Effects of skeletal separation method and postmortem ageing on carcass traits and shear force in cull cow beef

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Mandell, I. B., Campbell, C. P., Quinton, V. M. and Wilton, J. W. 2006. **Effects of skeletal separation method and postmortem ageing on carcass traits and shear force in cull cow beef**. Can. J. Anim. Sci. **86**: 351–361. Sixty-six cull cow carcasses were subjected to skeletal separation methods for improving beef tenderness as evaluated using shear force. Forty-one carcasses were used to evaluate the effect on longissimus muscle shear force from skeletal separation at various sites including: (1) the 11th thoracic vertebra, (2) the 12th thoracic vertebra, and (3) the 6th thoracic and 5th lumbar vertebrae. Longissimus muscle steaks from the posterior and anterior loin and posterior rib were aged for 2, 7, 14, and 28 d. Twenty-five carcasses underwent skeletal separation processing in the round with severing of the ischium and the junction between 4th/5th sacral vertebrae. Semimembranosus, semitendinosus, biceps femoris, vastus lateralis, and rectus femoris muscles were processed into steaks and aged for 2, 7, 14, and 28 d. Skeletal separation techniques involving thoracic and lumbar vertebrae decreased ($P < 0.04$) shear force in the posterior rib and anterior loin but not in the posterior loin. Shear force continued to decrease ($P < 0.01$) as postmortem ageing duration increased. The semimembranosus was the only muscle in the round in which shear force decreased ($P < 0.01$) with skeletal separation. Postmortem ageing for at least 14 d decreased ($P < 0.06$) shear force in semimembranosus and vastus lateralis steaks while there were no further decreases in shear force after 7 d ageing for semitendinosus and rectus femoris steaks. Skeletal separation increased ($P < 0.10$) sarcomere length in all muscles studied. Skeletal separation techniques have the potential to improve tenderness in the longissimus and semimembranosus muscles, which may increase utilization of cull cow beef.

Key words: Beef, cow, shear, tendercut, longissimus, round

Mandell, I. B., Campbell, C. P., Quinton, V. M. et Wilton, J. W. 2006. **Incidence de la méthode de séparation des muscles squelettiques et du rassissement post mortem sur les paramètres de la carcasse et sur la résistance au cisaillement de la viande des vaches réformées**. Can. J. Anim. Sci. **86**: 351–361. Les auteurs ont appliqué diverses méthodes de séparation des muscles squelettiques visant à améliorer la tendreté de la viande, évaluée d'après la résistance au cisaillement, à la carcasse de 66 vaches de réforme. Quarante et une carcasses ont servi à évaluer l'effet de la technique de séparation sur la résistance du *longissimus* au cisaillement à divers endroits, notamment au niveau 1) de la 11^{e} vertèbre thoracique, 2) de la 12^{e} vertèbre thoracique ainsi que 3) de la 6^{e} vertèbre thoracique et de la 5^{e} vertèbre lombaire. Ils ont également laissé rassir des biftecks de *longissimus* prélevés dans la partie postérieure ou antérieure de la longe et dans la partie postérieure de la côte pendant 2, 7, 14 et 28 jours. Vingt-cinq carcasses ont été soumises à une technique de séparation des muscles squelettiques de la ronde par ablation de l'ischion et de la jonction entre les 4^{e} et 5^{e} vertèbres sacrées. Enfin, les auteurs ont débité le semi-membraneux, le semi-tendineux, le *biceps femoris*, le *vastus lateralis* et le *rectus femoris* en biftecks qu'ils ont laissés rassir pendant 2, 7, 14 et 28 jours. Les techniques de séparation des muscles squelettiques affectant les vertèbres thoraciques et lombaires diminuent ($P < 0,04$) la résistance au cisaillement de la partie postérieure de la côte et de la partie antérieure de la longe, mais pas de la partie postérieure de cette dernière. La résistance au cisaillement continue de faiblir ($P < 0,01$) avec la durée du rassissement. Le semi-membraneux est le seul muscle de la ronde dont la résistance au cisaillement diminue ($P < 0,01$) avec la séparation des muscles squelettiques. Un rassissement post mortem d'au moins 14 jours réduit ($P < 0,06$) la résistance au cisaillement des biftecks tirés du semi-membraneux et du *vastus lateralis*, mais celle des biftecks provenant du semi-tendineux et du *rectus femoris* ne diminue plus après 7 jours de ce conditionnement. La séparation des muscles squelettiques accroît ($P < 0,10$) la longueur des sarcomères dans tous les muscles examinés. Les techniques de séparation pourraient attendrir la viande du *longissimus* et du semi-membraneux, avec la plus grande utilisation du bœuf des vaches réformées que cela laisse supposer.

Mots clés: Bœuf, vache, cisaillement, Tendercut, *longissimus*, ronde

Cull cows are mature females over 30 mo of age that have been eliminated from beef or dairy herds for various reasons including low productivity, poor health or condition, poor temperament, and (or) management decisions by the producer. Carcasses from cull cows are generally downgraded in North American grading systems based on assessment of skeletal and lean maturity. Cull cow beef generally is used for processing and grinding although fresh product may be prepared in restaurants. The discovery of BSE in Canada in May 2003 and the resulting ban on the export to the United States of America of any beef from animals over 30 mo of age, including live animals, have resulted in up to an 80% decrease in returns for cull cows.

While there is a need to increase utilization of cull cow beef domestically to improve producer returns, lack of consistency in tenderness and unsatisfactory eating experiences

Abbreviations: **BF**, biceps femoris; **LMA**, longissimus muscle area; **RF**, rectus femoris; **SM**, semimembranosus **ST**, semitendinosus; **VL**, vastus lateralis especially with tenderness are major problems for marketing whole muscle cuts from cull cow beef. The variability in the eating quality (tenderness, juiciness, flavour) of cull cow beef has long been recognized in the industry (Hodgson et al. 1992; Hilton et al. 1998), with age (maturity of the animal) and body condition (leanness) being the primary factors influencing quality (Shemeis et al. 1994). One approach to this problem is to place cows on high-grain diets for up to 56 d before slaughter (Schnell et al. 1997). While this approach has significantly improved product quality, current low prices for Canadian cull cows makes grain feeding an uneconomical option. Grading systems have been developed for cull cows to sort carcasses for the fresh meat, marination, or grinding trades (Hodgson et al. 1992; Hilton et al. 1998). However, these grading systems have only been implemented for the middle meats (rib and loin cuts) and not for lower-quality cuts such as those found in the round (hip) or the chuck (shoulder).

