K-STATE Research and Extension

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KANSAS STATE UNIVERSITY CATTLEMEN'S DAY

An Investigation on the Influence of Various Biochemical Tenderness Factors on Eight Different Bovine Muscles

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Abstract

The objective of this study was to identify the relative contribution of tenderness factors for eight beef muscles with various tenderness ratings. Top sirloin butt (TS), ribeye (R), brisket (B), flank (F), knuckle (K), eye of round (ER), chuck tender (CT), and shoulder clod (SC) were collected from ten U.S. Department of Agriculture upper 2/3 choice beef carcasses and were assigned to a 2- or 21-day aging period (n = 160). Sarcomere length, protein degradation, collagen content, mature collagen crosslink density, intramuscular lipid content, Warner-Bratzler Shear Force (WBSF), and trained sensory panel analysis were determined. Based on the correlation analysis, overall tenderness of F, CT, and SC were largely driven by the proteolysis of muscle fiber fibers (r = 0.45, 0.55, and 0.55, respectively; $P < 0.05$). In contrast, overall tenderness for B was determined by collagen content (r = -0.48; $P < 0.05$). Finally, overall tenderness of TS was correlated with lipid content (r = 0.51; $P < 0.05$). Interestingly, when all the cuts were combined together and analyzed as a whole, all of the biochemical measurements conducted in this study played a small but important role as an overall tenderness contributor ($P < 0.05$). Results from this study filled in some of the knowledge gap on the relative contribution of each tenderness component to the overall perception of tenderness from each cut. The industry can utilize this information to provide tenderness management strategies for each cut as well as improve the robustness of current tenderness predicting technology.

Introduction

Tenderness encompasses a universal term describing the amount of force required to bite through a piece of meat. Three factors underlie the complexity of tenderness: 1) the actomyosin effect or the influence of muscle fibers; 2) the background effect or the influence of connective tissue; and 3) the bulk density or lubrication effect, or the tenderness contributed by intramuscular fat. Each of these factors are further influenced by many different components contributing to the overall beef tenderness. Countless studies over the past three decades have evaluated the impact of various individual tenderness contribution components on meat tenderness. These components include proteolysis, sarcomere length, fat content, collagen content, and collagen crosslinks. However, the overall perception of beef tenderness is dependent on all the tenderness components as well as the interaction among them, and evaluating one or

two tenderness components does not provide the whole picture. Therefore, the objective of this study was to better understand the relationships of various biochemical tenderness-contributing components to the overall tenderness perception of eight different beef muscles.

Experimental Procedures

Ten U.S. Department of Agriculture upper 2/3 choice beef carcasses at one day postmortem were selected from a Midwest beef packing plant. Muscles TS, R, B, K, ER, and SC were collected only from the left side of the carcass. The F and CT muscles were collected from both sides of the carcass. The selected cuts of beef were vacuum packaged and transported to the Kansas State University Meat Lab for fabrication. The muscles were fabricated into steaks and assigned to two aging periods: 2 or 21 days. After aging, the sarcomere length, protein degradation, collagen content, mature collagen crosslink density, intramuscular lipid content, Warner-Bratzler Shear Force (WBSF), and trained sensory panel analysis were determined. The data were analyzed as a split plot design, with the whole plot being the beef cut, and the sub-plot factors being the aging time and the cut × aging time interaction.

Results and Discussion

As expected, all muscles studied increased in protein degradation from 2 to 21 days of postmortem storage ($P < 0.05$; Table 1). It is interesting to note that different muscles have different levels of protein degradation after aging. For example, R, B, K, ER, CT, and SC had more protein degradation ($P < 0.05$) compared to F after 21 days of aging. Due to the muscle function difference, B, K, CT, ER, and SC displayed greater collagen content ($P < 0.01$) compared to R and F (Figure 1), while TS was not different in collagen content ($P < 0.01$) compared to R and F. Muscles B and ER had greater collagen crosslink densities ($P < 0.01$) compared to the rest of the muscles (Figure 2). This result was expected since locomotive functions tend to display greater amounts of collagen content and higher collagen crosslink densities than muscles with a more postural or support function. Connective tissue layers specifically support and provide framework for transmission of contractile forces, therefore muscles that undergo more mechanical stress would be expected to contain higher amounts of collagen.

The differences in sarcomere length are potentially the result of differences in muscle fiber type. Muscles B and F displayed the longest sarcomeres, while R and TS displayed the shortest sarcomeres among the eight muscles evaluated ($P < 0.01$; Figure 3). The muscles that contain mainly oxidative muscle fibers displayed longer sarcomeres compared to muscles that contain mainly glycolytic muscle fibers. This may be because oxidative muscle fibers tend to contain lower levels of adenosine triphosphate (ATP) and reach rigor much faster than glycolytic fibers.

