alces alces</i>)	<i>P</i> -value
No. harvested	29	21	22	
Whole body (WB), kg	63.35 (\pm 9.37) ^a	238.92 (\pm 13.24) ^b	410.95 (\pm 9.61) ^c	< 0.001
Field dressed (FD), kg	48.51 (\pm 6.94) ^a	176.52 (\pm 9.82) ^b	302.22 (\pm 6.94) ^c	< 0.001
FD/WB, %	77.19 (\pm 2.03)	73.76 (\pm 2.88)	74.79 (\pm 2.08)	0.41
Skinned carcass (CARC), kg	40.53 (\pm 5.12) ^a	141.94 (\pm 7.24) ^b	226.06 (\pm 5.12) ^c	< 0.001
CARC/WB, %	64.44 (\pm 1.68) ^b	59.35 (\pm 2.38) ^{ab}	56.05 (\pm 1.72) ^a	0.04
CARC/FD, %	83.39 (\pm 0.51) ^c	80.48 (\pm 0.72) ^b	75.07 (\pm 0.51) ^a	< 0.001
Hide, kg	11.22 (\pm 4.21) ^b	28.57 (\pm 13.34) ^a	39.42 (\pm 24.09) ^c	< 0.001
Lean yield (LN), kg	26.44 (\pm 8.03) ^a	95.24 (\pm 11.35) ^b	150.83 (\pm 8.03) ^c	< 0.001
LN/WB, %	42.07 (\pm 1.64)	39.99 (\pm 2.32)	37.65 (\pm 1.68)	0.06
LN/FD, %	54.21 (\pm 1.89) ^b	54.19 (\pm 1.89) ^b	50.32 (\pm 1.33) ^a	0.04
LN/CARC, %	64.98 (\pm 1.68)	67.37 (\pm 2.37)	67.01 (\pm 1.68)	0.41
Shot loss (SHOT), kg	3.27 (\pm 1.44) ^a	14.69 (\pm 2.04) ^b	18.57 (\pm 1.44) ^c	0.02
SHOT/LN, %	13.24 (\pm 1.71) ^b	16.59 (\pm 2.42) ^c	12.32 (\pm 1.71) ^a	0.02

^{a-c}Means within a row with different superscripts differ by *P* < 0.05.

WB, FD, hide weight, LN, and SHOT in the order of moose, elk, and MUL (heaviest to lightest, kg). Moose produced the greatest proportion of lean tissue lost as shot loss (SHOT/LN), followed by MUL, and elk with the least. The lightweight MUL yielded a greater percentage of CARC/WB than moose (elk did not differ from MUL or moose; *P* = 0.04) and greater percentage of CARC/FD than both elk and moose (*P* < 0.001). Edible lean yield expressed as a percentage of WB or CARC did not differ across species. Mule deer and elk had a greater percentage of LN/FD than moose.

Wild game nutrient analysis and composition

The LSMEANS for nutrient content (\pm SE) of the trimmed LM are presented in Table 2. The LM from MUL deer had a greater percentage protein than LM from moose and elk (*P* < 0.001). The 3 species differed from each other in content of crude fat and kcal/100 g of meat sample (*P* < 0.013) with MUL possessing the greatest percentage of fat and energy, whereas elk and moose did not differ. Mule deer possessed greater content of cholesterol/100 g of meat sample (*P* < 0.001), followed by elk, then moose. With regard to saturated fatty acids, elk had the highest percentage of myristic (14:0; followed by MUL then moose) and palmitic acid (16:0; followed by moose and MUL which did not differ), yet the lowest content of stearic acid (18:0) followed by moose, then MUL. With regard to mono-unsaturated fats, elk possessed a greater content of myristoleic (14:1) and palmitoleic acid (16:1) than MUL or moose which did not differ. That said, elk had

the lowest concentration of oleic acid (18:1)/100 g of muscle, which differed from MUL (highest 18:1 concentration) and moose. Each species differed from the other for LM content of poly-unsaturated fatty acids with moose possessing the greatest percentage of linoleic (18:2) and arachidonic acid (20:4), which differed from elk, which differed from MUL. Mule deer had a greater content of α -linolenic acid (ALA; 18:3) than elk and moose which did not differ.