Postmortem processing of cull cow beef is needed to overcome meat quality problems regarding consistency and unsatisfactory eating experiences. Moisture enhancement is an option for improving product quality based on studies with graded beef (Vote et al. 2000; Lawrence et al. 2004) but responses to injection of cow beef with calcium chloride led to varying success with regard to increasing tenderness, and development of undesirable off-flavours (Morgan et al. 1991; DeYonge-Freeman et al. 2000).

Over the past decade, skeletal separation techniques were developed in which selected cutting of vertebrae, bone, minor muscles, fat, and connective tissue enabled muscles to be stretched by the weight of the hanging carcass, resulting in longer sarcomere lengths and increases in beef tenderness (Wang et al. 1996; Ludwig et al. 1997; Aalhus et al. 2000). This selected cutting could be incorporated on the kill floor or in the chill cooler prior to the development of rigor mortis. Studies were conducted on youthful carcasses from steers and heifers, but not to our knowledge on mature carcasses from cull cows and bulls.

While the Tendercut procedure of Ludwig et al. (1997) was successful for improving tenderness, the selected cuts to the carcass occurred at the grading site, impacting carcass measurements for fat and longissimus muscle area in a way that could result in lower returns for producers based on the estimation of carcass lean yield. Aalhus et al. (2000) modified the procedure, cutting the carcass at the 6th thoracic and 5th lumbar vertebrae. However, this procedure had the disadvantage of requiring two cuts on the carcass such that an additional two stations may be required on the kill floor for adopting the procedure. An alternative site for selected cuts on the carcass would be beneficial to avoid interfering with the grading site while minimizing labour inputs.

The benefits of postmortem ageing on improving product quality are well documented (Diles et al. 1994; Aalhus et al. 2004; Rider Sell et al. 2004). However, Ludwig et al. (1997) suggested that skeletal separation processes in combination with ageing may exert an additive effect on improving tenderness such that less ageing time may be required to ensure a tender product. The objectives of this study were to examine the effects of skeletal separation method and postmortem ageing on carcass traits and shear force in cull cow beef.

MATERIALS AND METHODS

Animals were cared for according to the guidelines and principles of the Canadian Council on Animal Care. Sixty-six cull cows (beef and dairy) of various ages were slaughtered at either a local abattoir or the University of Guelph Meat Laboratory according to industry procedures that included stunning with captive bolt prior to exsanguination. Electrical stimulation was not used at either abattoir. All carcasses were suspended by the Achilles tendon in the common vertical position; one randomly selected side was used as a control while the other side was designated to one of four prerigor skeletal separation treatments, which began approximately 30 to 45 min postmortem. Over the course of the work, approximately equal numbers of left and right sides were used for the respective control and skeletal separation treatments.

Forty-one carcasses were used to evaluate three methods of skeletal separation involving the longissimus muscle: (1) severance of the 11th vertebra (11/12th; 15 carcasses), (2) severance of the 12th vertebra (12/13th; 13 carcasses) (Ludwig et al. 1997), or (3) combination processing (COMB; 13 carcasses) severing both the 6th thoracic and 5th lumbar vertebrae (Aalhus et al. 2000). The skeletal separation techniques involved severing of vertebrae, connective tissue, and minor muscles such that only the longissimus muscle remained to support the weight of the carcass (Ludwig et al. 1997). A further 25 carcasses underwent skeletal separation processing in the round with severance of the ischium of the pelvic bone, the junction of the 4th/5th sacral vertebrae, and the connective tissues in the round/loin region (Tendercut; Wang et al. 1994).

Following a 24-h chill period in coolers varying from 1 to 2°C, carcasses were ribbed at the Canadian grade site, between the 12th and 13th ribs. Carcasses were assessed by an experienced carcass evaluator based on Livestock and Poultry Carcass Grading Regulations (Canadian Food Inspection Agency 1992) to determine carcass grade and yield characteristics. Carcasses were assessed at the grade site for the following measurements:

1. Subcutaneous fat (mm) at ¼, ½, and ¾ positions over the longissimus muscle;
2. Grade fat (mm), minimum fat depth in the last quadrant over the longissimus muscle;
3. Longissimus muscle area (LMA) (cm^2) estimated using the dot grid method.

For carcasses that underwent skeletal separation processing of various vertebrae, both the loin and rib were processed into a total of 18, trimmed, boneless 3.5-cm steaks with subcutaneous fat removed. The loin was processed into 13 steaks, which were individually identified (steak 1 to steak 13) starting from the 5th lumbar vertebra. Steaks 1 to 4 (posterior end of the loin) were randomly assigned to postmortem ageing periods of 2, 7, 14, or 28 d, while steaks 10 to 13 (anterior end of the loin) were similarly assigned to ageing treatments. Steaks 5 to 9 were aged for 7 d but only steak 5 was used in the present study. The posterior end of the rib was processed into five 3.5-cm steaks, which were individually identified starting from the 12^{th} thoracic vertebra. Steaks 15 to 18 were randomly assigned to postmortem ageing times analogous to loin steaks, while steak 14 was aged for 7 d. All steaks were vacuum packaged and aged for their appropriate times in a 1.5°C cooler. For steaks 5 (loin eye) and 14 (rib eye), a 3- to 5-g sample was removed at 2 d postmortem for subsequent determination of sarcomere length. Temperature and pH in all steaks were measured prior to freezing using a spear-tipped electrode and thermocouple attached to an Accumet 1002 pH meter (Fisher Scientific, Toronto, ON). All steaks and sarcomere length samples were then vacuum packaged and frozen for storage at –25°C.

The rounds from carcasses that underwent skeletal separation in the hip were dissected at 24 h postmortem into individual muscles with preparation of steaks from the semimembranosus (SM), biceps femoris (BF), rectus femoris (RF), semitendinosus (ST), and the vastus lateralis (VL) muscles. Five 3.5-cm steaks were prepared from each muscle with each steak individually identified. Steaks 1 to 4 were randomly assigned one of four ageing times (2, 7, 14 or 28 d), vacuum-packaged and aged in a 1°C cooler before being frozen and stored for later analysis. After ageing Steak 5 from each muscle for 7 d, a 3- to 5-g sample was removed, frozen and stored (–25°C) for subsequent determination of sarcomere length. Temperature and pH in steaks 1 to 4 were measured as previously described for skeletal separation processing of thoracic and lumbar vertebrae.

Sarcomere length was determined by adding approximately 2 g of frozen muscle to 20 mL of distilled water (Strydom et al. 2005) and blending for 30 s at 5000 rpm with a Polytron homogenizer (Brinkman Instruments, Toronto, ON). A drop of homogenate was mounted on a microscope slide and viewed through a Zeiss Axioskope microscope (Carl Zeiss, Don Mills, ON) at 100 × magnification with the oil immersion lens. Twenty different sarcomere lengths were measured manually.

