Beef Day 2021

Beef carcass weight and quality grade influence tenderness

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Objective

The objective was to investigate whether hot carcass weight (HCW) affected Warner-Bratzler shear force (WBSF) and tenderness formation of Denver, strip, and eye of round steaks from USDA Select (Se) and low Choice (LC) beef carcasses.

Study Description

Select and LC carcasses were selected at a commercial beef plant by HCW (light = 650–750 lb; middle = 850–950 lb; heavy = 1,025–1,150 lb). Steaks were fabricated and aged for 5, 10, and 14 days. Tenderness was determined through WBSF based on industry standards. Additionally, protein degradation was analyzed to determine tenderness formation.

Take Home Points

Warner-Bratzler shear force of Denver and eye of round steaks was toughest on day 5 with tenderness improving throughout aging. Strip steak WBSF was highest on day 5 in light weight carcasses compared to middle and heavy carcasses ($P < 0.0001$). By day 10, strip steaks were of similar tenderness ($P > 0.05$). Denver and eye of round steaks were not influenced by HCW ($P > 0.05$). In agreement with WBSF data from strip steaks, protein breakdown increased in middle and heavy carcasses on day 5. These data suggest strip steaks from light carcasses have reduced tenderness formation during early aging compared to middle and heavy carcasses.

Introduction

Product consistency is a challenge to the beef industry partly due to the complexity of postmortem biochemical changes of carcasses during the rigor process, but also other factors, such as quality grade, length of aging and muscle type. It is accepted that the rate of postmortem aging varies between and within muscles (Smith et al., 1978; Kim et al., 2010). As HCW increases, internal carcass temperature increases, which may influence postmortem biochemical changes, aging rate, and tenderness formation.

Multiple enzymatic systems play a role in postmortem protein degradation and tenderness formation. Proteins such as troponin-T and desmin are broken down by the calpain system contributing to or indicating tenderness formation. The calpain system is known to be impacted by changes to temperature and pH in the carcass.

Research is limited on the impact of HCW on beef muscles aged up to 14 days. Beef products from heavier carcasses could potentially have tenderness issues due to effects of internal carcass temperature during postmortem chilling on protein breakdown. Therefore, the objective of this study was to investigate the influence of hot carcass weight (HCW) on Warner-Bratzler shear force (WBSF) and protein degradation of Denver, strip, and eye of round steaks of USDA Select (Se) and low Choice (LC) beef carcasses.

Experimental Procedures

Carcass Selection and Processing

Carcasses were selected at a USDA inspected beef packing facility in the Midwest between June and September 2018. A-maturity beef carcasses (n = 312) were selected at approximately 45 min postmortem based on HCW [light (LW) = 650–750 lb; middle (MW) = 850–950 lb; heavy (HW) = 1,025–1,150 lb]. Stainless-steel data loggers were placed in the round, loin, and chuck of the right side of each carcass to track internal temperature. An 8-inch data logger (ThermoWorks, American Fork, UT) was inserted in the center of the round near the femur 48 minutes postmortem. A second 8-inch data logger was placed in the chuck in or near the Denver 50 minutes postmortem. A 4-inch data logger was placed in the striploin at the third lumbar vertebra 50 minutes postmortem. Carcasses entered the chilling cooler and internal carcass temperature (°F) was recorded every 15 minutes for 26 hours. During the 26-hour chilling period, carcasses received continual air movement and intermittent spray chilling, per normal plant operation (80 seconds of water spray every 32 minutes). Approximately 26-30 hours postmortem, carcasses were ribbed and carcass traits (12th rib backfat, ribeye area, and marbling score) were measured by trained South Dakota State University personnel. Following grading, the chuck roll, striploin, and eye of round were collected from selected USDA Se (n =56) and LC (n = 60) carcasses. Subprimals were transported under refrigeration to the South Dakota State University Meat Laboratory in Brookings, SD for further processing. The Denver was fabricated from the chuck roll and the striploin and eye of round were trimmed of excess fat prior to fabrication. Steaks were cut 1-inch thick for WBSF and 0.25-inch thick for proteolysis. Steaks were aged for 5, 10, or 14 days.

