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# Increasing Tenderness of Beef Round and Sirloin Muscles Through Prerigor Skeletal Separations

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# Increasing tenderness of beef round and sirloin muscles through prerigor skeletal separations[1]

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**ABSTRACT:** Crossbred steers (n = 30) were used to explore and compare tenderness improvements in beef round and sirloin muscles resulting from various methods of prerigor skeletal separations. Animals were slaughtered according to industry procedures, and at 60 min postmortem one of six treatments was applied to each side: A) control, B) saw pelvis at the sirloin-round junction, C) separate the pelvic-femur joint, D) saw femur at mid-point, E) combination of B and C, and F) combination of B and D. After 48 h, the following muscles were excised from each side: semimembranosus, biceps femoris, semitendinosus, and adductor from the round; vastus lateralis and rectus femoris from the knuckle; and gluteus medius, biceps femoris and psoas major from the sirloin. Following a 10-d aging period, samples were removed from each muscle to determine the effect of treatment on sarcomere length and Warner-Bratzler shear force. Most skeletal separation treatments resulted in longer sarcomeres than controls for semimembranosus, adductor, semitendinosus, and gluteus medius muscles. All skeletal separation treatments yielded shorter sarcomeres for the psoas major as compared with controls. Warner-Bratzler shear force differed among treatments for rectus femoris, semitendinosus, and psoas major. For rectus femoris, treatments C, D, E, and F resulted in lower ($P < 0.05$) shear values than for controls. Treatments B, D, and F increased shear force of the semitendinosus relative to controls ($P < 0.05$) within muscle. Treatment F resulted in higher shear force values for the PM than controls ($P < 0.05$). Correlations between sarcomere length and shear force were found to be low and quite variable among muscles. In general, treatments increased sarcomere length of several muscles from the sirloin/round region, but had mixed effects on shear force values.

Key Words: Beef, Sarcomeres, Tenderness

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## Introduction

The National Beef Tenderness Survey (Morgan et al., 1991), conducted in 1990, identified problems with tenderness in beef rounds and top sirloin steaks. A follow-up study, the National Beef Tenderness Survey-1998 (Brooks et al., 2000), revealed that improvements in tenderness of cuts from the round were still needed. In an effort to improve tenderness, some researchers have centered on physically stretching or controlling the shortening of sarcomeres during rigor development.

Two methods of prerigor muscle stretching that have been considered and extensively investigated include alternative suspension of carcasses, first studied by Herring et al. (1965) and Hostetler et al. (1970b), and applying tension to muscles with weights or mechanical devices (Buege and Stouffer, 1974; Sonaiya and Stouffer, 1982). Even hind leg “twisting” (Odusanya and Okubanjo, 1983) has been attempted. However, these procedures have not been readily adopted by the industry.

More recently, researchers at Virginia Polytechnical Institute and State University (Wang et al., 1994; 1996; Ludwig et al., 1997) and later in a commercial setting (Claus et al., 1997) and at the University of Arkansas (Beaty et al., 1999) have examined prerigor skeletal cuts (separations) to improve beef tenderness. This procedure, sometimes referred to as the “Tendercut Process,” has been tested on the longissimus muscle and on sirloin and round cuts. Researchers have found tenderness improvements in the longissimus muscle, round, and sirloin; but the greatest improvement has been shown in the longissimus muscle. Furthermore, these researchers have only reported results for one cut location in the round/sirloin region, and tenderness improvements have not been reported on all of the major round and sirloin muscles. Therefore, this study was

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designed to explore and compare tenderness improvements in beef round and sirloin muscles resulting from various methods of prerigor skeletal separations.