Steaks were thawed for 24 h in a 1°C cooler in preparation for shear force determinations. Each steak was weighed prior to cooking on a Garland electric grill (ED-30B broiler, Garland Commercial Range LTD., Mississauga, ON). Steaks were turned every 4 min during grilling until an internal endpoint temperature of 70°C was reached. Internal temperature was monitored using data output from a Type K thermocouple inserted in the geometric centre of each steak. Cooked steaks were removed from the grill, weighed, placed into individual plastic bags, immersed in ice water, and cooled overnight at 1°C. The following day, steaks were allowed to equilibrate to room temperature (25°C) and eight, 1.5-cm diameter cores were removed parallel to the muscle fibres using a hand-held stainless steel cork bore. Individual peak shear force was determined on each core perpendicular to the muscle fibres using an MC3000 Nene (Nene Instruments LTD., Wellingborough, UK) equipped with a Warner-Bratzler blade. Crosshead speed was set at 229 mm min^{-1}.

Carcasses for the two packing plants were randomized across the three methods of skeletal separation (11/12th, 12/13th, COMB). Carcass and sarcomere length data involving the effects of skeletal separations on longissimus muscle were statistically analyzed using a mixed linear model (SAS Institute, Inc. 1994). This model included the fixed effects of commercial packing plant, carcass side (which examines the main effect of skeletal separation including control and skeletally separated sides), method of prerigor skeletal separation (11/12th, 12/13th, COMB), and all interactions, and the random effect of carcasses within packing plant and method of skeletal separation in a split plot design. The main plot included packing plant and method of skeletal separation, while the subplot included carcass side and interactions with method of skeletal separation and packing plant. Each carcass served as its own control with one side left intact with the other side undergoing skeletal separation. Side weight and grade fat were included in the model as covariates for the analysis of sarcomere length data. Grade fat data were collected for all sides while side weights were determined by dividing hot carcass weight by two. For all experimental data involving skeletal separation of vertebrae, packing plant and the interactions involving packing plant were nonsignificant ($P > 0.10$) and then dropped from the statistical model. Differences amongst treatment means were determined using orthogonal contrasts for: (a) Skeletal separation – control sides versus skeletally separated sides, (b) Methods of skeletal separation – single versus 2 site methods = the average of 11/12th and 12/13th treatments versus COMB; within single site methods = 11/12th versus 12/13th. The previously described contrasts were used as the bases for developing contrasts for two-way interactions where appropriate.

Due to heterogeneous variances found between sites along the longissimus (posterior loin, anterior loin, posterior rib), pH, shear force, and cooking loss data were statistically analyzed on an individual site basis using a mixed linear model. This model included the fixed effects of commercial packing plant, carcass side, method of prerigor skeletal separation (11/12th, 12/13th, COMB), postmortem ageing time, and all interactions, and the random effect of carcasses within packing plant and method of skeletal separation in a repeated measures design based on postmortem ageing. As previously stated, the factor, packing plant and interactions involving packing plant were nonsignificant, and these terms were dropped from the statistical model. Side weight and grade fat were included in the model as covariates for the analysis of shear force and cooking loss data. The appropriate covariance structure was used to minimize the value for Akaike's Information Criterion (Wang and Goonewardene 2004). Differences amongst treatment means were determined using orthogonal contrasts previously described for prerigor treatment and the following orthogonal contrasts for postmortem ageing: (a) 2 vs. (7, 14, 28) = 2 d aged beef versus the average of 7, 14, and 28 d aged beef; (b) 7 vs. (14, 28) = 7 d aged beef versus the average of 14, and 28 d aged beef; (c) 14 vs. 28 = 14 d aged beef versus 28 d aged beef. The previously described contrasts for skeletal separation, method of skeletal separation, and postmortem ageing were used as the bases for developing contrasts for two-way and three-way interactions where appropriate.

Sarcomere length data for muscles from the round were statistically analyzed using a mixed linear model (SAS

Institute, Inc. 1994) that included skeletal separation treatment (control or Tendercut processing). Shear force, pH, and cooking loss data for muscles from the round were statistically analyzed on an individual muscle basis using a mixed linear model, which included the fixed effects of prerigor treatment and postmortem ageing time and their interaction in a repeated measures design based on postmortem ageing. The appropriate covariance structure was used to minimize the value for Akaike's Information Criterion. Differences among treatment means were determined using orthogonal contrasts for each treatment as previously described for postmortem ageing. There were no prerigor treatment by postmortem ageing interactions ($P > 0.10$).

RESULTS AND DISCUSSION

The three methods used in the present study for applying skeletal cuts involving the longissimus muscle are based on past work in this area. Skeletal separation at the 12th/13th ribs is the basis of the Tendercut procedure of Ludwig et al. (1997), while severing the 6th thoracic and 5th lumbar vertebrae is the modified on-line altered suspension technique of Aalhus et al. (2000). A concern with the traditional site of Tendercut processing is that the carcass is altered where carcasses are currently graded between the 12th and 13th ribs, and may have an impact on the determination of North American yield grades that can affect carcass value. The approach of Aalhus et al. (2000) avoids the grade site but requires the additional labour for performing two cuts to the carcass. A single cut between the 11th/12th thoracic vertebrae avoids the grade site and may reduce labour inputs. Cull cows are generally not graded in Canada. However, there has been discussion about grading cows in the United States of America over the past 15 yr (Hodgson et al. 1992; Hilton et al. 1998), and it is prudent that any technique used to improve eating quality of beef be evaluated for its impact on carcass traits that may affect returns to producers.

The effects of skeletal cuts processing on carcass traits of cull cows are presented in Table 1. In the present study, carcasses were randomly assigned to method of skeletal separation without any regard to carcass weight or fatness with the exception that dairy cow carcasses were equally distributed across experimental treatments. Hot carcass weights for carcasses separated at the 11/12th or 12/13th sites were much greater ($P < 0.001$) than COMB carcasses with carcass weights ranging from 245 to 496 kg across the whole data set. Skeletal separation did not affect ($P > 0.30$) any backfat measurements when compared with the control sides when examining the main effect or the skeletal separation by method interaction. While all carcasses were randomly assigned to methods of skeletal separation, backfat measurements at all positions over the longissimus were greater ($P < 0.04$) for carcasses processed between the 11/12th and 12/13th vertebrae versus those COMB processed. The impact of skeletal separation on grade fat measurements is a concern as this site is used for determination of fat class in the Canadian Beef Grading System for estimating saleable meat yield. Any significant increase to grade fat from skeletal separation techniques may lower estimation of carcass lean yield and result in discounting of the carcass in the current grading system if the technique was applied to steer and heifer carcasses. Claus et al. (1997) found USDA yield grade to increase with skeletal cuts at the 12th/13th thoracic vertebrae, indicating fatter carcasses. The modified on-line altered suspension approach of Aalhus et al. (2000) increased fat score, decreased muscle score, rib eye areas, and marbling, resulting in lower estimated lean yields.