Discussion

North Dakota processors of wild game recognize that game meat is an important source of animal protein (D. Reed Jr., unpublished data, 2019). Consumers like to know where their food comes from and are most concerned about food safety (Berg, 2015). Social food movements and concern for sustainability in agriculture have piqued the concerns of consumers and spurred food retailers to seek avenues for the creation of locally grown niche markets (Lafave, 2013). Improving the availability of locally obtained meat products (Tidball et al., 2013) is becoming increasingly important to the current generation of consumers that appear to be more interested in the story behind the food than they are the cost of the food (Low et al., 2015). Wild game is fabricated by local processors who appeal to the local clientele because they are more likely to form a personal relationship with that local processor.

Game meat is an alternative source of animal protein. All 3 species represented in this study had over

Table 2. Least square means (\pm SE) for nutrient analysis and fatty acid composition of trimmed *longissimus* muscle (LM) of mule deer, elk, and moose harvested in North Dakota

Item	Mule deer (<i>Odocoileus hemionus</i>)	Elk (<i>Cervus canadensis</i>)	Moose (<i>Alces alces</i>)	P-value
No. harvested	29	21	22	
Proximate analysis				
Moisture, %	73.41 (0.26) ^a	74.43 (0.31) ^a	75.85 (0.25) ^b	< 0.001
Crude protein, %	23.22 (0.23) ^a	22.99 (0.27) ^a	22.11 (0.21) ^a	< 0.013
Crude fat (CF), %	1.60 (0.11) ^c	1.03 (0.13) ^b	0.59 (0.11) ^a	< 0.013
Ash, %	1.10 (0.04) ^a	1.24 (0.04) ^b	1.13 (0.03) ^a	< 0.05
Cholesterol, mg/100 g	87.13 (4.64) ^c	60.27 (5.46) ^a	61.71 (4.42) ^b	< 0.001
Energy, kcal/100 g	150.78 (1.86) ^a	143.10 (2.19) ^b	132.81 (1.77) ^c	< 0.001
Fatty acid				
Myristic acid (14:0)				
CF, %	1.56 (0.16) ^b	4.95 (0.20) ^b	0.48 (0.15) ^a	< 0.001
LM, mg/100 g	24.96	50.99	2.88	
Myristoleic acid (14:1)				
CF, %	0.15 (0.06) ^a	1.72 (0.08) ^b	0.19 (0.06) ^a	< 0.001
LM, mg/100 g	2.40	17.72	1.14	
Palmitic acid (16:0)				
CF, %	21.28 (1.07) ^b	26.68 (1.35) ^c	14.79 (1.01) ^a	< 0.001
LM, mg/100 g	340.48	274.80	88.74	
Palmitoleic acid (16:1)				
CF, %	1.77 (0.35) ^b	10.21 (0.45) ^c	1.11 (0.34) ^a	< 0.001
LM, mg/100 g	28.32	105.16	6.66	
Stearic acid (18:0)				
CF, %	24.76 (0.50) ^c	12.83 (0.64) ^a	21.62 (0.48) ^b	< 0.001
LM, mg/100 g	396.16	132.15	129.72	
Oleic acid (18:1)				
CF, %	29.79 (1.17) ^c	14.52 (1.49) ^a	24.18 (1.11) ^b	< 0.001
LM, mg/100 g	476.64	149.56	145.08	
Linoleic acid (18:2)				
CF, %	11.64 (1.61) ^a	18.99 (2.05) ^b	23.34 (1.53) ^c	< 0.001
LM, mg/100 g	186.24	195.60	140.04	
Alpha-Linolenic (18:3)				
CF, %	4.40 (0.27) ^b	3.15 (0.34) ^a	3.72 (0.25) ^a	0.005
LM, mg/100 g	70.40	32.45	22.32	
Arachidonic acid (20:4)				
CF, %	4.15 (0.64) ^a	6.72 (0.81) ^b	10.61 (0.61) ^c	0.01
LM, mg/100 g	66.40	69.22	63.66	
Total saturated fatty acids				
CF, %	47.6 (0.09) ^c	44.46 (0.30) ^b	36.89 (0.73) ^a	< 0.001
LM, mg/100 g	761.60	457.94	221.34	
Total unsaturated fatty acids				
CF, %	51.8 (1.05) ^a	55.31 (0.59) ^b	63.15 (1.23) ^c	0.042
LM, mg/100 g	828.80	569.69	378.90	

^{a-c}Means within a row with different superscripts differ by $P < 0.05$.

