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The Evaluation of Meat Yield and Quality in Elk (Year 2)

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Introduction

A research project and subsequent report completed last year provided new information on carcass and venison quality of elk ranging in age from 2 to 4 years (Robertson *et al.*, 2000). A modified temperature conditioning (MTC) treatment, in which carcass sides were held at $6^{o}C$ for 24 h post-mortem, was demonstrated to be beneficial in improving tenderness of grilled elk steaks, and improved muscle color without increasing weight losses during chilling or drip losses of retail-packaged steaks. Some preliminary investigations into the use of simple carcass measurements to predict carcass meat yield for classification purposes was also undertaken during that study.

The current study is a logical extension of the previous year's work, developing a larger database and, consequently, more reliable information on composition of elk carcasses, and of methods to estimate carcass composition. Additional goals were to confirm the effects of modified temperature conditioning of elk carcasses on venison quality, and to examine the effect on tenderness of cooking venison from the fresh state or from previously frozen and thawed product.

Executive Summary

1. A total of sixty bulls aged 2 to 4 years were cut out. Yield of total cuts averaged 29.4% and ranged from 25.9% to 33.3%. This range would represent about 15 kg of valuable cuts in an average elk carcass weighing approximately 200 kg. With stew meat and 85% lean trim added in, total meat yield averaged 75.65 and ranged from 70.0% to 78.5%. Readily dissected fat in the carcass ranged from 3.4% to 14.5%. A cut out chart giving means and ranges for individual cuts and other carcass components is provided (Table 7).

2. Yield of total cuts from carcasses of 4 year old animals was 2% lower than from 2 or 3 year old animals, but the older animals had higher amounts of 85% lean trim, with the result total meat yield was the same for all ages.

3. Simple carcass measurements were investigated for prediction of yields of cuts or total meat yield. Total meat yield (R^2=0.64) was more readily predicted than yield of cuts (R^2=0.38).

4. For animals aged 2 to 4 years, muscle pH, color and water holding properties were not affected by age. However, rib eye steaks from 2-year old animals had higher shear values (tougher) than steaks from 3 or 4-year old animals.

5. Rib eye steaks derived from carcasses of 8 to 12-year old cows (n=4) were found to be as tender as those from 3 and 4-year old bulls, and more tender compared to 2-year old bulls. Muscle color of the cull cows was darker compared to the younger animals, but 24 h pH of the muscle was not indicative of the dark cutting condition.

6. Moderate high temperature conditioning of carcass sides (5-6^{o}C) reduced shear values of rib eye steaks by an average of 16% compared to steaks derived from conventionally chilled sides (1-2^{o}C), confirming results of the previous trial. In 50%

of the side to side comparisons, shear values were reduced by more than 1 kg, above which untrained consumers would readily detect differences in tenderness. Regulatory implications of modified temperature chilling are discussed.

7. Average shear value and within-steak variation was greatly reduced when rib eye steaks were frozen and thawed prior to cooking compared to their counterparts cooked from the fresh state with the same period of aging. For steaks from conventionally chilled sides, the improvement in average shear value was 3 kg (31.6%). A smaller but still very significant improvement was found for steaks derived from the modified temperature conditioned sides: 1.365 kg (20.4%). However, it is not known whether flavor intensity, juiciness and overall palatability would be negatively impacted by freezing and thawing.

Materials and Methods

A total of 46 animals were used in the study, slaughtered over three kill dates: August 1, 7 and 20. The ages and sex of the study animals were as follows: six 2-year old bulls, thirty 3-year old bulls, five 4-year old bulls, one 8-year old bull, two 8-year old cows, one 9-year old cow and one 12-year old cow. All but three of the animals originated from a single source. All animals from the previous year's study were 2 to 4 years of age and were all bulls (26 total). Carcass data was combined over the two years (2 to 4 year old bulls only). Cut out information was not obtained on all carcasses in the second year so the number of carcasses in the combined data set is 60.

Most procedures were identical to the previous year. Animals were shipped the morning of slaughter and held in specially designed pens until dispatched by captive bolt pistol. A final live weight was obtained immediately prior to slaughter of the animal. Carcass side weights were recorded following dressing of the carcass. Alternating between left and right sides, carcass sides were assigned to conventional chilling (CC) at 1 – 2^{o}C or a moderate high temperature conditioning (MTC) treatment at 5 to 6^{o}C.

Muscle pH and temperature was measured at 50 min post-mortem in the loin eye (longissimus lumborum, LL) at the 1st lumbar vertebra. The pH and temperature measurements were made by insertion of a spear type electrode and stainless steel thermocouple through the overlaying silverskin. Temperature loggers were used to track temperature decline at the center of the LL and the deep hip in five CC sides and five MTC sides over the three kills.

Following chilling the carcass sides were knife-ribbed between the 12th and 13th ribs. Muscle color was measured on the exposed face of the rib eye muscle (longissimus thoracis, LT) at the 12th rib after a 20 min bloom period using a Minolta CR300 reflectance meter. CIE L*, a* and b* values were recorded. Hue and chroma (saturation) were calculated using the a* and b* values. Three fat thickness measurements were made of the subcutaneous fat over the rib eye at the ¼, ½ and ¾ positions, and averaged. The minimum thickness of fat in the 4th quadrant (distal to the chine bone) was also recorded. The rib eye area was measured using a transparent grid ruled in 1 cm squares and a GR measurement was made (total tissue depth 7 cm from the end of the rib eye). Finally, muscle pH and temperature measurements were made by insertion of the electrode and thermocouple in the exposed face of the LT.

Carcass sides were re-weighed to determine loss due to evaporation and drip during cooling. The CC sides were cut out to determine yield of cuts and total meat yield. Total meat yield is the sum of cuts plus the weight of stew meat and 85% lean trim. A 15 to 18 cm portion of the LT anterior to the 12th rib was collected from both CC and MTC sides, vacuum packaged and aged to provide a total aging period of 7 d. Following aging, a 20 mm thick steak was cut from the 12th rib end, weighed, placed on an absorbent pad in a retail display tray and over-wrapped with oxygen-permeable film. The steak was held for 5 d at 4^{o}C, blotted dry and re-weighed to determine drip loss. A second steak was fabricated from the area of the 10-11th rib for determination of shear values from fresh venison. Two additional, adjacent steaks were fabricated, vacuum packaged and frozen at –25^{o}C for subsequent determination of shear value from previously frozen and thawed venison. (Note: Shear values were obtained from previously frozen and thawed steaks in the previous trial).