There were no differences ($P > 0.15$) in longissimus muscle area across treatments. Due to the large differences in hot carcass weight across methods of skeletal separation, longissmus muscle area was calculated on a 100-kg hot carcass weight basis. While skeletal separation decreased ($P < 0.01$) longissimus muscle area/100 kg hot carcass weight (LMA), more important is the presence of a skeletal separation by method interaction ($P < 0.01$). There was almost no effect on LMA when the COMB technique was used, while skeletal separation at single sites (11/12th or 12/13th) decreased LMA as compared with control sides (Single versus 2 site methods; $P < 0.05$). Skeletal separation at the 12/13th site tended to decrease LMA to a greater extent as compared with skeletal separation at the 11/12th site (within single site methods; $P < 0.02$). Past studies (Ludwig et al. 1997; Claus et al. 1997; Aalhus et al. 2000) found that skeletal separation techniques often reduce longissimus muscle area, which may be beneficial to the beef industry. The decrease in LMA in the present study with skeletal separation at the 12th/13th thoracic vertebrae is supported by findings from Claus and co-workers (Ludwig et al. 1997; Claus et al. 1997). The lack of an effect on LMA using the COMB technique may be due to the omission of severing the pelvic bone in the present study as compared with the separation technique developed by Aalhus et al. (2000). Over the past decade, heavy carcass weights across North America have increased portion size for steaks processed from the middle meats due to large rib and loin eye areas. Skeletal separation processing does not affect the weight of the longissimus muscle but simply stretches the muscle under the weight of the forequarter (Claus et al. 1997). This process may decrease loin and rib eye areas, which can enable more steaks to be cut from the longissmus. The smaller loin and rib areas may provide a more desirable portion size for consumers along with enabling thicker steaks to be cut which may result in better eating experiences for consumers as it may decrease the risk of overcooking. Based on the present findings, this desirable effect on reducing longissimus muscle area may not be achieved depending on the specific skeletal separation method used on cull cow carcasses. While others (Claus et al. 1997; Aalhus et al. 2000) found skeletal separation processing to affect estimated lean yield, no differences between skeletal separation and control sides were found for most backfat measurements, LMA, and determination of lean yield (dissection, grade ruler or equation methods) in heifer and steer carcasses processed at a commercial packing plant in Ontario (unpublished data). However, Aalhus et al. (2000) found less perceived marbling in skeletal separation processed sides versus their control counterparts. Although marbling was not assessed in the present study, the effect of skeletal separation on the pre-

Table 1. Effects of skeletal separation and method of skeletal separation on measurements of subcutaneous backfat, longissimus muscle area and sarcomere length in cull cows

	Effect of skeletal separation[z]				Evaluation of carcasses assigned to method of skeletal separation[x]					Contrasts for evaluation of carcasses assigned to separation method[w]		Skeletal separation by method interaction						Contrasts for skeletal separation by method interaction[u]	
Trait	Control side	Skeletally separated side	SE[y]	P > F	11/12th (N = 15)	12/13th (N = 13)	COMB (N = 13)	SE[y]	P > F	Single versus 2 site methods	Within single site methods	Side[v]	11/12th	12/13th	COMB	SE[y]	P > F	Single versus 2 site methods	Within single site methods
Hot carcass weight (kg)	Not applicable[t]				374.7	386.1	308.7	12.83	0.001	0.001	0.529				Not applicable[t]				
Backfat at ¼ position (mm)	17.1	15.2	1.77	0.306	21.1	15.9	11.5	2.62	0.044	0.038	0.175	Control	21.3	18.5	11.5	3.05	0.485	0.465	0.301
												Separated	20.9	13.2	11.4				
Backfat at ½ position (mm)	11.4	12.6	2.20	0.783	14.8	12.6	7.5	2.12	0.051	0.023	0.486	Control	14.5	13.3	6.3	2.82	0.789	0.547	0.712
												Separated	15.2	12.0	8.7				
Backfat at ¾ position (mm)	9.0	9.33	1.26	0.825	12.5	9.0	6.0	1.71	0.034	0.031	0.168	Control	11.9	9.0	6.1	2.17	0.927	0.812	0.777
												Separated	13.1	9.0	5.9				
Grade fat (mm)	8.5	8.7	1.14	0.882	11.5	8.3	5.9	1.46	0.037	0.033	0.143	Control	10.6	8.8	6.0	1.97	0.740	0.822	0.466
												Separated	12.4	7.8	5.8				
Longissimus muscle area (cm^2)	81.0	77.3	3.29	0.149	84.9	80.4	72.1	5.26	0.246	0.121	0.545	Control	86.3	84.6	72.1	5.69	0.384	0.285	0.357
												Separated	83.5	76.2	72.2				
Longissimus muscle area (cm^2 100 kg^{-1} carcass weight)	22.8	20.9	0.61	0.006	22.8	20.9	23.1	1.00	0.235	0.310	0.169	Control	23.0	22.3	23.1	1.05	0.009	0.044	0.012
												Separated	22.6	19.4	23.1				
Sarcomere length, loin eye (μm)	1.95	2.09	0.021	0.001	1.98	2.07	2.01	0.028	0.109	0.669	0.038	Control	1.92	2.01	1.92	0.037	0.651	0.359	0.950
												Separated	2.04	2.13	2.10				
Sarcomere length, rib eye (μm)	1.88	2.03	0.016	0.001	1.99	1.96	1.92	0.023	0.143	0.084	0.362	Control	1.89	1.91	1.85	0.029	0.186	0.970	0.069
												Separated	2.09	2.01	2.00				

[z] Effect of skeletal separation compares control sides versus skeletally separated sides.

[y] SE = standard error.

[x] Method for skeletal separation includes: 11/12th where the 11th thoracic vertebra was severed; 12/13th where the 12th thoracic vertebra was severed; COMB where the 6th thoracic vertebra and the 5th lumbar vertebra were severed.

[w] Evaluation of carcasses assigned to skeletal separation includes two contrasts: Single versus 2 site methods = the average of 11/12th and 12/13th versus COMB with contrast coefficients of 1 1 –2 for skeletal separation technique; Within single site methods = 11/12th versus 12/13th with contrast coefficients of 1 –1 0 for skeletal separation technique.

[v] Side includes control in which the side was chilled unaltered, or separated, in which skeletal separation was applied using one of three skeletal separation methods.