## Materials and Methods

### *Carcass Treatment*

Crossbred steers (n = 30) were slaughtered in four groups (two groups per week) at the South Dakota State University Meat Laboratory according to industry procedures. Carcasses were suspended by the Achilles tendon in the common vertical position, split, and one of six treatments was applied to each side: A) control, B) saw pelvis at the sirloin-round junction, C) separate the pelvic-femur joint, D) saw femur at mid-point, E) combination of B and C, and F) combination of B and D. Six different treatments assigned in pairs across carcasses resulted in 15 paired treatment combinations with every possible treatment combination represented. Each unique treatment pair was randomly assigned to each carcass (15 carcasses per wk). For treatment D, a knife was inserted between the vastus medialis and pectineus muscles to expose the femur bone for sawing. Average time between stunning and treatment application was 60 min and ranged from 47 to 76 min.

### *Carcass Length Measurement*

Carcass length was measured from top of the carcass rail to the most anterior point of the first cervical vertebra prior to and immediately after treatment application and at 24 h after treatment. To compensate for the length of the trolley, 8.26 cm was subtracted from each measurement. Average length of control carcasses at treatment time was 251.5 cm and at 24 h was 255.8 cm. Initial and total 24-h carcass length drops were calculated from carcass length measurements.

### *Sampling and Storage*

Following a 48-h chill period in a 1°C cooler, carcasses were ribbed between the twelfth and thirteenth ribs, and USDA yield and quality grade data (USDA, 1997) were collected from right sides by experienced evaluators. At 48 h postmortem, the following muscles were excised from each side: semimembranosus (**SM**), biceps femoris (**BF-R**), semitendinosus (**ST**), and adductor (**AD)** from the round; vastus lateralis (**VL**) and rectus femoris (**RF**) from the knuckle; and gluteus medius (**GM**), biceps femoris (**BF-S**) and psoas major (**PM**) from the sirloin. Psoas major muscles were only obtained from the last two slaughter groups. Muscles were vacuum-packaged and aged until 10 d postmortem in a 1°C cooler before being frozen and stored (–18°C). At a later date, whole muscles were removed from freezer storage, and 2.5-cm-thick steaks were cut frozen on a bandsaw. Steaks were cut perpendicular to the long axis of each muscle at the approximate mid-point of each muscle. For sarcomere length determination, a 3- to 5-g sample was removed from frozen steaks adjacent to steaks designated for shear force. Shear force and sarcomere length samples were then individually vacuum-packaged or placed in plastic bags, respectively, and stored (–16°C) for later analysis.

### *Warner-Bratzler Shear Determinations*

Steaks were thawed for 24 h in a 1°C cooler and then broiled on Farberware Open Hearth electrical broilers (Farberware, Bronx, NY). Steaks were turned every 4 min during broiling until an internal temperature of 71°C was reached. Internal temperature was monitored by a digital thermometer placed in the approximate geometric center of each steak. Cooked steaks were cooled to room temperature (≈20°C) before four to eight cores (1.27 cm) were removed parallel to the longtitudinal orientation of the muscle fibers. Individual cores were sheared once on a Warner-Bratzler shear machine. An average shear force was calculated and recorded for each steak.

### *Sarcomere Length Measurements*

Sarcomere length was determined using a modified laser diffraction method (Cross et al., 1980). Approximately 4 g of tissue was cut from each frozen sample, placed into 15 to 20 mL of cold solution containing 0.25 *M* sucrose and 0.002 *M* KCl, and homogenized until fiber separation was noted. A drop of homogenate was then placed on a slide, and sarcomere lengths were measured with a He-Ne laser (Model 155A; Spectra-Physics, Inc., Mt. View, CA). Nine measurements were made per sample. Calculations were performed according to the formula by Cross et al. (1980).

### *Statistical Analysis*

Simple descriptive statistics were computed for live weight and carcass traits to characterize the sample of animals obtained for the experiment.