Shear values

All steaks were grilled on a Garland grill (Model ED30B, Condon Barr Food Equipment Ltd., Edmonton, AB). Temperature at the center of the steaks was monitored using spear tip thermocouples connected to a data logger. The steaks were cooked on one side to 35^{o}C, turned and cooked to 67^{o}C. An ice/water bath was used to arrest the cooking process, and then the steaks were held overnight at 4^{o}C. Three cores of 19 mm diameter were removed from each steak parallel to the muscle fibers. The cores were sheared at right angles to the muscle fibers in a Warner-Bratzler shear cell attached to an Instron Materials Testing System. Crosshead speed was 200 mm/min. The peak shear force required to shear through the cores was recorded. For the determination of effect of MTC on tenderness, both frozen and thawed steaks were used in the statistical analyses (total of six cores per sample). To determine the effect of freezing and thawing on tenderness, the shear values obtained from the fresh steak were compared to those of the adjacent frozen/thawed steak (three cores per sample).

Results and Discussion

Effect of animal age on carcass characteristics

Because of the limited number of older animals, and complications in the statistical analyses of including sex and sex*year, the principal analyses of carcass characteristics included only the 2, 3 and 4 year old bulls from both years. Information on the 8 to 12 year old cows is presented for comparative purposes (Appendix 1), but no statistical comparisons are provided. The effect of animal age on carcass characteristics for the 2-year combined data (Tables 1 & 2) mirror the results of the previous year. Four-year old animals had heavier live and carcass weights compared to 2 and 3-year old animals. Hot carcass yield expressed as a percentage of final (shrunk) live weight was also greater in the older animals. Rib eye area, measured at the 12th rib, and fat cover over the rib eye muscle increased with age. However, at any age, fat cover over the rib eye and loin muscle was thin, averaging 1 to 3 mm in thickness. The principle fat depots for more highly conditioned animals were observed to be intermuscular fat deposited in the rib cage, and thick deposits of subcutaneous fat over the tail head (Figures 6 & 7).

The proportion of bone in the carcass decreases, and readily dissected fat tends to increase with animal age (Table 2). Although there are some statistically significant differences in individual cuts expressed as a proportion of carcass side weight, they are not of great practical consequence. However, there was a 2% reduction in the proportion of total valuable cuts in 4-year old bulls compared to 2 and 3 year olds. This difference was essentially reversed for trim (85% lean), with the result that there were no significant differences in total meat yield. Among all animals, readily dissected fat ranged from a low of 3½% to 14½% (Table 7).

Effect of animal age on meat quality traits

There were no differences noted for muscle pH, color or water holding properties (drip loss) attributable to animal age in the current study for animals aged 2 to 4 years (Table 3). In the previous trial, 4-year old animals produced meat which was slightly darker than younger animals, but the difference in L* value was of a magnitude which would not be expected to impact acceptability of the product. As with the previous trial, steaks derived from 2-year old animals were found to be tougher and more variable in tenderness than steaks from 3 and 4-year old animals, as determined by mechanical shearing in a Warner-Bratzler shear cell. This was true whether the steaks were cooked from the fresh state or from previously frozen and thawed samples.

One needs to be cautious in comparing the data of the 8 to 12 year old animals to the rest of the study animals since the trial was not designed to do that. These older animals were of limited number (5), were mainly of opposite sex, and were only represented in the final kill date. Nonetheless, there is a great deal of interest in the elk industry in knowing how the meat quality of older animals, particularly cull cows, would compare to youthful slaughter animals. There is nothing in this trial which would suggest that older elk produce meat of inferior eating quality compared to their younger counterparts. As expected, muscle color was darker (lower L* value) in the older compared to the younger animals. Six of the ten carcass sides from the 8 to 12 year old animals were rated by an experienced evaluator as having very dark rib eye muscle color at the time of grading, compared to two of 82 carcass sides for the 2 to 4 year old animals. However, average 24 h pH of this muscle from these six sides ranged from 5.60 to 5.91 with an overall average of 5.71, below the generally accepted cut off for dark cutting meat of pH 6.0 (Murray, 1995).

Of real significance is the fact shear values of rib eye steaks obtained from the older animals were similar to those of the 3 and 4-year old animals, and lower than shear values of steaks from 2-year old animals. The content and type of connective tissue (collagen) found in red meat are important contributing factors in variation in tenderness. In general, it is recognized there is an inverse relationship between the age of slaughter animals and tenderness of the meat derived from them. This is due, not to an increase in content of connective tissue, but rather to increased intra- and intermolecular cross-linking of collagen polypeptide chains (Lawrie, 1998). With increasing age, collagen becomes less heat soluble and less susceptible to attack by enzymes. Since collagen content or solubility were not determined for the meat samples in this study, it is not known whether or not the unusual findings related to animal age and tenderness in elk is due to low content of connective tissue and/or limited cross-linking of collagen molecules. Also, because taste panels were not part of the study, we don't know the impact of animal age on flavor, juiciness, perceptible connective tissue, and overall acceptability. For future studies it would be worth considering designing the trial to include age effects for all potential ages of slaughter animals and incorporate taste panel analyses to properly investigate the suitability of older, cull animals for venison.

Effect of pre-slaughter Nutri-charge™ treatment on meat quality

Animals in the first two kills (n=34) only were assigned to control or pre-transport Nutri-charge™ treatment groups. There were no differences in any of the measured meat quality parameters including muscle pH, muscle color, drip loss or shear values between control and treated animals (Table 4).