Warner-Bratzler Shear Force

The procedures used for WBSF followed those outlined by the American Meat Science Association (AMSA, 2015). Steaks were removed from the freezer and allowed to thaw prior to cooking. Steaks were cooked to an internal temperature of 160°F using a clamshell grill (George Foreman model GR2144P; Beachwood, OH). Internal temperature was monitored using thermocouples (model 39658-K; Atkins Technical, Gainesville, FL). Following cooking steaks were cooled to 39°F and then brought to room temperature. Six cores were taken from each steak and sheared using a texture analyzer (Shimadzu, model EZ SX; Suzhou Instruments Manufacturing, Co., LTD, Jiangsu, China). Peak force was recorded and averaged across all six cores for statistical analysis.

Protein Extraction

Frozen samples were powdered in stainless steel blender cups using a commercial blender (model 51BL32; Waring, Torrington, CT) until the sample was uniformly powdered and used for protein extraction. Protein concentrations were determined using the methods outlined by Melody et al. (2004). Briefly, powdered sample was homogenized in a whole muscle buffer [2% sodium dodecyl sulfate (SDS), 10 mM sodium phosphate; WMB] and centrifuged. Protein samples were diluted to similar concentrations and frozen (14°F) until use.

Western Blot Analysis

A 15% and 10% polyacrylamide separating gels were used for determination of troponin-T and desmin breakdown, respectively. Blots were incubated with primary antibody overnight at 39°F with JLT-12 (Sigma, St. Louis, MO) and rabbit anti-desmin antibody (purified in the Lonergan lab, Iowa State University) for troponin-T and desmin respectively. Secondary antibody was applied to each membrane [troponin-T: goat anti-mouse horseradish peroxidase (Thermo Fisher Scientific) and desmin: goat anti-rabbit horseradish peroxidase (Thermo Fisher Scientific)]. Membranes were developed using the ECL Prime detection kit (GE Healthcare, Lafayette, CO). Images were obtained via chemiluminescence using a FluorChem M multifluor imaging system (Protein Simple, San Jose, CA) and analyzed using AlphaView programming (v 3.4.0.0; Protein Simple).

Statistical analysis

Data were analyzed using the MIXED procedure in SAS (v 9.4; SAS Inc., Cary, NC) with repeated measures. Hot carcass weight, quality grade, and aging day were used as main effects. Post-hoc Tukey tests were used to determine significance between treatments at $\alpha = 0.05$.

Results

Warner-Bratzler Shear Force

Warner-Bratzler shear force of Denver steaks was increased in day 5 steaks, with day 14 steaks being the most tender ($P < 0.0001$; Figure 1). Quality grade and HCW did not influence WBSF in Denver steaks (Table 1). A HCW x aging day interaction was observed in strip steaks (P < 0.01; Figure 2). Day 5 strip steaks from LW carcasses were toughest ($P < 0.02$) and day 5 steaks from MW carcasses were of equal tenderness to day 5 steaks from HW carcasses. By day 10 no differences were observed among weight groups. Quality grade did not influence WBSF in strip steaks (Table 1). Day 5 eye of round steaks had increased toughness over day 10 and day 14 steaks; day 10 steaks were the most tender ($P < 0.0001$; Figure 3). Quality grade and HCW did not impact WBSF in eye of round steaks (Table 1).

Protein Degradation

The abundance of intact troponin-T in Denver steaks was highest in day 5 steaks, followed by day 10, and day 14 steaks had the least amount of intact troponin-T ($P < 0.0001$; Figure 4). Quality grade and HCW did not influence intact troponin-T in Denver steaks (Table 2). Intact troponin-T in strip steaks was not influenced by HCW, quality grade, or aging day (Table 2). A quality grade x aging day interaction was observed in the eye of round for intact troponin-T ($P < 0.01$; Figure 5). Day 10 eye of round steaks from LC carcasses had an increased amount of intact troponin-T compared to day 10 steaks from Se carcasses ($P < 0.01$). Hot carcass weight did not influence the abundance of intact troponin-T in eye of round steaks (Table 2).