[u] Contrasts for carcasses assigned to skeletal separation by method interaction: Single versus 2 site methods = the average of 11/12th and 12/13th versus COMB with contrast coefficients of 1 –1 1 –1 –2 2 for skeletal separation technique by side interaction; Within single site methods = 11/12th versus 12/13th with contrast coefficients of 1 –1 –1 1 0 0 for skeletal separation technique by side interaction.

[t] Not applicable as data only recorded for hot carcass weight and not weights for individual sides.

sentation of marbling may be a problem for producers that are marketing on a grid based on marbling.

Regardless of skeletal separation method used, sarcomere length increased ($P < 0.01$) with skeletal separation relative to control sides at both rib and loin-eye sites (Table 1). Several researchers (Herring et al. 1965; Hostetler et al. 1972) have noted that increasing prerigor muscle length and maintaining the stretched state until rigor is complete is known to result in longer sarcomeres. However, the relative increase in sarcomere length from skeletal cuts in the present study was much lower than previous findings (Claus et al. 1997; Ludwig et al. 1997) evaluating steer and heifer carcasses altered at the 12th/13th vertebrae. The effect on sarcomere length from skeletal cuts in the present study is similar to those found by Beaty et al. (1999) who applied skeletal cuts to the thoracic vertebra and pelvic bone, while exceeding the increases in sarcomere length in the posterior longissimus lumborum from severing the 6th thoracic and 5th lumbar vertebrae (Aalhus et al. 1999). Sarcomere length in the loin eye was greater ($P < 0.04$) with separation at the 12/13th site as compared with the 11/12th site. The COMB method tended to have the smallest ($P < 0.09$) sarcomere lengths in the present study for the rib eye amongst methods of skeletal separation. The impact of site of skeletal separation on sarcomere length may be related to the distance between where skeletal separation occurred and the location of the sample for sarcomere length determination, with less effect on sarcomere length when sampling at greater distances from the point of skeletal separation. This may be supported by Ludwig et al. (1997) where a zone by skeletal separation treatment interaction was reported such that the Tendercut process (12/13th site) increased sarcomere lengths to a greater extent in the posterior rib and anterior loin than the posterior loin. The presence of a skeletal separation by method interaction ($P < 0.07$) for sarcomere length for the rib eye was due to a greater increase in sarcomere length with skeletal separation using the 11/12th site as compared with the 12/13th site.

There was no effect ($P = 0.34$) of skeletal separation on pH values in the rib eye nor was a skeletal separation by method interaction present for muscle pH (Table 2). Eikelenbloom et al. (1998) found 48 h pH values did not differ when hanging the carcass by pelvic suspension versus the conventional method of using the Achilles tendon. Skeletal separation did not affect pH at 24 h and 6 d postmortem in the longissimus thoracis et lumborum (Aalhus et al. 1999) and at 24 h postmortem in the longissimus lumborum (Aalhus et al. 2000). There was no consistent effect of postmortem ageing on muscle pH (Table 3).

Shear force in the posterior loin was not affected ($P = 0.69$) by skeletal separation (Table 2), which is in contrast to previous studies where shear force was decreased in the longissimus lumborum when skeletal cuts were made between the 12th/13th vertebrae with additional cuts to the pelvic bone (Aalhus et al. 1999; Beaty et al. 1999). However, Ludwig et al. (1997) found a nonsignificant decrease in shear force when the Tendercut process was applied to the posterior loin. Shear force tended to be greater ($P < 0.10$; data not presented) with the COMB technique as compared with skeletal separation at the 11/12th and 12/13th sites. Higher background shear force values for COMB carcasses are likely responsible for this difference, as no skeletal separation by method interaction ($P > 0.78$) was present to suggest shear force was affected differently when the different skeletal separation techniques were applied. The apparent higher background shear force values for COMB carcasses are found throughout the longissimus muscle data (Table 2) when examining the presence of skeletal separation by method interactions for shear force. The differences in background toughness can not be explained as carcasses were randomly assigned to each skeletal separation technique, albeit separation technique differences in hot carcass weight and backfat measurements have been previously stated. Side weight was not significant as a covariate and was dropped from the statistical model while all shear force data are presented with the presence of gradefat as a covariate in the statistical model. However separation technique differences in hot carcass weight and backfat measurements ($P < 0.04$, Table 1) may be contributing to differences in background toughness in the present study due to potential differences in rates of carcass chilling and subsequent impact on tenderness (Aalhus et al. 2001).

Postmortem ageing affected ($P < 0.01$) shear force with values steadily decreasing ($P < 0.01$) with longer durations of ageing (Table 3), similar to findings for beef from youthful (Aalhus et al. 2004) and cull cow (Diles et al. 1994; Rider Sell et al. 2004) carcasses. Ludwig et al. (1997) found that the Tendercut procedure was effective in reducing shear force in product aged 3 and 10 d.

In contrast to findings for the posterior loin, skeletal separation decreased ($P < 0.04$) shear force in the anterior loin and the posterior rib (Table 2). Site differences along the longissimus muscle to the effect of skeletal separation in the present study may be due to site differences in connective tissue content, the use of lower-quality cull cow beef, or the distance between actual site for skeletal separation and sampling site for shear force determination. Claus et al. (1997) found that skeletal separation at the 12th/13th vertebrae decreased shear force in the anterior longissimus of USDA Select carcasses, but not in the posterior longissimus. In contrast, skeletal separation decreased shear force in both the anterior and posterior longissimus of USDA Choice carcasses. Aalhus et al. (2000) found a greater response to skeletal separation (lower shear force values) within the longissimus lumborum as compared with the longissimus thoracis. The absence of skeletal separation method by side interactions for shear force in the anterior loin eye and posterior rib eye ($P > 0.47$) provides packing plants with flexibility in choosing a tenderness-improvement technique that is complementary to the layout and operation of a given facility.