Effect of cooler temperature on carcass shrink and meat quality

One of the primary objectives of the current study was to confirm the positive effects of modified temperature conditioning of the carcass on venison quality, particularly tenderness, which was reported from last year's study. In that study, MTC improved muscle color and average shear values were reduced by 0.9 kg (14%) in conditioned samples compared to control samples. In 42% (11 of 26) of the samples MTC reduced shear values by more than 1 kg, which is the point which untrained consumers would likely detect differences in tenderness (Les Jeremiah, personal communcation). In the current study, as was found in the earlier study, the slower rate of chilling resulted in brighter, more highly saturated muscle color at time of grading, and tended to lower 24 h pH without affecting carcass shrink during chilling, or drip loss of steaks held in retail packages. For previously frozen and thawed samples, the average shear value of steaks obtained from conditioned sides was 0.984 kg (16.0%) lower than that of steaks obtained from the conventionally chilled control sides (Table 5). Shear values were reduced by more than 1 kg in approximately one-half of the side to side comparisons (Figure 1). Within-steak variation among core samples was also significantly lower in the conditioned samples. Therefore the current study has confirmed the efficacy of a moderate high temperature conditioning treatment of elk carcasses for optimizing tenderness. The mechanism of improved tenderness from MTC is likely a combination of reduction in cold shortening of the myofibrils (Locker, 1985; Tornberg, E. 1996) and increased rate and extent of postmortem proteolysis (Koohmaraie, 1996). Given the rather modest difference in temperature decline of the rib eye muscle between CC and MTC sides in the first 10 h post-mortem (Figure 2), it is likely the latter mechanism is of greater impact.

Regulatory aspects of modified temperature chilling

The cooling performance standards for the chilling of red meat carcasses of the Canadian Food Inspection Agency (Anonymous, 2001) are:

1) The cooling of carcasses is continuous.
2) Surface temperature of carcasses is $7^{o}C$ or less within 24 h following the dressing of the carcass.

3) The internal temperature of the warmest part (generally deep hip) of the carcass is 7°C or less before the product is cut.
4) Product temperatures must continue to go down in a continuous manner to 4°C or less.

The first two conditions are readily met by the modified chilling process employed in this study. Figure 3 provides the temperature profiles for the deep hip temperature of five carcasses for both conventionally chilled and modified temperature conditioned sides. Some of the MTC sides monitored did not cool to 7°C by 24 h post-mortem (approximately 23 h post-dressing). Therefore in order to comply with the third requirement for carcass chilling, it is necessary to chill the carcasses longer than 23 h prior to cutting. Either the additional chilling of the carcass would have to be in a lower temperature environment, or the product following cutting would have to be chilled in a manner to reduce the final product temperature to 4°C in a timely fashion. Rooms used for holding or storing carcasses or product following chilling to 4°C must be able to maintain a temperature of 4°C or less.

Effect of cooking fresh or frozen/thawed steaks on tenderness of venison

In the 2000 study, and again in the current study, we have reported average shear values much lower than we obtained in previous trials (unpublished data). We have attributed this in part to improved pre-slaughter handling and lairage, longer aging times, cooking method and a lower end-point temperature to which the steaks were cooked. It was thought a significant portion of the difference was likely due to the fact steaks from the 2000 study were frozen and thawed prior to cooking, while in earlier studies steaks were cooked from the fresh state. Hence a sub-sample of 35 carcasses from 2 to 4 year old bulls from the current trial were used to determine the extent of improvement in shear values which may be gained by cooking previously frozen steaks rather than fresh steaks.

Both average shear value and within-steak variation was greatly reduced when steaks were frozen and thawed prior to cooking compared to their counterparts cooked from the fresh state (Table 6). For steaks derived from conventionally chilled sides, the improvement in average shear value was 3 kg or 31.6%. A smaller but still very significant improvement was found for steaks derived from MTC sides: 1.365 kg or 20.4%. The reduction in shear value obtained by carcass conditioning at 5 – 6^{o}C was also greater in the tougher steaks cooked from the fresh state (30%) compared to the more tender steaks which had been previously frozen (18%). Similarly, Drew *et al.* (1988) found venison samples which had been frozen and thawed were often considerably more tender than non-frozen samples. They reported improvements in tenderness ranging from 10 to 40%.

In the course of our study, it was observed during the shearing of muscle core samples that extremely high maximum loads were recorded when, rather than the blade actually shearing through the muscle fibers, bundles of muscle fibers were pulled up into the shear cell by the blade and were binding between the sides of the shear cell. This phenomenon was generally restricted to the most distal core from the chine bone side of the steak, and was completely eliminated by cooking previously frozen steaks, accounting for some of the very large differences observed in individual cases (Figures 4 and 5).

While some authors have reported no difference in shear force or panel tenderness ratings between fresh and frozen beef (Wheeler *et al.*, 1990), others have demonstrated a beneficial effect of freezing (Whipple and Koohmaraie, 1992; Dugan and Aalhus, 1998). Our results are very comparable to those of Dugan and Aalhus (1998). They reported that freezing and thawing of beef loin steaks reduced shear values, and the reduction in shear value was greater for tough steaks than for tender or moderately tender steaks. The average shear value of tender steaks was improved by 7%, moderately tender steaks by 14% and tough steaks by 49%. The increase in tenderness brought about by freezing may be explained by intrafibrillar ice formation which causes rupture of muscle fibers and rupture and stretching of connective tissue (Whipple and Koohmaraie, 1992). In the case of the elk samples, the ultimate pH was found to be slightly higher (average 24 h pH over both years = 5.70) than typically seen in beef (generally ≅ 5.5), and drip losses of steaks held in retail packages were low. The minimum water-holding capacity of the principle muscle proteins is reached at pH 5.4 to 5.5, the isoelectric point (Lawrie, 1998). The higher pH and low drip loss are, therefore, indicative of a higher water-holding capacity which would lend the samples to ice formation during freezing and the subsequent impact on muscle fibers and connective tissue. In the case of beef, some of the flavor intensity may be sacrificed by freezing, and aging specifications for steaks to be frozen should be sufficiently long to maximize flavor development prior to freezing (Wheeler *et al.*, 1990). Future research for venison should perhaps include taste panel analyses to evaluate the impact of freezing not only on tenderness but also on the other palatability attributes.

Simple carcass measurements and estimation of yield

In comparison to last year's study, some of the animals in the current study (particular in the two early August kills) were fatter, although as indicated the greatest evidence of this was in two fat depots: over the ribs and over the tail head. Consequently, when the data from both years are combined, the result is a data set which has a broader range of carcass characteristics compared to that of the first year. For the larger data set, the range in total cuts (expressed as a percentage of cold side weight) is approximately 7.5%, while total meat yield varies by about 8.5%. For an average carcass weighing 198 kg, then, the yield of valuable cuts could vary as much as 15 kg which at current prices for elk meat represents a very significant difference in value. Clearly, as the elk venison market develops, a yield grading system based on easily obtained carcass measurements will be of substantial benefit to the industry for purposes of settlement between buyer and seller.