The amount of intact desmin in Denver steaks was not influenced by HCW ($P = 0.12$), quality grade ($P = 0.26$), or aging day ($P = 0.12$; Table 3). A HCW x quality grade interaction was observed for intact desmin strip steaks ($P = 0.04$; Figure 6). Strip steaks from Se LW carcasses had increased amounts of intact desmin compared to steaks from Se MW and Se HW carcasses ($P < 0.05$). An increased amount of intact desmin was observed in strip steaks from Se LW carcasses compared to LC LW carcasses ($P = 0.01$). Intact desmin in strip steaks was also influenced by aging day ($P < 0.0001$), with day 5 steaks having the most intact desmin and day 14 having the least (Figure 7). The abundance of intact desmin in eye of round steaks was highest in day 5 steaks and least in day 14 steaks (P < 0.0001; Figure 8). Neither HCW ($P = 0.73$) nor quality grade ($P = 0.52$; Table 3) influenced the amount of intact desmin in eye of round steaks.

Discussion

With advancements in beef cattle genetics and nutrition regimes, the beef industry is producing heavier cattle resulting in heavier and higher quality carcasses. Egolf et al. (2020) reported elevated temperatures in heavier carcasses, especially in carcasses over 1,025 lb. Muscles that maintain elevated temperatures during postmortem chilling can negatively impact product tenderness and protein breakdown (Kim et al., 2010; Kim et al., 2012).

Carcasses should enter rigor prior to achieving internal temperatures below 50ºF to prevent increased toughness in meat products. The decreased tenderness formation observed on day 5 in strip steaks from light carcasses may be due to light carcasses reaching this threshold prior to entering rigor [for temperature data reference Egolf et al. (2020)]. At the opposing temperature extreme, temperatures too high have been reported to negatively impact tenderness. Kim et al. (2010) observed beef deep round muscles maintained at higher temperatures had decreased product quality compared to outside round muscles. A previous study of internal carcass temperature (Egolf et al., 2020) reported higher carcass temperatures during postmortem chilling in heavy beef carcasses (greater than 1,025 lb). In the current study, heavy carcasses with higher temperatures had increased tenderness at early aging points compared to light carcasses with lower temperatures during chilling. These results agree with Thomson et al. (2008) who reported increased tenderness on day 1 strip steaks held at 95ºF until a pH of 5.6 was attained compared to strip steaks held at 59ºF until pH 5.6 was attained.

Measuring the abundance of intact protein products is an indicator of tenderness formation. Thomson et al. (2008) reported by day 3, steaks incubated at higher temperatures did not exhibit a further increase in tenderness, whereas the steaks incubated at 59ºF had increased tenderness and were more tender through 21 days of aging. In the current study, as postmortem aging progressed, the abundance of intact troponin-T and desmin decreased indicating improved tenderness regardless of HCW. Koohmaraie (1992) reported higher temperatures increase the rate of calpain activation, an enzyme that breaks down the majority of proteins during postmortem aging. This could be beneficial in carcasses with higher internal temperatures because it could increase aging at early postmortem times. However, Dransfield (1994) used a model to conclude calpains are inactivated at increased temperatures, which would indicate heavier carcasses with higher internal temperatures would have steaks with increased toughness. Although calpain was not analyzed during this study, the lack of differences in protein degradation and shear force values between HCW suggests the extended time at higher temperatures in heavier carcasses does not considerably affect product tenderness. In the current study, aging day had a stronger influence on tenderness. Despite some steaks having increased toughness at early aging days (i.e. day 5 strip steaks from LW carcasses), increasing the aging time provided a sufficient amount of time for those muscles to increase in tenderness and be comparable to steaks from heavier carcasses.

Implications

The current study found minimal impact of HCW on shear force and protein degradation under common industry chilling practices. Aging day, however, contributed greatly to tenderness. The interaction between HCW and aging in strip steaks is likely due to decreased primal weight and increased chilling rate compared to the Denver and eye of round steaks. With regard to Denver and strip steaks, provided steaks are sufficiently aged, consumers should feel confident steaks will meet their expectations for tenderness regardless of carcass size.

Acknowledgements

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Tables

Table 1. Mean values (± SE) of Warner-Bratzler shear force of Denver, strip, and eye of round steaks from USDA Select and low Choice carcasses by hot carcass weight and quality grade.