Most likely due to muscle function differences and muscle fiber type, F and R displayed the first and second greatest lipid contents, followed by TS, K, ER, and B, with CT having the lowest lipid content among the eight muscles evaluated ($P < 0.01$; Figure 4). Locomotive muscles tend to have lower lipid content compared to support muscles. Also, F most likely contains a large amount of lipid due to the prevalence of oxidative muscle fibers, which tend to be higher in lipid content.

As expected, B had the greatest WBSF value, while F and R exhibited the lowest WBSF values ($P < 0.05$; Figure 5). According to the biochemical analysis, R was expected to have one of the lowest WBSF values due to large amounts of protein degradation, low amounts of collagen content and collagen crosslink density, and a relatively high lipid content compared to the other muscles. On the other hand, B displayed long sarcomere lengths and displayed a fair amount of protein degradation at 21 days; however, B still had the highest WBSF values. The high WBSF value for B was likely attributed to the high amount of collagen and the highest collagen crosslink density found in the muscles. The higher rating for F's overall tenderness was likely attributed to the bulk density effect, for it had the highest lipid content. In addition, F displayed one of the longest sarcomere lengths. Shorter sarcomere lengths in comparison to longer sarcomere lengths are usually contracted muscle fibers and tend to increase toughness of the muscle due to the increased overlap of thick and thin filaments, requiring more penetration force. Furthermore, correlations between sarcomere length and tenderness tend to be strong in muscles that contain mainly oxidative fibers.

At 21 days of aging, R, F, and SC displayed the highest overall tenderness rating, followed by TS, K, CT, and ER, with B displaying the lowest rating for overall tenderness when evaluated by trained panelists ($P < 0.05$; Table 1). It is interesting to note that K and B only improved minimally in overall tenderness after 21 days of postmortem aging, while the other muscles improved significantly in overall tenderness. The correlation analysis is displayed in Table 2. The overall tenderness for TS showed a positive correlation with lipid content (r = 0.51; $P < 0.05$). The overall tenderness for B showed a negative correlation with collagen content (r = -0.48; $P < 0.05$) and a positive correlation with collagen crosslink density (r = 0.52; $P < 0.05$). There was a positive correlation for overall tenderness and protein degradation for F, CT, and SC (r = 0.45, 0.55, and 0.55, respectively; $P < 0.05$). On the other hand, overall tenderness for B may be driven by collagen content (r = -0.48; $P < 0.05$), and overall tenderness for TS was correlated with lipid content (r = 0.51; $P < 0.05$). Finally, the overall tenderness value for the combination of all eight cuts used in this study (n = 160) showed positive correlations for protein degradation (r = 0.33; $P < 0.05$) and lipid content (r = 0.22; $P < 0.05$), and a negative correlation for collagen content (r = -0.23; $P < 0.05$), collagen crosslink density (r = -0.24; $P < 0.05$), and sarcomere length (r = -0.41; $P < 0.05$).

Implications

Results from this study filled in some of the knowledge gap on the relative contribution of each tenderness component to the overall perception of tenderness from each cut. The industry can utilize this information to provide a tenderness management strategy for each cut as well as improve the robustness of current technology to predict tenderness.

Table 1. Interaction effects of eight retail beef cuts[1] aged for 2 or 21 days (n = 160)

Items	Days of aging	TS	R	B	F	K	ER	CT	SC	SEM[2]	*P*-value
Protein degradation, %										4.88	<0.05
	2	36.45^{Babc}	39.43^{Bab}	20.33^{Bd}	26.72^{Bcd}	44.56^{Ba}	30.64^{Bbcd}	36.53^{Babc}	28.77^{Bbcd}		
	21	50.87^{Abc}	62.23^{Aab}	55.47^{Aab}	40.88^{Ac}	64.67^{Aa}	53.89^{Aab}	61.29^{Aab}	60.47^{Aab}		
Overall tenderness[3]										2.87	<0.05
	2	42.30^{Bcd}	57.61^{Ba}	16.94^{Ae}	44.84^{Bbc}	50.23^{Bab}	37.95^{Bcd}	37.15^{Bd}	51.69^{Bab}		
	21	54.74^{Ac}	70.23^{Aa}	19.85^{Ad}	61.50^{Ab}	53.08^{Ac}	54.16^{Ac}	51.11^{Ac}	60.64^{Ab}		
Connective tissue amount[3]										2.84	<0.05
	2	31.05^{Ade}	19.95^{Af}	69.33^{Aa}	38.98^{Abc}	25.4^{Aef}	35.08^{Acd}	43.28^{Ab}	25.71^{Aef}		
	21	17.20^{Bd}	9.09^{Ae}	67.13^{Aa}	28.41^{Bb}	26.3^{Ab}	18.69^{Bcd}	23.70^{Bbc}	18.16^{Bd}		

$^{A-B}$Within a column, means without a common superscript differ at $P < 0.05$.

$^{a-f}$Within a row, means without a common superscript differ at $P < 0.05$.

[1]TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

[2] Standard error mean.

[3] Sensory scores: 0 = extremely tough/none 50 = neither tough nor tender; 100 = extremely tender/abundant.