The results of the previous trial, although based on a very small number of animals (n=26), showed very good potential for predicting yield of carcass cuts or total meat yield based on ruler measurements of fat cover over the rib eye and total tissue thickness through the rib (GR) combined with warm carcass weight. Selected equations were able to explain approximately 70% of the variation in either yield endpoint. For the combined data set (n=58), total yield was more readily predicted than cut yield. Approximately 65% of variation in total meat yield was explained (R^2 = 0.64) by a regression equation incorporating minimum fat thickness in the fourth quadrant, the GR measurement and warm carcass weight (Table 9). The standard deviation of the difference between predicted and actual total meat yield, which gives an indication of the precision of prediction, was 1.24%. These values can be compared to the prediction of lean yield in beef carcasses, where typically 50 to 58% of the variation in carcass lean content is explained using similar types of measurements, with residual standard deviations of approximately 3% (Jones *et al.*, 1989). Light reflectance probes used for yield grading in the Canadian pork industry typically are able to explain 65 to 77% of variation in pork carcass yield (Tong and Jones, 1994; Fortin *et al.,* 2001).

The best regression equations for prediction of yield of cuts of the elk carcasses from the combined data set was only able to explain 40% of the variation in actual cut yield (Table 8), much lower in accuracy compared to the 70% explained by the best equations obtained from the smaller, first year data set. None of the ruler measurements, alone or in combination, were very useful predictors without warm carcass weight. Rib eye area was not a very useful variable for prediction of either yield endpoint. The differences in results obtained between the smaller data set and the combined data set, illustrate the danger of trying to develop prediction equations from small sample numbers. It will require much larger numbers of animals varying in weight, muscling and fatness to develop robust equations which could be applied confidently.

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Table 1. Effect of animal age on carcass characteristics (combined data from both years – 2, 3 and 4 year old bulls only).

	Age of animal (years)		
	2	3	4
n	11	34	15
Final live wt., kg	301.9*b*	327.8*b*	360.7*a*
Hot carcass wt., kg	177.4*b*	194.6*b*	221.8*a*
HCW, % of final live wt.	58.7*b*	59.3*b*	60.3*a*
Cooler shrink, %	1.65	1.62	1.49
Rib eye area[1], sq. cm.	59.6*b*	62.9*ab*	66.3*a*
Average fat[1], mm	1.2	2.3	2.5
Minimum fat in 4th quadrant[1], mm	1.2*b*	2.5*a*	2.9*a*
GR measurement[1,2], mm	33.5	40.4	41.8

ab Least square means accompanied by different letters are significantly different (P<0.05)

[1] Measurements made at the 12th rib, average of both sides of carcass.

[2] GR measurement is total thickness of tissue at 7 cm from the tip of the rib eye muscle.

Table 2. Effect of animal age on carcass composition, % of side (combined data from both years).

	Age of animal (years)		
	2	3	4
n	11	34	15
Hot carcass wt., kg	177.4*b*	194.6*b*	221.8*a*
2 X 3 Boneless rib	2.98	2.81	2.93
Inside round	4.59*a*	4.59*a*	4.12*b*
Outside round	4.10*ab*	4.26*a*	3.75*b*
Eye of round	1.49	1.50	1.43
Sirloin tip, peeled	4.83*a*	4.73*a*	4.35*b*
1 X 0 Strip loin	3.56	3.64	3.48
Top butt	2.79*ab*	2.92*a*	2.59*b*
Tenderloin, whole	1.52	1.49	1.44
Hind shank meat	1.90*a*	1.87*a*	1.76*b*
Osso buko	2.24	2.08	2.07
Total cuts	29.99*a*	29.90*a*	27.92*b*
Stew meat	9.33	10.80	9.35
85% Lean	35.26*ab*	33.65*b*	37.85*a*
Total meat yield	74.58	74.36	75.11
Readily dissected fat	8.41	9.63	10.15
Bone	16.93*a*	15.76*b*	14.61*c*

abc Least square means accompanied by different letters are significantly different (P<0.05)

Table 3. Effect of animal age on meat quality traits (2001 slaughter).

	Animal age, years[1]			
	2	3	4	8 – 12
n[2]	6	30	5	5
L* (brightness)	28.4*a*	28.5*a*	28.6*a*	27.4*b*
Chroma (saturation)	17.8	18.4	18.7	17.6
Hue angle	20.7	20.9	21.0	21.0
pH initial (50 min)	6.81*a*	6.75*a*	6.71*ab*	6.66*b*
pH (24 h)	5.78	5.72	5.67	5.69
Drip loss in retail package, %	2.46	2.56	2.49	2.34
Warner-Bratzler shear				
Cooked from frozen/thawed:				
Shear value, kg	6.577*a*	5.523*b*	4.921*b*	5.647*ab*
Within-steak variation (stdev)	1.586*a*	0.983*b*	0.917*b*	1.039*b*
Cooked from fresh:				
n[2]	5	26	4	5
Shear value, kg	9.034*a*	7.463*b*	7.807*ab*	6.981*b*
Within-steak variation (stdev)	2.035	1.553	1.526	1.208

[1] 2, 3 and 4 year olds were all bulls, 8 – 12 year olds consisted of one 8-year old bull, two 8-year old cows, one 9-year old cow and one 12-year old cow.
[2] *n* = number of carcasses, data is from both control and modified temperature conditioned sides.

ab Least square means accompanied by different letters are significantly different (P<0.05)

Table 4. Effect of pre-slaughter Nutri-charge™ treatment on meat quality.[1]

	Control	Treated	P
L* (brightness)	28.8	28.7	0.87
Chroma (saturation)	19.0	18.6	0.19
Hue angle	21.3	21.1	0.17
pH initial	6.71	6.70	0.68
pH (24 h)	5.68	5.69	0.44
Drip loss in retail package, %	2.50	2.56	0.67
Shear value[2], kg	5.423	5.455	0.92

[1] Data subset included animals from first two kills of 2001 slaughter only (no treatment applied to animals in third kill, n = 34).
[2] From frozen/thawed steaks cooked to 67^{o}C.