Item	WBSF (lb)	SE	P-value
Denver			
Hot Carcass Weight[1]			
LW	7.7	0.22	0.36
MW	8.1	0.22	
HW	8.1	0.22	
Quality grade[2]			
Se	8.0	0.19	0.58
LC	7.9	0.19	
Strip			
Quality grade			
Se[1]	10.2	0.4	0.62
LC	10.5	0.4	
Eye of round			
Hot Carcass Weight[1]			
LW	13.7	0.3	0.66
MW	13.4	0.3	
HW	13.8	0.3	
Quality grade[2]			
Se	13.7	0.3	0.81
LC	13.6	0.3	

[1]LW = light weight, 650–750 lb; MW = middle weight, 850–950 lb; HW = heavy weight, 1,025–1,150 lb

[2]Se = USDA Select; LC = low Choice

Table 2. Abundance of intact troponin-T in Denver, strip, and eye of round steaks from USDA Select and low Choice carcasses by hot carcass weight, quality grade, and aging day.

Item	Troponin-T[1]	SE	*P*-value
Denver			
Hot Carcass Weight[2]			
LW	1.26	0.06	
MW	1.16	0.06	0.38
HW	1.26	0.06	
Quality grade[3]			
Se	1.25	0.05	0.43
LC	1.20	0.05	
Strip			
Hot Carcass Weight[2]			
LW	0.89	0.05	
MW	0.87	0.05	0.41
HW	0.96	0.05	
Quality grade[3]			
Se	0.94	0.04	0.33
LC	0.88	0.04	
Aging day			
5	0.99	0.05	
10	0.84	0.05	0.09
14	0.90	0.05	
Eye of round			
Hot Carcass Weight[2]			
LW	1.28	0.09	
MW	1.33	0.09	0.31
HW	1.15	0.09	

[1]Values are reported as a ratio of the sample protein to an internal standard sample.

[2]LW = light weight, 650–750 lb; MW = middle weight, 850–950 lb; HW = heavy weight, 1,025–1,150 lb

[3]Se = USDA Select; LC = low Choice

Table 3. Abundance of intact desmin in Denver steaks from USDA Select and low Choice carcasses by hot carcass weight, quality grade, and aging day

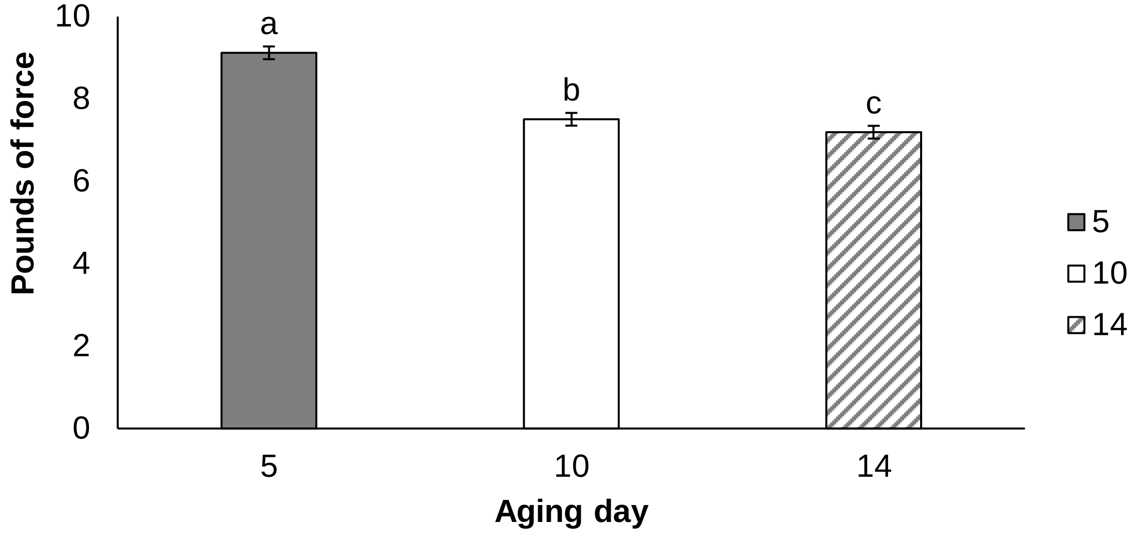
Item	Desmin[1]	SE	P-value
Denver			
Hot Carcass Weight[2]			
LW	1.13	0.03	0.12
MW	1.17	0.03	
HW	1.20	0.03	
Quality grade[3]			
Se	1.18	0.02	0.26
LC	1.15	0.02	
Aging day			
5	1.21	0.03	0.14
10	1.14	0.03	
14	1.15	0.03	
Eye of round			
Hot Carcass Weight[2]			
LW	1.16	0.3	0.73
MW	1.14	0.3	
HW	1.12	0.3	
Quality grade[3]			
Se	1.16	0.3	0.52
LC	1.13	0.3	