The effects of postmortem ageing on longissimus muscle from the anterior loin and posterior rib eye are similar to findings for the posterior loin (Table 3). However, three-way interactions (skeletal separation by method of skeletal separation by postmortem ageing) were present for the anterior loin and posterior rib eye ($P < 0.09$ and $P < 0.05$, respec-

Table 2. Effects of skeletal separation and method of skeletal separation on muscle pH, shear force values and cooking losses in cull cow beef

	Effect of skeletal separation[z]				Skeletal separation by method interaction						Contrasts for skeletal separation by method interaction[w]	
Trait	Control side	Skeletally separated side	SE[y]	P > F	Side[x]	11/12th	12/13th	COMB	SE[y]	P > F	Single versus two site methods	Within single site methods
pH of rib eye	5.65	5.65	0.014	0.342	Control	5.63	5.63	5.68	0.025	0.508	0.547	0.329
					Separated	5.65	5.63	5.68				
Shear force (kg)												
Posterior loin	4.80	4.73	0.160	0.693	Control	4.59	4.60	5.22	0.280	0.781	0.514	0.768
					Separated	4.53	4.68	4.99				
Anterior loin	4.95	4.60	0.198	0.033	Control	4.46	4.74	5.66	0.345	0.479	0.252	0.655
					Separated	4.15	4.60	5.06				
Posterior rib eye	4.98	4.24	0.209	0.001	Control	4.61	4.80	5.55	0.364	0.988	0.950	0.885
					Separated	3.82	4.08	4.82				
Cooking losses (%)												
Posterior loin	23.8	22.4	0.71	0.014	Control	21.9	23.8	25.7	1.24	0.070	0.904	0.022
					Separated	22.2	20.8	24.2				
Anterior loin	20.5	20.8	0.89	0.608	Control	19.1	20.3	22.3	1.55	0.592	0.462	0.453
					Separated	19.1	21.3	22.0				
Posterior rib eye	20.9	21.1	0.86	0.706	Control	19.8	20.3	22.5	1.51	0.610	0.390	0.667
					Separated	19.4	20.5	23.3				

[z] Effect of skeletal separation compares control sides versus skeletally separated sides.

[y] SE = standard error.

[x] Side includes control, in which the side was chilled unaltered, or separated, in which skeletal separation was applied using one of three skeletal separation methods.

[w] Contrasts for skeletal separation by method interaction: Single versus 2 site methods = the average of 11/12th and 12/13th versus COMB with contrast coefficients of 1 –1 1 –1 –2 2 for skeletal separation technique by side interaction; within single site methods = 11/12th versus 12/13th with contrast coefficients of 1 –1 –1 1 0 0 for skeletal separation technique by side interaction.

Table 3. Effect of postmortem ageing on muscle pH, shear force values and cooking losses in cull cow beef

	Postmortem ageing (d)[z]						Evaluation of days for postmortem ageing[x]		
Trait	2 days	7 days	14 days	28 days	SE[y]	P > F	2 vs. (7, 14, 28)	7 vs. (14, 28)	14 vs. 28
pH of rib eye	5.68	5.63	5.66	5.64	0.018	0.183	0.047	0.124	0.543
Shear force (kg)									
Posterior loin	5.41	5.15	4.72	3.79	0.172	0.001	0.001	0.001	0.001
Anterior loin	5.45	5.12	4.74	3.81	0.206	0.001	0.001	0.001	0.001
Posterior rib eye	5.25	5.06	4.44	3.70	0.209	0.001	0.001	0.001	0.001
Cooking losses (%)									
Posterior loin	23.5	22.8	22.9	23.2	0.80	0.763	0.351	0.701	0.707
Anterior loin	19.9	20.9	21.0	20.9	0.97	0.457	0.123	0.985	0.908
Posterior rib eye	20.2	21.1	21.6	21.1	0.93	0.236	0.064	0.660	0.435

[z] Days of postmortem ageing include 2, 7, 14, or 28 d after slaughter.

[y] SE = standard error.

[x] Evaluation of days for postmortem ageing includes the three contrasts: 2 vs. (7, 14, 28) = 2 vs. the average of 7, 14, and 28 d with contrast coefficients of 3 –1 –1 –1 for postmortem ageing; 7 vs. (14, 28) = 7 vs. the average of 14 and 28 d with contrast coefficients of 0 2 –1 –1 for postmortem ageing; 14 vs. 28 = 14 vs. 28 d with contrast coefficients of 0 0 1 –1 for postmortem ageing.

tively) between COMB carcasses and carcasses processed at the 11/12th and 12/13th sites when comparing 2 d versus longer durations of ageing. Shear force values for the three-way interaction for the posterior rib eye are presented in Fig. 1. The interaction is most likely due to the limited effectiveness of the two site skeletal separation technique (COMB) for tenderness enhancement in 2 d aged product as compared with single site skeletal separation methods (11/12th and 12/13th sites). A decrease in shear force with minimal ageing of skeletally separated beef is desired as Ludwig et al. (1997) reported significantly lower shear force values and increased tenderness scores with skeletal separation at the 12/13th site in 3 d aged product. For COMB carcasses, there was a trend for a linear decrease in shear force from 2 to 28 d ageing with skeletal separation as compared with trends for increases in shear force at the 11/12th site from 7 to 14 d ageing and the 12/13th site from

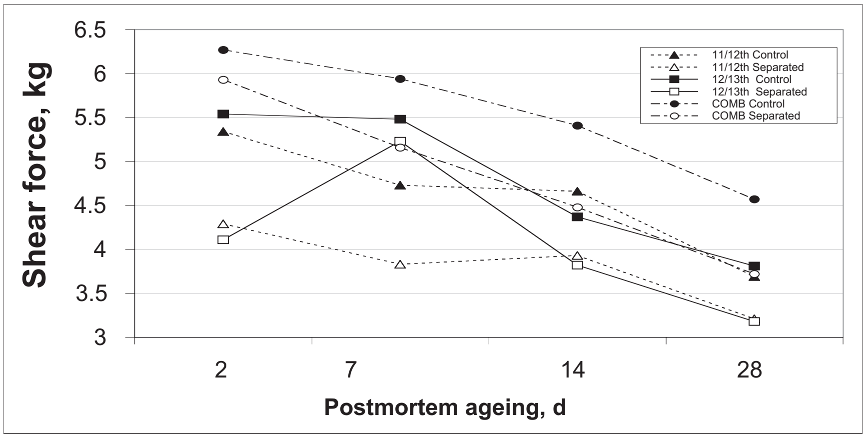

Fig. 1. Skeletal separation by method by postmortem ageing interaction ($P = 0.049$) for shear force in the posterior rib eye involving 2 versus the average 7, 14, and 28 d postmortem ageing. SE = 0.44.

2 to 7 d ageing. Despite these increases in shear force for single site skeletal separation methods (11/12th and 12/13th sites), shear force continued to decrease with longer durations of ageing. These findings are supported by previous work with cull cow beef where Rider Sell et al. (2004) found shear force to increase from 2 to 7 d of ageing before starting to decline with 7 or 14 d of additional ageing. The linear nature of the decline in shear force with COMB processing as compared with the trend for a quadratic decline with single site skeletal separation methods may be indicative of more effective tenderness enhancement with extended ageing when a two-site approach (COMB) is used in skeletal separations despite higher background toughness in COMB carcasses. However, the use of more homogenous carcasses in regard to carcass weight and fatness may be needed to test this hypothesis across methods of skeletal separation in future studies. Ludwig et al. (1997) suggested that a skeletal separation process in combination with ageing may exert an additive effect on tenderness such that skeletally separated beef may require less postmortem ageing to improve tenderness as compared with ageing of control or conventionally processed beef. This may be supported in the present study with 12/13th site and COMB skeletal separation procedures, with 14 d aged, skeletally separated beef having similar shear force values to beef from control carcasses aged 28 d.