Table 5. Effect of cooler temperature on carcass shrink and meat quality.[1]

	Average cooler temperature		
	1^{o}C	5.5^{o}C	P
Cooler shrink, %	1.59	1.68	0.33
L* (brightness)	28.0	29.0	0.003
Chroma (saturation)	17.7	19.0	0.011
Hue angle	20.8	20.9	0.55
pH (24 h)[1]	5.76	5.69	0.065
Drip loss in retail package, %	2.52	2.49	0.90
Shear value[2], kg	6.166	5.182	0.007
Within steak variation[3]	1.375	0.949	0.014

[1] Data subset included 2 to 4 year old bulls from 2001 slaughter only (n = 41).
[2] From frozen/thawed steaks cooked to 67^{o}C.
[3] Standard deviation of six cores.

Table 6. Effect on shear value of modified temperature conditioning of the carcass and cooking fresh or frozen/thawed steaks.[1]

	Average cooler temperature		
	1°C	5.5°C	P
Cooked from fresh:			
Shear value, kg	9.502	6.700	<0.0001
Within-steak variation[3]	2.265	1.145	0.009
Cooked from frozen/thawed:			
Shear value, kg	6.504	5.335	0.012
Within-steak variation[3]	1.275	0.896	0.010
Difference[2]:			
Shear value, kg	2.998	1.365	0.002

[1] Data subset included 2 to 4 year old bulls from 2001 slaughter only (n = 35).
[2] Difference (fresh minus frozen-thawed).
[3] Standard deviation of three cores.

Table 7. Carcass cut out (% of side)

	All 2, 3 & 4 year old bulls (n = 60)		
	Mean	Minimum	Maximum
Hot carcass wt., kg	198.3	139.4	263.0
2 X 3 Boneless rib	2.87	2.14	3.52
Inside round	4.47	2.71	5.59
Outside round	4.11	2.91	4.96
Eye of round	1.48	1.14	1.82
Sirloin tip, peeled	4.65	3.40	5.75
1 X 0 Strip loin	3.58	2.92	4.38
Top butt	2.81	2.09	3.63
Tenderloin, whole	1.48	1.24	1.82
Hind shank meat	1.85	1.45	2.27
Osso buko	2.11	1.64	2.84
Total cuts	29.42	25.85	33.29
Stew meat	10.17	5.10	15.61
85% Lean	35.00	28.67	44.00
Total meat yield	74.59	69.98	78.54
Readily dissected fat	9.54	3.40	14.45
Bone	15.69	12.22	18.44

Table 8. Utility of various carcass measurements for prediction of yield of total cuts expressed as a percentage of side weight (both years: n = 58)

Measurements included in the model	R^2	+ HCW
GR measurement	0.07	0.34
Minimum fat in 4th quadrant	0.07	0.31
Average fat	0.02	0.32
Rib eye area (REA)	0.09	0.36
Minimum fat + GR	0.08	0.38
Average fat + GR	0.07	0.34
Minimum fat + REA	0.12	0.37
Average fat + REA	0.09	0.37
Minimum fat + GR + REA	0.13	0.40
Average fat + GR + REA	0.10	0.38
Hot carcass weight (HCW)	0.31	

Table 9. Utility of various carcass measurements for prediction of total meat yield expressed as a percentage of side weight (both years: n = 58).

Measurements included in the model	R^2	+ HCW
GR measurement	0.48	0.64
Minimum fat in 4th quadrant	0.30	0.30
Average fat	0.38	0.38
Rib eye area (REA)	0.06	0.06
Minimum fat + GR **(Equation 1)**	0.50	0.64
Average fat + GR	0.52	0.66
Minimum fat + REA	0.30	0.31
Average fat + REA	0.38	0.40
Minimum fat + GR + REA	0.59	0.65
Average fat + GR + REA	0.60	0.66
Hot carcass weight (HCW)	0.04	

Equation 1

Estimated total meat yield (%) =
74.570 – 0.118(minimum fat, mm) - 0.188(GR, mm) - 0.038(HCW, kg)

Standard deviation of difference (predicted – actual) = 1.24%

Figure 1. Individual differences in shear value (CC – MTC) for steaks cooked from previously frozen and thawed samples (2 to 4 year old bulls only).

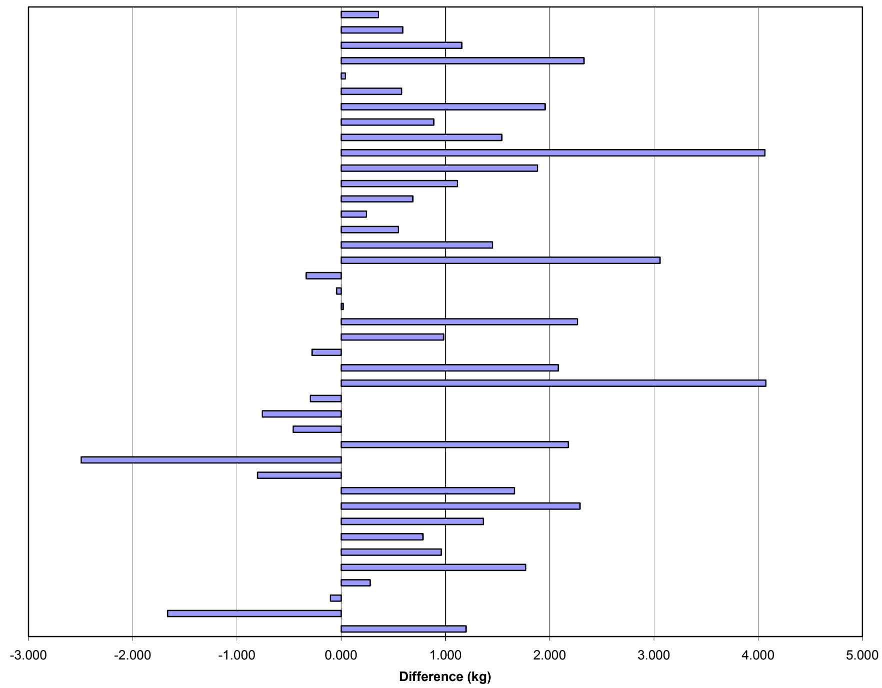


Figure 2. Temperature decline at the center of the loin in conventionally chilled (CC) and modified temperature conditioned (MTC) elk carcass sides.