[1]Values are reported as a ratio of the sample protein to an internal standard sample

[2]LW = light weight, 650–750 lb; MW = middle weight, 850–950 lb; HW = heavy weight, 1,025–1,150 lb

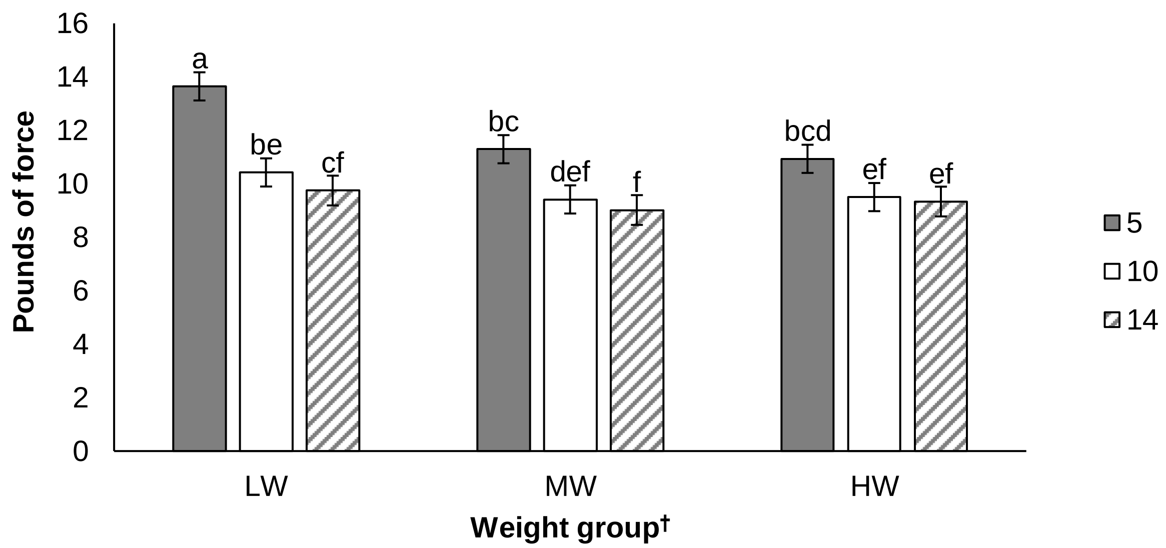
[3]Se = USDA Select; LC = low Choice

Figures



[a-c] Means with different superscripts are significantly different ($P < 0.05$)

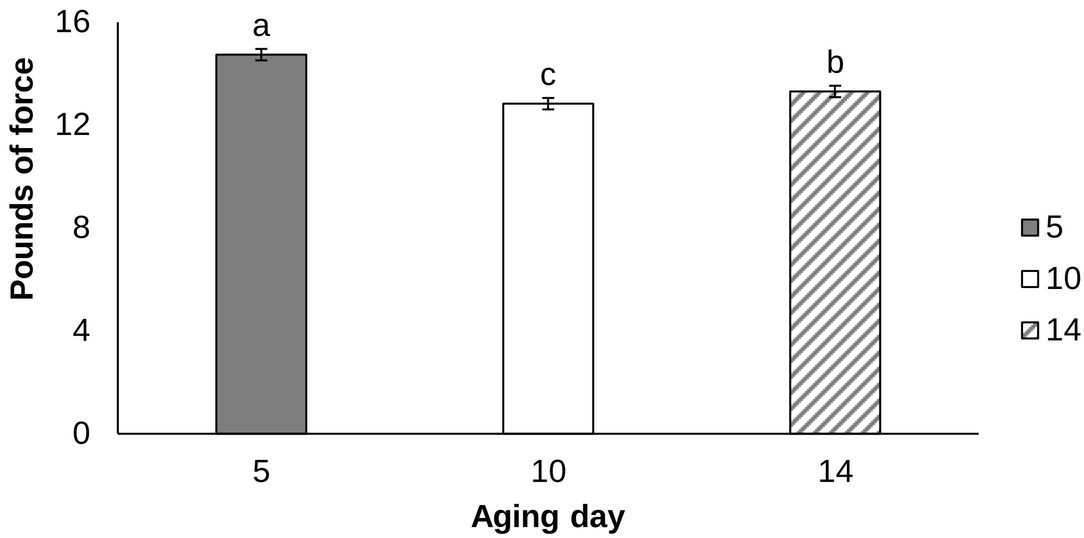
Figure 1. Mean values (± SE) of Warner-Bratzler shear force of Denver steaks by aging day from USDA Select and low Choice carcasses.