Skeletal separation decreased ($P < 0.02$) cooking losses in the posterior loin only (Table 2), which contrasts with past studies (Wang et al. 1996; Ludwig et al. 1997; Eikenbloom et al. 1998; Aalhus et al. 1999) where skeletal separation to carcasses has not affected cooking losses. A skeletal separation by method interaction ($P < 0.03$) for cooking losses in the posterior loin was due to skeletal separation decreasing cooking losses for carcasses processed at the 12/13th sites as compared with increasing cooking losses with skeletal separation at the 11/12th site. For the most part, postmortem ageing did not affect ($P > 0.10$) cooking losses across sites along the longissimus (Table 3). The exception is the tendency for lower ($P < 0.07$) cooking losses in 2 d aged steaks from the rib eye versus longer durations of ageing, which contrasts with the trend found by Ludwig et al. (1997) where cooking losses tended to decrease in product from 3 to 10 d of ageing. Diles et al. (1994) found similar cooking losses for cow loin steaks aged 7 and 14 d, while Maher et al. (2004) found no consistent effect of postmortem ageing on cooking losses when gender, genotype, and slaughter weight were also examined.

In the hip, the Tendercut process significantly increased ($P < 0.01$) sarcomere lengths within the SM, BF, ST and RF muscles, while there was a limited increase ($P < 0.10$) in sarcomere length in the VL muscle (Table 4). Although greater sarcomere lengths tend to be associated with more tender beef (Hostetler et al. 1972), researchers (Shanks et al. 2002; Sorheim and Hildrum 2002) have noted that increases in sarcomere length driven by skeletal separation treatments are not always associated with improvements in beef tenderness whether assessed by shear force or a specific taste panel tenderness attribute. Sarcomere length increased for SM and ST muscles with Tendercut processing of the round (Beaty et al. 1999; Shanks et al. 2002). Tendercut processing did not affect sarcomere lengths of BF and RF muscles in the Shanks et al. (2002) study, in contrast to increasing sarcomere length in work by Beaty et al. (1999) and Wang et al. (1994). Shanks et al. (2002) concluded that the differences in magnitude of response for sarcomere length among muscles were probably influenced by the proximity of the individual muscle in relation to skeletal separation point and by muscle fibre orientation in relation to tension.

Tendercut processing decreased ($P < 0.09$) pH in ST and RF muscles, which may be due to a skeletal separation induced increase in carcass cooling postmortem (Aalhus et al. 1999). In contrast, there was no effect ($P > 0.23$) of skeletal separation on pH in SM, VL, and BF muscles. Aalhus et al. (2000) did not find any changes in muscle pH of ST muscle

Table 4. Effects of skeletal separation to the hip and postmortem ageing on pH, shear force and cooking losses in five muscles from the rounds of cull cows

					Postmortem ageing (d)[z]						Evaluation of days for postmortem ageing[x]		
Trait	Control	Skeletal separation	SE	P > F	2 days	7 days	14 days	28 days	SE[y]	P > F	2 vs. (7, 14, 28)	7 vs. (14, 28)	14 vs. 28
Sarcomere length (μm)													
Semimembranosus	1.85	2.00	0.021	0.001	Not applicable								
Semitendinosus	2.13	2.31	0.031	0.001	Not applicable								
Vastus lateralis	2.05	2.10	0.019	0.095	Not applicable								
Biceps femoris	1.87	1.98	0.019	0.001	Not applicable								
Rectus femoris	2.10	2.21	0.026	0.004	Not applicable								
pH													
Semimembranosus	5.61	5.59	0.013	0.311	5.62	5.57	5.61	5.58	0.015	0.001	0.059	0.168	0.260
Semitendinosus	5.66	5.62	0.011	0.008	5.64	5.61	5.66	5.66	0.012	0.124	0.958	0.186	0.744
Vastus lateralis	5.63	5.64	0.010	0.580	5.64	5.60	5.65	5.66	0.012	0.001	0.961	0.001	0.198
Biceps femoris	5.61	5.59	0.011	0.239	5.59	5.56	5.60	5.63	0.014	0.009	0.696	0.003	0.128
Rectus femoris	5.69	5.65	0.016	0.081	5.65	5.63	5.71	5.69	0.017	0.002	0.277	0.001	0.366
Cooking losses (%)													
Semimembranosus	19.6	20.2	0.29	0.153	20.9	19.4	19.9	19.4	0.53	0.217	0.057	0.609	0.403
Semitendinosus	23.9	23.7	0.42	0.698	24.2	23.1	23.4	24.4	0.57	0.292	0.423	0.223	0.206
Vastus lateralis	23.3	24.3	0.56	0.209	23.8	23.5	23.7	24.3	0.73	0.839	0.999	0.560	0.484
Biceps femoris	21.2	21.4	0.34	0.712	21.7	21.0	20.4	22.2	0.55	0.120	0.478	0.699	0.023
Rectus femoris	22.1	23.1	0.47	0.139	22.9	22.5	21.9	23.1	0.70	0.623	0.614	0.975	0.222
Shear force (kg)													
Semimembranosus	5.68	5.13	0.091	0.001	5.75	5.50	5.32	5.05	0.129	0.001	0.003	0.051	0.133
Semitendinosus	5.64	5.52	0.090	0.349	5.84	5.55	5.50	5.42	0.127	0.115	0.021	0.544	0.639
Vastus lateralis	5.60	5.59	0.087	0.929	6.20	5.72	5.40	5.07	0.131	0.001	0.001	0.003	0.091
Biceps femoris	7.19	7.05	0.112	0.357	7.34	7.30	6.80	7.04	0.215	0.334	0.313	0.193	0.391
Rectus femoris	4.54	4.70	0.116	0.333	5.18	4.53	4.51	4.27	0.151	0.002	0.001	0.329	0.142

[z] Days of ageing include 2, 78, 14, or 28 days after slaughter.

[y] SE = standard error.