Data were analyzed (SAS Inst. Inc., Cary, NC) as a randomized incomplete block design, with animal serving as the block (six treatments with two treatments per block). For those dependent variables (initial carcass length drop, total 24-h carcass length drop, SM sarcomere length, AD sarcomere length, BF sarcomere length, ST sarcomere length, RF sarcomere length, GM sarcomere length, PM sarcomere length, SM shear force, AD shear force, ST shear force, GM shear force, and PM shear force), where animal was not a significant ($P > 0.05$) source of variation, the animal effect was removed and data were analyzed as a completely randomized design. Least-squares means were calculated and separated ($P < 0.05$) using pairwise *t*-tests (PDIFF option of SAS). To examine relationships between sarcomere length and shear force, simple correlations were computed within muscles.

**Table 1.** Means, standard deviations, and minimum and maximum values for live weight and carcass traits

| Trait | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Live weight, kg | 560 | 14 | 539 | 581 |
| Hot carcass wt, kg | 346 | 10 | 330 | 363 |
| Adjusted fat thickness, cm | 1.22 | 0.36 | 0.64 | 2.29 |
| Longissimus muscle area, $cm^2$ | 80.6 | 7.7 | 69.0 | 98.7 |
| Actual kidney, pelvic, and heart fat, % | 3.5 | 0.7 | 2.4 | 5.1 |
| USDA yield grade | 3.3 | 0.7 | 2.0 | 4.9 |
| Overall maturity[a] | 154 | 11 | 130 | 180 |
| Marbling score[b] | 413 | 57 | 330 | 570 |

[a]100 = $A^{00}$, 200 = $B^{00}$, etc.
[b]300 = $Slight^{00}$, 400 = $Small^{00}$, etc.

## Results and Discussion

Mean carcass trait values (Table 1) were generally representative of the population sampled in the 1995 NBQA (Boleman et al., 1998). However, less variation (lower SD) existed among carcasses in this project than in the 1995 NBQA. Therefore, this group of carcasses was an excellent test sample because they were: a) representative of the industry average, and b) consistent.

Table 2 presents least squares means for initial and total 24-h carcass length drop of treated and control sides. Treatment F resulted in the greatest initial carcass length drop (7.4 cm); treatments B, D, and E were intermediate; and treatment C resulted in the least amount of initial carcass length drop (3.2 cm). Subsequently, sides subjected to treatment F had the largest amount of total carcass length drop at 24 h (10.6 cm).

Sarcomere lengths differed among treatments for the SM, AD, ST, GM, and PM muscles (Table 3). In general, either treatments B and C individually or combined (treatment E) were the most effective at lengthening sarcomeres. For the SM, treatments B, C, E, and F resulted in longer sarcomeres than controls. For the AD, treatments B, C, D, and E resulted in longer sarcomeres than controls. For the ST, treatment C resulted in longer sarcomeres than controls. For the GM, only treatments B and E resulted in longer sarcomeres than controls. Correspondingly, Beaty et al. (1999) found that the Tendercut process, which is analogous to treatment B in the current study, increased sarcomere length in the SM and ST muscles. Apparently, longer sarcomeres observed in the current study for the SM, AD, ST, and GM were due to stretching that resulted from the skeletal separations. Differences in the magnitude of response for sarcomere length among muscles subjected to different treatments were probably influenced by the proximity of the individual muscle in relation to skeletal separation point and by muscle fiber orientation in relation to tension.

All treatments yielded shorter sarcomeres in the PM muscle as compared with controls (Table 3). Herring et al. (1965) observed similar outcomes; they discovered that horizontal placement vs conventional suspension of carcasses resulted in lengthened sarcomeres for several muscles, but considerably shortened sarcomeres for the PM. In the current study, control sides had an average sarcomere length of 3.52 $\mu$m, vs 2.41 $\mu$m for the average of treatments B through F. Treatment D resulted in a lesser degree of sarcomere shortening as compared with the other treatments, which was likely due to the greater linear distance between the point of skeletal separation (midpoint of the femur) and the PM muscle. Thus, with treatment D, intact connective tissue and tendons associated with the PM muscle may have maintained adequate resistance, hence keeping sarcomeres from shortening as much as with other treatments. In contrast to treatment D, the posterior insertion of the PM muscle was in close proximity to the site of treatment application for B, C, E, and F. Therefore, shorter sarcomeres found in the PM for treatments B, C, E, and F were probably a result of tension release, which probably occurred when connective tissue and tendons associated with the PM muscle were severed during treatment application.