†LW = light weight, 650–750 lb; MW = middle weight, 850–950 lb; HW = heavy weight, 1,025–1,150 lb

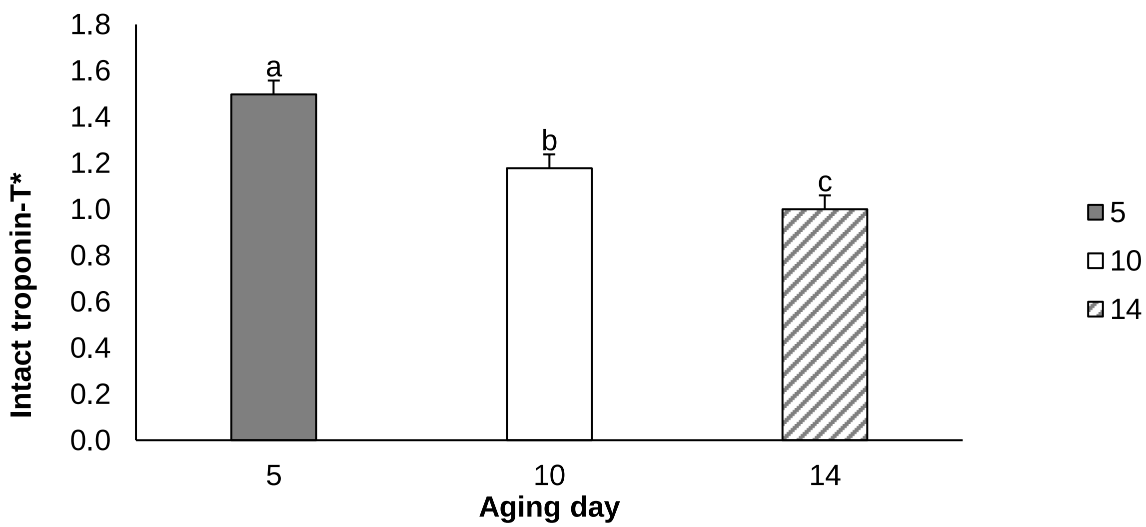
[a-f] Means with different superscripts are significantly different ($P < 0.05$)

Figure 2. Mean values (± SE) of Warner-Bratzler shear force of strip steaks from USDA Select and low Choice carcasses by aging day within weight group.



[a-c] Means with different superscripts are significantly different ($P < 0.05$)