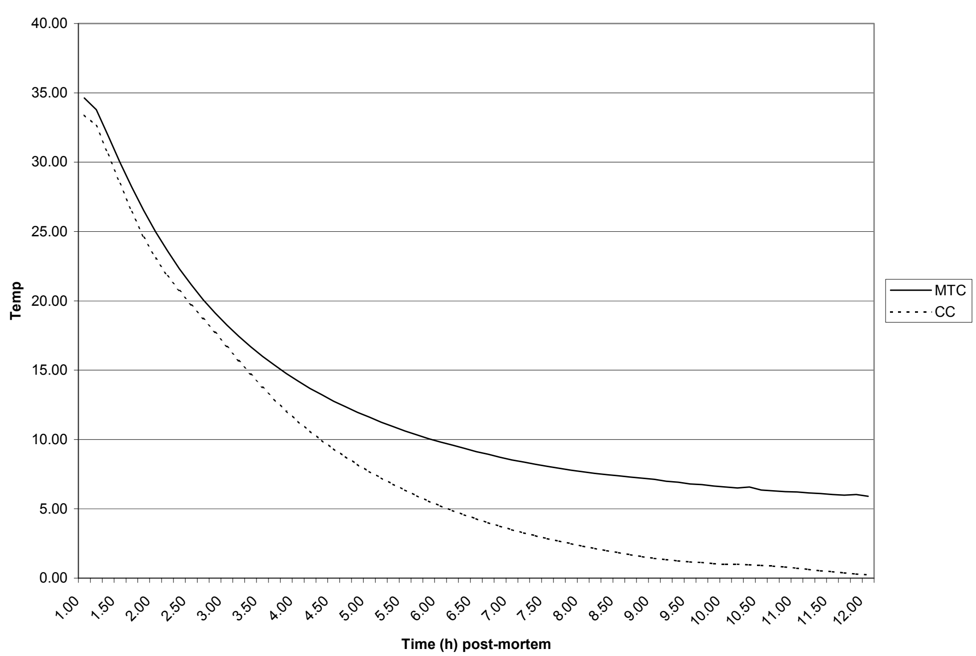


Figure 3. Temperature decline in the deep hip of conventionally chilled (CC) and modified temperature conditioned (MTC) elk carcass sides.

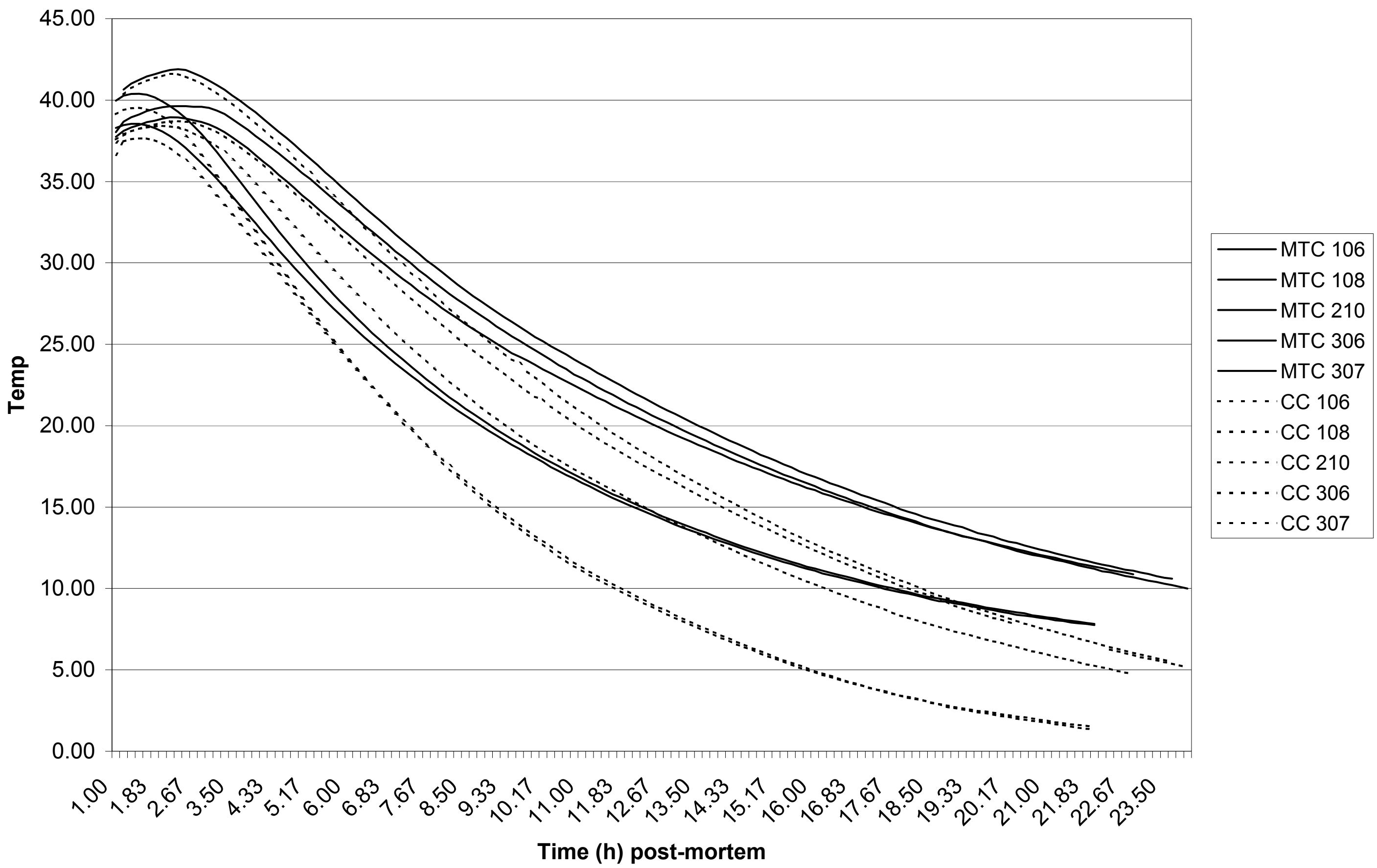


Figure 4. Individual differences in shear value (fresh – frozen/thawed) for samples derived from conventionally chilled carcass sides.