**Table 2.** Least squares means for initial carcass length drop (centimeters) and total 24-h carcass length drop (centimeters) of control and treated sides

| | Treatment[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trait | A | B | C | D | E | F | *P*-value | RMSE |
| Initial carcass length drop | 0.0[b] | 4.3[cd] | 3.2[c] | 4.1[cd] | 4.9[d] | 7.4[e] | 0.0001 | 1.5 |
| Total 24-h carcass length drop | 4.3[b] | 7.1[c] | 7.2[c] | 6.1[bc] | 7.9[c] | 10.6[d] | 0.0001 | 2.3 |

[a]A = control; B = saw pelvis at the sirloin-round junction; C = separate the pelvic-femur joint; D = saw femur at the mid-point; E = combination of B and C; F = combination of B and D.
[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

**Table 3.** Least squares means for sarcomere length (micrometers) of muscles from control and treated sides

| Muscle | Treatment[a] A | B | C | D | E | F | *P*-value | RMSE |
|---|---|---|---|---|---|---|---|---|
| Round | | | | | | | | |
| Semimembranosus (top round) | 1.82$^{b}$ | 2.00$^{ed}$ | 1.91$^{cd}$ | 1.88$^{cb}$ | 2.04$^{e}$ | 1.96$^{cde}$ | 0.0002 | 0.10 |
| Adductor (top round) | 1.88$^{b}$ | 2.02$^{cd}$ | 2.13$^{d}$ | 2.03$^{cd}$ | 2.02$^{cd}$ | 1.93$^{bc}$ | 0.0048 | 0.14 |
| Biceps Femoris (bottom round) | 1.86 | 1.92 | 1.92 | 1.90 | 1.89 | 1.86 | 0.4294 | 0.08 |
| Semitendinosus (eye of round) | 2.19$^{b}$ | 2.46$^{cd}$ | 2.19$^{b}$ | 2.39$^{c}$ | 2.45$^{c}$ | 2.54$^{d}$ | 0.0001 | 0.09 |
| Knuckle | | | | | | | | |
| Vastus lateralis (sirloin tip) | 1.99 | 1.99 | 2.00 | 2.01 | 2.12 | 2.12 | 0.1070 | 0.14 |
| Rectus femoris (sirloin tip) | 2.26 | 2.46 | 2.40 | 2.28 | 2.37 | 2.49 | 0.1919 | 0.24 |
| Sirloin | | | | | | | | |
| Gluteus medius (top sirloin) | 1.79$^{bc}$ | 1.96$^{d}$ | 1.93$^{cd}$ | 1.87$^{bcd}$ | 2.11$^{e}$ | 1.76$^{b}$ | 0.0001 | 0.16 |
| Psoas major (tenderloin) | 3.52$^{b}$ | 2.15$^{d}$ | 2.31$^{d}$ | 3.22$^{c}$ | 2.29$^{d}$ | 2.09$^{d}$ | 0.0001 | 0.21 |

[a]A = control; B = saw pelvis at the sirloin-round junction; C = separate the pelvic-femur joint; D = saw femur at the mid-point; E = Combination of B and C; F = combination of B and D.

[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

Treatment had no effect ($P > 0.05$) on sarcomere length for the BF-R, VL, or RF muscles. The lack of response observed in sarcomere length for the BF-R may have reflected the anatomical location of the BF-R in relation to the treatment sites. For the VL and RF, one could speculate that substantial stretching already occurs with traditional carcass hanging procedures. Thus, the weight and angle of conventionally suspended carcasses may be more effective than prerigor cuts at increasing sarcomere length in these muscles. In contrast to our results, Beaty et al. (1999) found that the Tendercut process increased BF-R sarcomere length, and Wang et al. (1994) found that the Tendercut process resulted in significantly longer sarcomeres for RF and VL compared with control samples. In a later study, Wang et al. (1996) also found longer sarcomeres for Tendercut-treated RF and BF steaks.