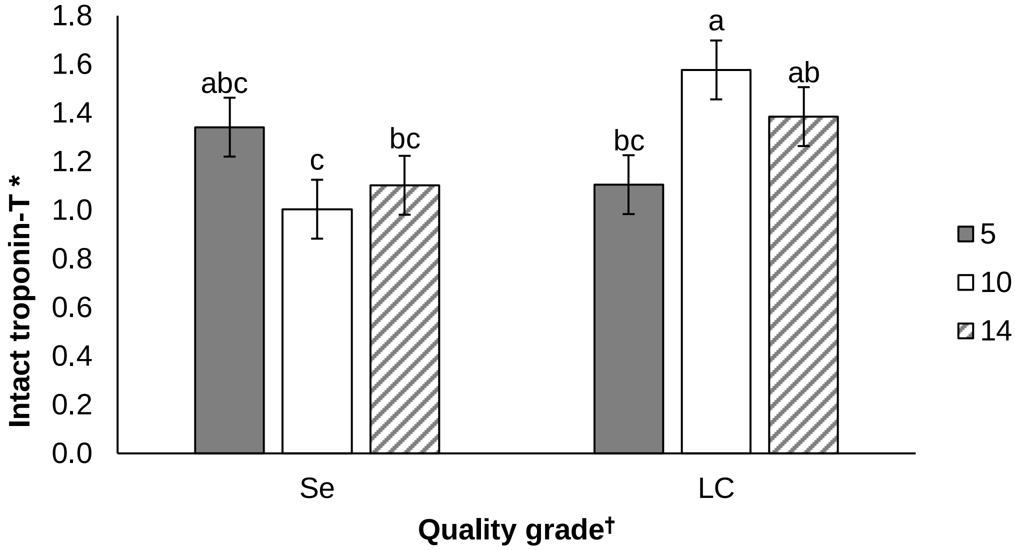
Figure 3. Mean values (± SE) of Warner-Bratzler shear force of eye of round steaks from USDA Select and low Choice carcasses by aging day.



*Values are reported as a ratio of the sample protein to an internal standard sample

[a-c] Means with different superscripts are significantly different ($P < 0.05$)

Figure 4. Abundance of intact troponin-T in Denver steaks from USDA Select and low Choice carcasses by aging day.

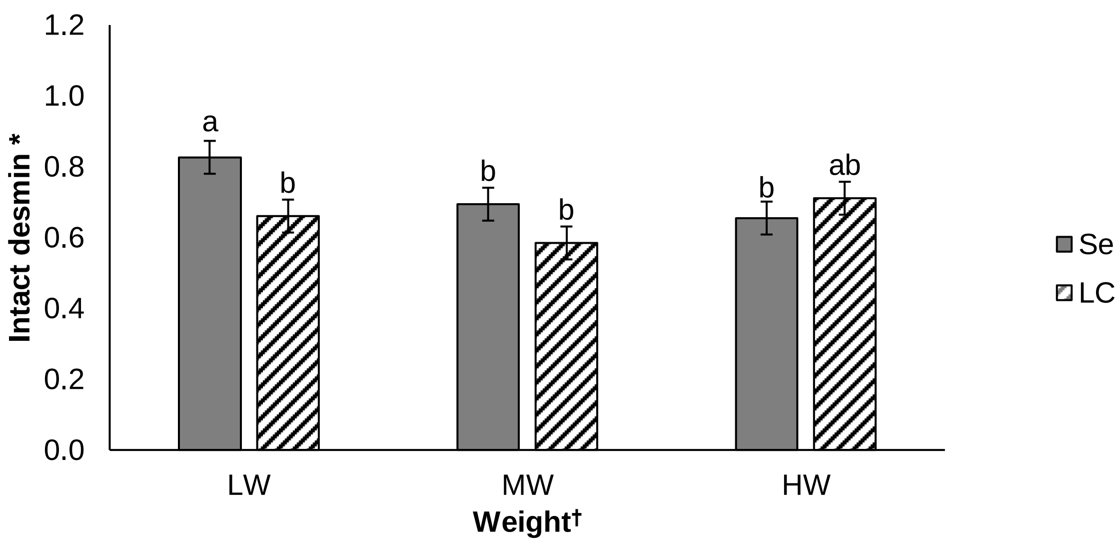


†Se = USDA Select; LC = low Choice

*Values are reported as a ratio of the sample protein to an internal standard sample ($P < 0.05$)

[a-c] Means with different superscripts are significantly different ($P < 0.05$)

Figure 5. Abundance of intact troponin-T in eye of round steaks from USDA Select and low Choice carcasses by quality grade and aging day.