[x] Evaluation of days for postmortem ageing includes the three contrasts: 2 vs. (7, 14, 28) = 2 vs. the average of 7, 14, and 28 d with contrast coefficients of 3 –1 –1 –1 for postmortem ageing; 7 vs. (14, 28) = 7 vs. the average of 14 and 28 d with contrast coefficients of 0 2 –1 –1 for postmortem ageing; 14 vs. 28 = 14 vs. 28 d with contrast coefficients of 0 0 1 –1 for postmortem ageing.

aged 6 d. Muscle pH was affected ($P < 0.01$) by postmortem ageing for SM, VL, BF, and RF muscles. The pH in SM muscle tended to be greater ($P < 0.06$) in 2 d aged product as compared with longer periods of ageing, while muscle pH values were lowest for 7 d aged product versus longer periods of ageing for VL, BF, and RF muscles. Skeletal separation did not affect ($P > 0.20$) cooking losses for any evaluated steak from the round. The absence of an effect on cooking losses is desirable as any treatment that increases cooking losses may be predisposing the consumer to juiciness problems with the cooked product (Toscas et al. 1999). Cooking losses in muscles from the round have not been affected by Tendercut processing in past studies (Wang et al. 1994, 1996). Postmortem ageing for the most part did not affect ($P > 0.10$) cooking losses with the exceptions of greater ($P < 0.06$) cooking losses at 2 d ageing for SM versus longer periods of ageing and greater ($P < 0.03$) cooking losses for 28 d aged BF muscle as compared with a 14 d aged product.

Shear force for the SM decreased ($P < 0.01$) with Tendercut processing while there was no effect ($P > 0.33$) on shear force for all other muscles using the Tendercut process (Table 4). In other studies, the Tendercut process was not effective for decreasing shear force in BF, ST and SM muscles (Beaty et al. 1999; Shanks et al. 2002), BF steaks (Wang et al. 1996; Claus et al. 1997), VL muscle (Shanks et al. 2002), and RF muscle (Wang et al. 1996). The Tendercut process has, however, to the present, decreased shear force in RF (Wang et al. 1994; Claus et al. 1997) and VL (Wang et al. 1994) muscles. The limited effect of Tendercut processing for reducing shear force has been attributed to the connective tissue content of many muscles found in the round (Claus et al. 1997; Shanks et al. 2002) with the process having no impact on quantitative or qualitative collagen content (Wang et al. 1994; Wang et al. 1996). The absence of any improvement in tenderness from Tendercut processing of SM muscle in past studies (Beaty et al. 1999; Shanks et al. 2002) may be due to past ageing of the product for no more than 10 d as compared with ageing for up to 28 d in the present study, thereby increasing the statistical power of the observation by averaging over multiple evaluation times. Cooking temperature may also be a factor, as Eikelenbloom et al. (1999) found that carcasses hung by the aitch bone increased sarcomere length in the SM as compared with hanging the carcass by the Achilles tendon, but shear force either increased or was not affected using cooking temperatures ranging from 55 to 70°C. While the limited response to Tendercut processing in the present study may be due to slight deviations in the site of skeletal alteration as proposed by Wang et al. (1994), Sorheim et al. (2002) felt that minor deviations to the position of skeletal alteration would not have an impact on the process.

With the exception of the decrease in shear force for the SM, the limited improvement with Tendercut processing of the round in cull cows may not be surprising given that other studies (Wang et al. 1996; Claus et al. 1997; Beaty et al. 1999; Shanks et al. 2002) found no effect on specific muscles using steers and heifers that were physiologically less mature than the animals used in the present study. In the Beaty et al. (1999) study, shear force tended to increase for BF and SM muscles with Tendercut processing. While Shanks et al. (2002) found that Tendercut processing did improve tenderness of the rectus femoris muscle (sirloin tip), shear force values for the psoas major muscle (tenderloin) increased by up to 1 kg in some instances.

The lack of any improvement in tenderness from skeletal separation for most muscles in the round suggests that this is not an effective postmortem processing technique in agreement with Shanks et al. (2002). However, based on the present findings, Tendercut processing can be used to enhance tenderness of the SM muscle and reduce ageing time required to improve beef tenderness, and can be used to enhance tenderness along the longissimus muscle when combined with other skeletal cuts (Aalhus et al. 1999, 2000). The present study examined cull cow carcasses without any consideration for carcass maturity since skeletal separation is applied in the prerigor state prior to determination of carcass maturity. Numerous researchers (Hodgson et al. 1992; Schnell et al. 1997; Hilton et al. 1998) have reported the impact of carcass maturity on shear force and(or) tenderness determinations of cull cow beef. Advancing carcass maturity does not necessarily produce tough beef as Powell (1991) found similar shear force and taste panel tenderness and juiciness scores for 1.5- and 4.5-yr-old Hereford steers.

There was no effect ($P > 0.33$) of postmortem ageing on shear force in BF muscles regardless of duration of ageing the product. Ageing the product for at least 7 d decreased ($P < 0.03$) shear force in all other muscles from the round as compared with 2 d ageing. There were no further benefits of increasing ageing past 7 d for ST and RF muscles; these findings are supported by Rider Sell et al. (2004) examining the effect of ageing up to 21 d on shear force in ST steaks. Aalhus et al. (2004) noted that extended ageing was not beneficial for all muscles for enhancing tenderness and reported no beneficial effect on shear force when examining within muscle ageing of the SM for 14 d as compared with product aged 6 d. In contrast, the present study found shear force to be further reduced ($P < 0.06$) in the SM by ageing for at least 14 d which is similar to the findings of Eilers et al. (1996) when comparing 6 versus 12 d aged product. The VL was the only muscle from the round studied where shear force continually decreased ($P < 0.10$) as postmortem ageing increased.

CONCLUSION

The discovery of BSE in Canada negatively impacted the Canadian cull cow market with resultant restrictions on the export of live animals and cull cow beef to the Unites States. There is a need to increase utilization of cull cow beef domestically to improve returns to cow-calf producers. Any postmortem enhancement of cull cow beef (pre- or post-rigor) may increase usage of cull cow beef in food service and retail meat industries. The present study demonstrates that skeletal separation techniques involving severance of thoracic and lumbar vertebrae have the potential to increase tenderness of the longissimus muscle from cull cow carcasses. Skeletal separation of the round improved tenderness of the SM muscle while shear force for most other muscles in the round was unaffected. Sensory evaluation of cull cow beef that has been produced from skeletal separation is still needed to determine the effects on the primary palatability attributes, tenderness, juiciness, and flavour. In addition, studies need to be conducted to examine effects on appearance and shelf life to determine the potential for marketing this product in the fresh meat case. The present study examined the range of cull cow carcass characteristics that are encountered in commercial packing plants with random allocation of cows to methods of skeletal separation without any regard for balancing carcass grade, maturity, or size across experimental treatments. Further studies could examine the effect of carcass grade on the enhancement in tenderness from skeletal separation to segregate cull cow beef for the fresh meat trade or further processing.

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