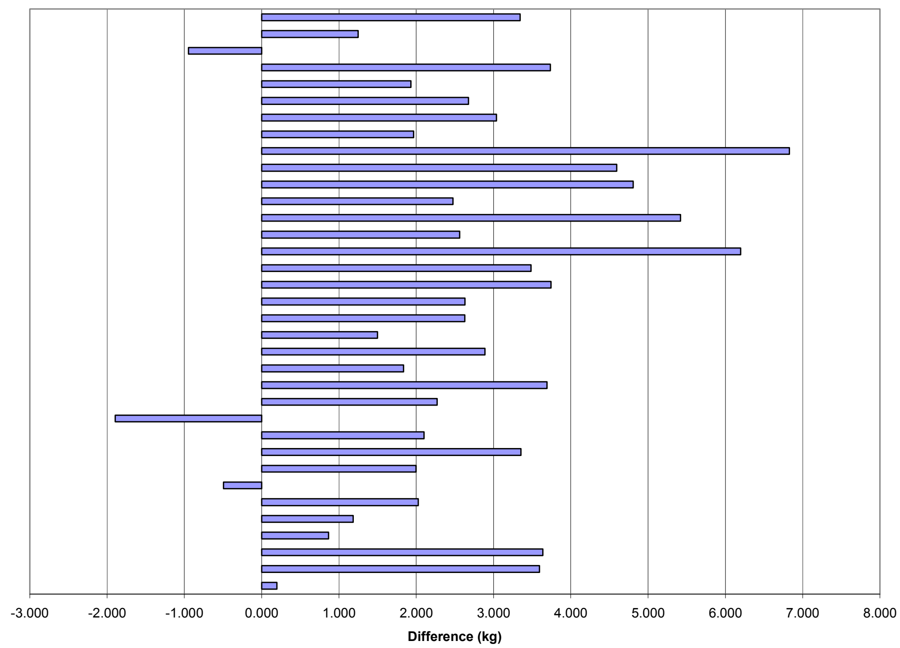


Figure 5. Individual differences in shear value (fresh – frozen/thawed) for samples derived from MTC carcass sides.

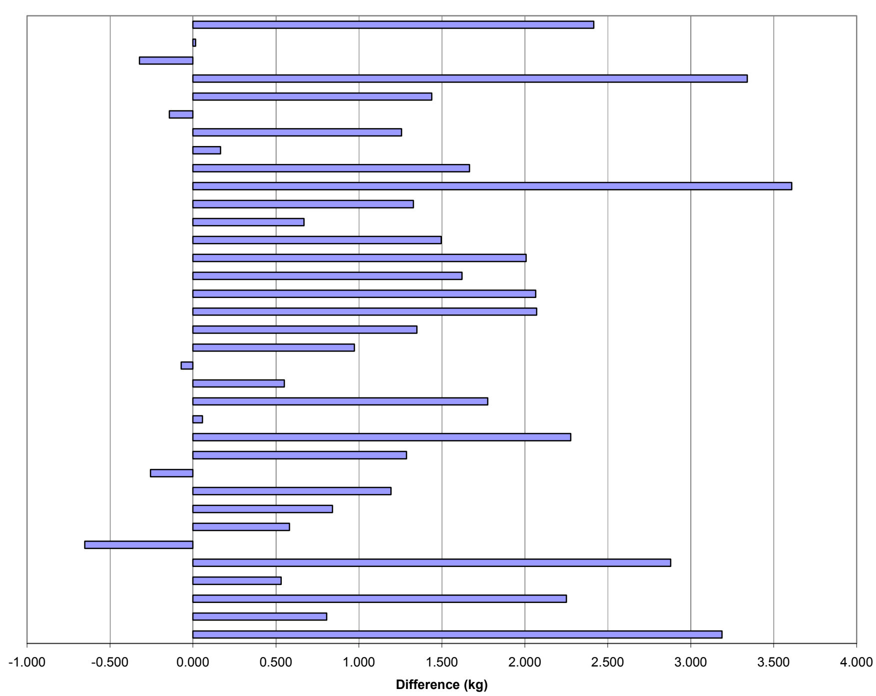


Figure 6. Fat deposition over the rib cage.