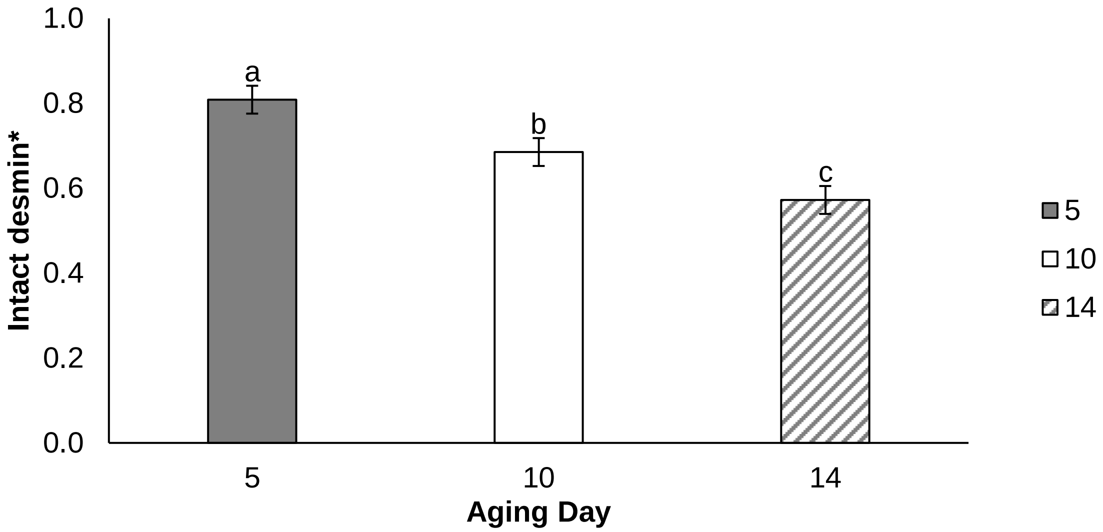


†LW = light weight, 650–750 lb; MW = middle weight, 850–950 lb; HW = heavy weight, 1,025–1,150 lb

*Values are reported as a ratio of the sample protein to an internal standard sample

[ab] Means with different superscripts are significantly different ($P < 0.05$)

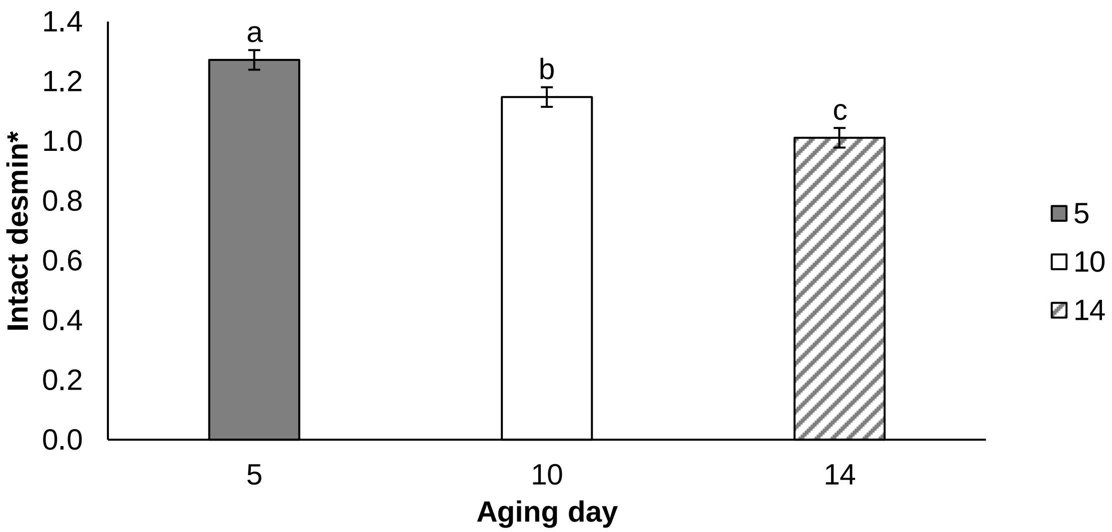
Figure 6. Abundance of intact desmin of strip steaks from USDA Select and low Choice carcasses by quality grade within weight group.



*Values are reported as a ratio of the sample protein to an internal standard sample

[a-c]Means with different superscripts are significantly different (*P* < 0.05)

Figure 7. Abundance of intact desmin in strip steaks from USDA Select and low Choice carcasses by aging day.



*Values are reported as a ratio of the sample protein to an internal standard sample

[ab]Means with different superscripts are significantly different (*P* < 0.05)

Figure 8. Abundance of intact desmin in eye of round steaks from USDA Select and low Choice carcasses by aging day.