The effect of prerigor skeletal separation treatments on the shear force of cooked steaks was inconsistent across muscles (Table 4). For the RF, all treatments, except B, resulted in lower ($P < 0.05$) shear values than for controls. Contrary to our lack of an effect for treatment B, some researchers have indicated that a prerigor cut at the round/sirloin juncture enhanced tenderness in the RF muscle (Wang et al., 1994; 1996; Claus et al., 1997). Differences between treatments and controls for shear force values were not found in the present study for the SM, AD, BF-R, VL, GM, or BF-S ($P > 0.05$). In agreement with our findings, Beaty et al. (1999) reported no difference in the BF-R, ST, and SM shear force between Tendercut-treated and control sides. In contrast to our results, other studies have found that the VL (Wang et al., 1994) and GM muscles (Claus et al., 1997) from Tendercut-treated carcasses had lower shear force values when compared with controls. However, Wang et al. (1996) and Claus et al. (1997) discovered no improvement in Warner-Bratzler or Lee-Kramer shear values for Tendercut-treated BF steaks. These authors suggested that the location of the BF relative to the treatment site was too far apart to sufficiently stretch the muscle. They also acknowledged

**Table 4.** Least squares means for shear force (kilograms) of cooked steaks from control and treated sides

| Muscle | Treatment[a] A | B | C | D | E | F | *P*-value | RMSE |
|---|---|---|---|---|---|---|---|---|
| Round | | | | | | | | |
| Semimembranosus (top round) | 4.44 | 4.17 | 4.49 | 4.61 | 4.14 | 4.60 | 0.3857 | 0.63 |
| Adductor (top round) | 4.20 | 4.23 | 4.09 | 4.31 | 4.04 | 4.48 | 0.2909 | 0.45 |
| Biceps femoris (bottom round) | 5.35 | 5.00 | 5.46 | 5.22 | 5.12 | 5.38 | 0.7679 | 0.60 |
| Semitendinosus (eye of round) | 3.75$^{b}$ | 4.18$^{cd}$ | 3.84$^{bc}$ | 4.23$^{d}$ | 3.92$^{bcd}$ | 4.03$^{bcd}$ | 0.0530 | 0.39 |
| Knuckle | | | | | | | | |
| Vastus lateralis (sirloin tip) | 4.79 | 5.03 | 4.85 | 4.55 | 4.71 | 4.52 | 0.3943 | 0.45 |
| Rectus femoris (sirloin tip) | 4.27$^{b}$ | 4.11$^{bc}$ | 3.32$^{de}$ | 3.45$^{de}$ | 3.69$^{cd}$ | 3.20$^{e}$ | 0.0001 | 0.37 |
| Sirloin | | | | | | | | |
| Gluteus medius (top sirloin) | 3.97 | 3.60 | 3.56 | 3.59 | 3.80 | 3.95 | 0.2521 | 0.50 |
| Biceps femoris (top sirloin cap) | 3.18 | 3.25 | 3.05 | 3.22 | 3.13 | 3.06 | 0.8783 | 0.34 |
| Psoas major (tenderloin) | 3.09$^{b}$ | 3.35$^{b}$ | 3.54$^{bc}$ | 3.48$^{b}$ | 3.00$^{b}$ | 4.10$^{c}$ | 0.0133 | 0.46 |

[a]A = control; B = saw pelvis at the sirloin-round junction; C = separate the pelvic-femur joint; D = saw femur at the mid-point; E = combination of B and C; F = combination of B and D.

[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

that the amount of collagen in the BF could have masked the effect of the treatment.