22 g protein/100 g of lean tissue. In 2017, ND hunters harvested a total of 2,101 MUL, 221 moose, and 211 elk. Calculating the average weight of bulls and cows and adding the percent of edible lean, North Dakota averaged 28,682 kg for MUL, 23,571 kg moose, and 13,648 kg elk. The Dietary Reference Intake (Institute

of Medicine of the National Academies of Science) suggests males 19 to 70 yr of age should consume 56 g/d of protein and females ages 14 to 70 yr consume 46 g/d (0.8 g/kg of body weight; US Department of Health and Human Services). Based on these numbers, the amount of edible product generated from the har-

vest of MUL in ND could provide the average recommended daily allowance of high quality protein to 1,000 mature American women for 623 d and 1,000 American men for 512 d. Likewise, the ND elk and moose harvest could feed 1,000 American men for 665 d.

All 3 species are a very lean source of protein that possess less than 2 g fat/100 g lean sample. Total cholesterol closely paralleled the total crude fat content present in loin tissue. Moose had the least proportion of saturated fat and most unsaturated when expressed as a percentage of total crude fat. Recent studies by Smith (2016) reported that individuals who consumed ground beef that possessed a greater content of oleic acid were linked to favorable high-density lipoprotein (HDL; the so-called “good” cholesterol) profile in both men and women.

Mule deer had the greatest concentration of oleic acid; elk the lowest. A project conducted by Japanese restaurants evaluating wagyu beef consumers noticed that an increase in marbling did not generate a greasy mouth feel, but rather was described as “melt in the mouth beef” that possessed a pleasant taste (Torigoe, 2009) concluded that the key to succulent palatability was associated with the high percentage of oleic acid present in the intramuscular fat. Further, the “melt in the mouth” palatability trait increased as the content of oleic acid increased in the beef. This impact of oleic acid on palatability perception may not be as pronounced in low-fat meats such as those evaluated in the present study. Although the exact geographic location and the agriculture landscape is not known for each game animal harvested, North Dakota MUL habitat is often in closer proximity to land used for crop production. Therefore, the increased content of oleic acid seen in the MUL population of this study could have been consuming more corn. Corn and other conventionally farmed grains contain a greater proportion of oleic acid than grasses and forages traditionally consumed by game species who live in the upper Great Plains. The habitat for North Dakota moose and elk is traditionally more remote and further removed from land used for crop production. Increased sightings of moose and elk in areas of greater crop production could result in a change in the meat palatability characteristics of these species of game. As human farming moves closer to elk and moose grazing areas, it is likely that the oleic acid content will increase in the edible lean. Future research should be performed on the sensory characteristics of wild game meat compared to farm-raised game that are fed in a manner similar to other domesticated meat-animal species.

Mule deer also had the greatest linolenic acid content which could be due to an increased consumption of grass and not grain. The main fatty acid produced as a result of

a grass diet is linolenic acid and it can give an off-flavor to meat and has been seen to cause beef to taste fishy (Prieto et al., 2017). Grass fed ruminants generate greater levels of linolenic acid. Only when concentrations of α -linolenic acid (18:3) approach 3% of neutral lipids or phospholipids are there any adverse effects on meat quality, defined in terms of shelf life (lipid and myoglobin oxidation) and flavor (Wood et al., 2004). The ALA content of LM obtained from MUL was 4.4% of the total extracted CF in the present study. At these levels, the ALA content of the lean tissue could result in the production of a “fishy” off-flavor (Arshad et al., 2018). That said, the LM from MUL also had the greatest content of oleic acid (29.8% CF) which has been linked to desirable meat flavor; particularly in beef (Torigoe, 2009). It is beyond the scope of this research to speculate if the level of oleic acid in LM from MUL can offset the potential detrimental influence of ALA. Future research should examine the influence of fatty acid content of game meat on meat palatability.

The NIH (2019) recommends an “adequate intake” of omega-3 fatty acids to be 1.6 and 1.1 g/d for males and females ages 14 and older. In the current study, 100 g of LM from MUL would provide the greatest amount of ALA at 70.4 mg, with elk and moose providing less (Table 2). With the small amount of fat present in the tissue of the LM samples in the present study, it is unlikely that consumption of nominal amounts of these species would result in improved health benefits associated with omega-3 fatty acids (Shahidi and Ambigaipalan, 2018).

We can conclude from these findings that game meat is an excellent source of high quality, low-fat dietary protein that may appeal to consumer’s seeking more locally obtained foods.

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