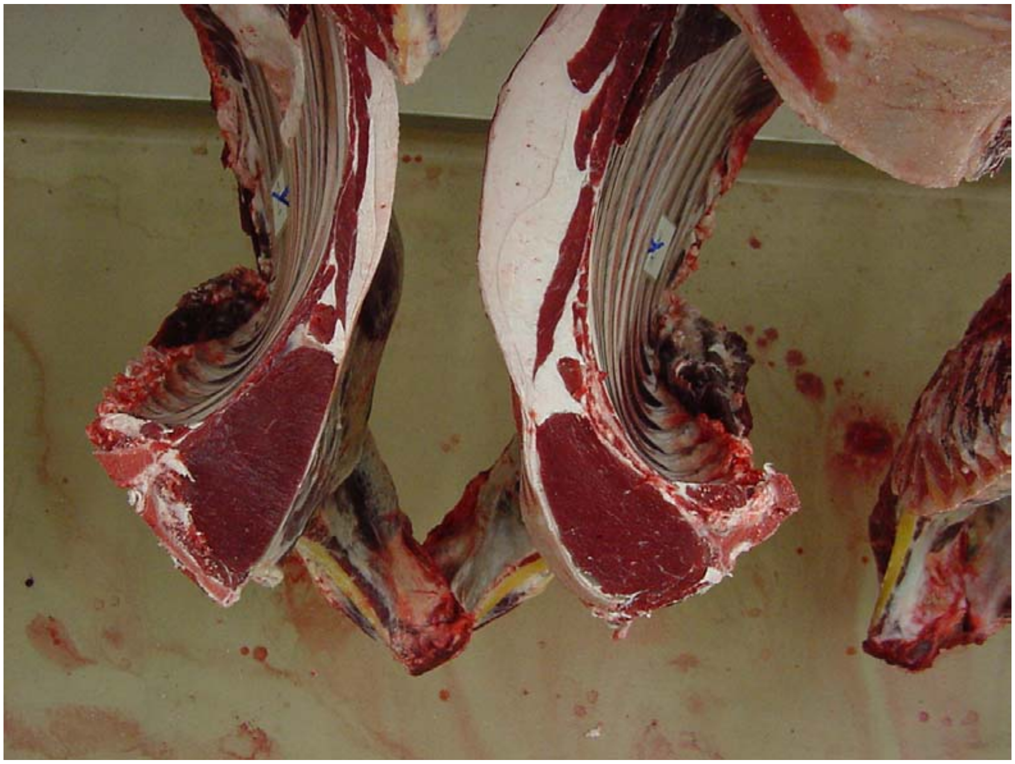
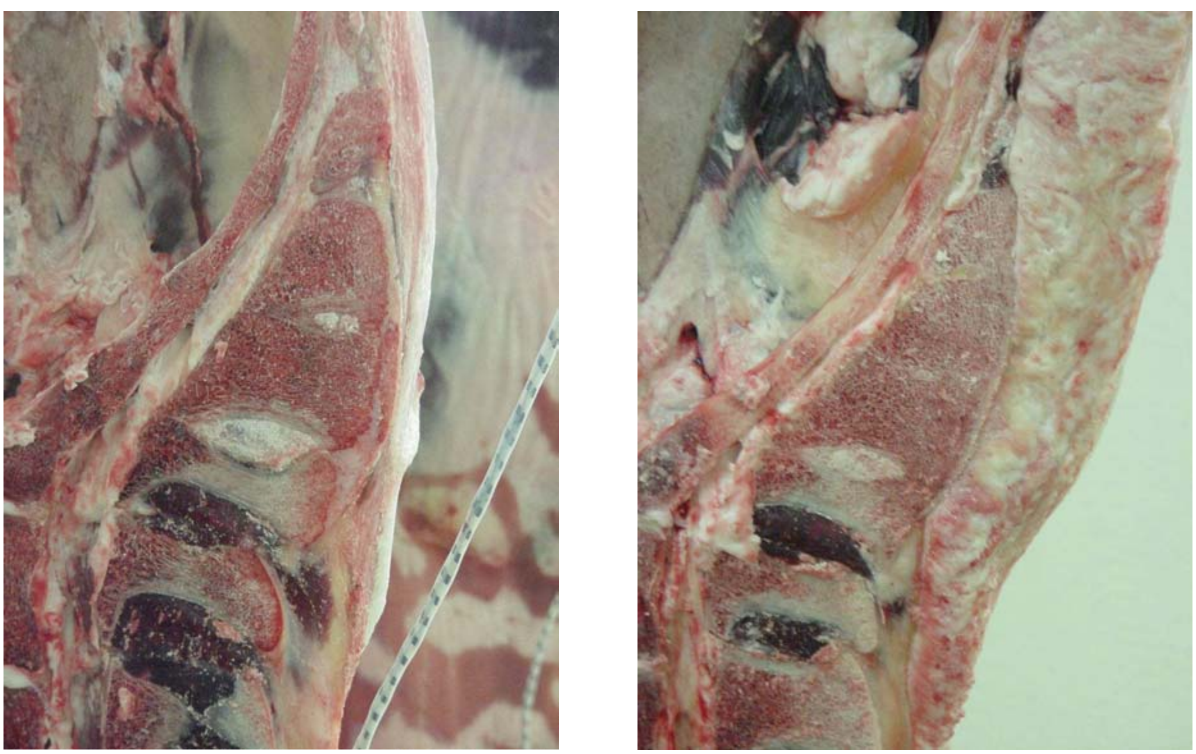


Figure 7. Fat deposition over the tail head.



Appendix 1: Carcass characteristics of four 8 to 12-year old cow elk.

Characteristic	Mean
Final live wt., kg	293.1
Hot carcass wt., kg	169.8
HCW, % of final live wt.	57.8
Components, % of side:	
2 X 3 Boneless rib	2.57
Inside round	4.87
Outside round	4.45
Eye of round	1.47
Sirloin tip, peeled	4.68
1 X 0 Strip loin	3.75
Top butt	3.67
Tenderloin, whole	1.53
Hind shank meat	1.86
Osso buko	2.05
Total cuts	30.90
Stew meat	12.89
85% Lean	28.88
Total meat yield	72.67
Readily dissected fat	11.06
Bone	15.81

Appendix 2: Effect of carcass weight on yield of cuts and other carcass components (% of side)

	Warm carcass weight, kg			
	139 - 170	170.1 - 200	200.1 - 230	230.1 - 263
n	11	24	13	12
2 X 3 Boneless rib	2.73	2.93	2.94	2.80
Inside round	4.83*a*	4.50*ab*	4.19*b*	4.39*b*
Outside round	4.34	4.06	4.10	4.00
Eye of round	1.54	1.47	1.48	1.46
Sirloin tip, peeled	5.17*a*	4.67*b*	4.47*bc*	4.34*c*
1 X 0 Strip loin	3.83*a*	3.51*b*	3.55*b*	3.53*b*
Top butt	2.80	2.85	2.84	2.72
Tenderloin, whole	1.55*a*	1.51*ab*	1.43*b*	1.43*b*
Hind shank meat	2.02*a*	1.87*b*	1.78*c*	1.72*c*
Osso buko	2.25*a*	2.15*ab*	2.03*ab*	1.97*b*
Total cuts	31.07*a*	29.53*b*	28.81*bc*	28.37*c*
Middle meats[z]	10.92*a*	10.80*ab*	10.76*ab*	10.48*b*
Stew meat	11.15	9.80	9.86	10.35
85% Lean	33.46	35.08	34.97	36.28
Total meat yield	75.68*a*	74.40*ab*	73.64*b*	75.00*ab*
Readily dissectable fat	6.68*c*	9.50*b*	10.97*a*	10.69*ab*
Bone	17.45*a*	15.91*b*	15.22*b*	14.14*c*
Waste (fat & bone)	24.12*b*	25.41*ab*	26.19*a*	24.83*ab*

abc LSMeans with different letters are significantly different ($P<0.05$)
[z] Middle meats = 2x3 rib eye + 1x0 strip loin + top butt + tenderloin

Data from 60 two to four year old bull elk cut out at Lacombe Research Centre (2000-2001) in a co-operative study by Agriculture and Agri-Food Canada, Alberta Elk Association and Canadian Rocky Mountain Ranch.