In the present study, Treatment F resulted in higher PM shear force values than controls ($P < 0.05$). Also, treatments B, D, and F increased shear force of the ST relative to controls ($P < 0.05$). Hostetler and Carpenter (1972) showed tendencies for the PM and ST to decrease in tenderness with alternative vs conventional suspension treatments, while other muscles from the round/ sirloin region remained unchanged or improved.

Locker (1960) demonstrated that as sarcomere length decreases, tenderness of muscles declines. Therefore, one would have expected the muscles in this study with longer sarcomeres to have enhanced tenderness. However, only the RF, which had similar ($P > 0.05$) sarcomere lengths for control and treated sides, responded favorably in tenderness. Even more noteworthy, in the ST, treatments B, D, and F produced substantially longer sarcomeres than controls, but control muscles were more tender ($P < 0.05$). Correspondingly, Barnier and Smulders (1994) observed increases in sarcomere length for the SM, GM, ST, and BF as a result of alternative carcass positioning, and Beaty et al. (1999) observed increases in sarcomere length for Tendercut-treated BF, ST, and SM, but both studies reported negligible or adverse changes in tenderness. Earlier studies (Hostetler et al., 1970a; 1972; 1973) also established that increased sarcomere length was not always associated with improved shear force and taste panel tenderness, especially for ST muscles. Furthermore, Hostetler et al. (1973) found that increased sarcomere length was accompanied by increased shear force in the BF, and considerable nonlinearity was found between change in sarcomere length and change in shear force for AD, GM, and PM muscles. These authors attributed the lack of tenderness improvement seen with longer sarcomeres to the amount of connective tissue present in the muscles. Another possible explanation for these findings was elucidated in a detailed experiment conducted by Marsh and Carse (1974); they detected a "peak" of toughness in muscles that were held in a 25 to 30% extended state during rigor onset.

Correlations between sarcomere length and shear force were found to be low and quite variable among muscles (Table 5). For the AD, VL, RF, and PM muscles, significant ($P < 0.05$) negative correlations (–0.26 to –0.36) were detected, indicating that longer sarcomeres were associated with lower shear force values. Yet, for the SM, BF-R, and GM correlations between sarcomere length and shear force were slight and not statistically different than zero ($P > 0.05$). Indeed, a positive correlation (0.26) was observed for ST, indicating that longer sarcomeres were associated with higher shear force values. Previous correlations between sarcomere length and shear force of several different muscles have ranged from –0.34 to –0.80 (Herring et al., 1965; Hostetler et al., 1972; Dutson et al., 1976; Wang et al., 1994). Hostetler et al. (1972) concluded that sarcomere length is only one of many numerous factors associated with meat tenderness; our findings strongly support this presumption.

**Table 5.** Correlation coefficients between sarcomere length and shear force for different muscles

| Muscle | r | *P*-value |
|---|---|---|
| Round | | |
| Semimembranosus (top round) | 0.11 | 0.4176 |
| Adductor (top round) | –0.28 | 0.0284 |
| Biceps femoris (bottom round) | 0.02 | 0.8843 |
| Semitendinosus (eye of round) | 0.26 | 0.0464 |
| Knuckle | | |
| Vastus lateralis (sirloin tip) | –0.26 | 0.0444 |
| Rectus femoris (sirloin tip) | –0.31 | 0.0154 |
| Sirloin | | |
| Gluteus medius (top sirloin) | –0.19 | 0.1485 |
| Psoas major (tenderloin) | –0.36 | 0.0530 |

## Implications

Most of the prerigor skeletal treatments studied increased sarcomere length of muscles from the sirloin/ round region, but had mixed effects on shear force values, thus clearly demonstrating that meat tenderness is not always positively associated with sarcomere length. None of the five treatments studied appears to have practical application in their current form because they either: a) had only minimal effects on tenderness, or b) increased tenderness in some muscles while decreasing tenderness in other muscles. Because some treatments did improve tenderness in some muscles, it may be possible to modify one or more of the treatments studied in order to elicit only positive effects on tenderness and thereby increase the value of beef cuts from the round and sirloin.

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