Table 2. Correlation coefficient (r) of overall tenderness (trained panel) with different tenderness components of eight retail beef cuts[1]

Treatment	All cuts	TS	R	B	F	K	ER	CT	SC
Protein degradation	0.33*	0.15	0.43	0.37	0.45*	0.29	0.55*	0.37	0.55*
Collagen content	-0.23*	-0.08	0.37	-0.48*	-0.17	0.08	-0.29	0.13	0.05
Collagen crosslink density	-0.24*	-0.12	-0.07	0.52*	-0.21	0.34	0.35	0.07	-0.12
Lipid content	0.22*	0.51*	-0.36	0.20	0.05	-0.19	0.11	-0.38	-0.07
Sarcomere length	-0.41*	0.09	0.16	-0.16	-0.21	-0.28	-0.31	-0.14	-0.31

*$P < 0.05$

[1]TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

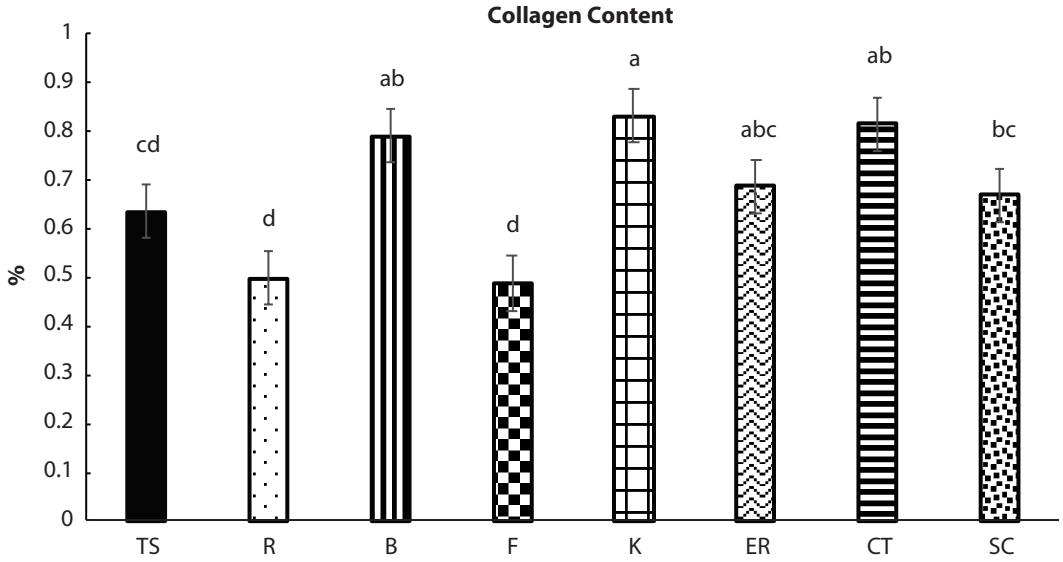

Figure 1. Collagen content of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

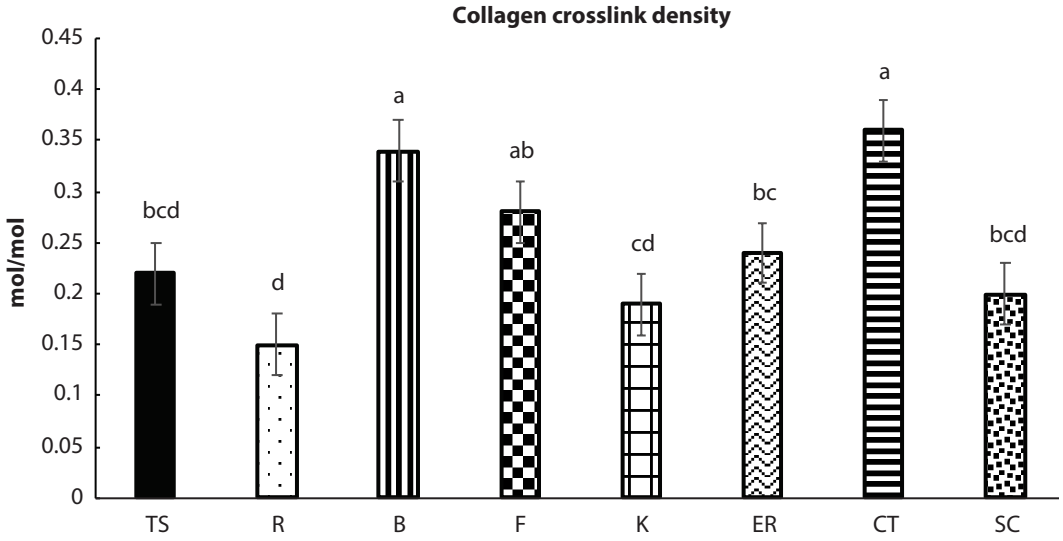

Figure 2. Collagen crosslink density of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

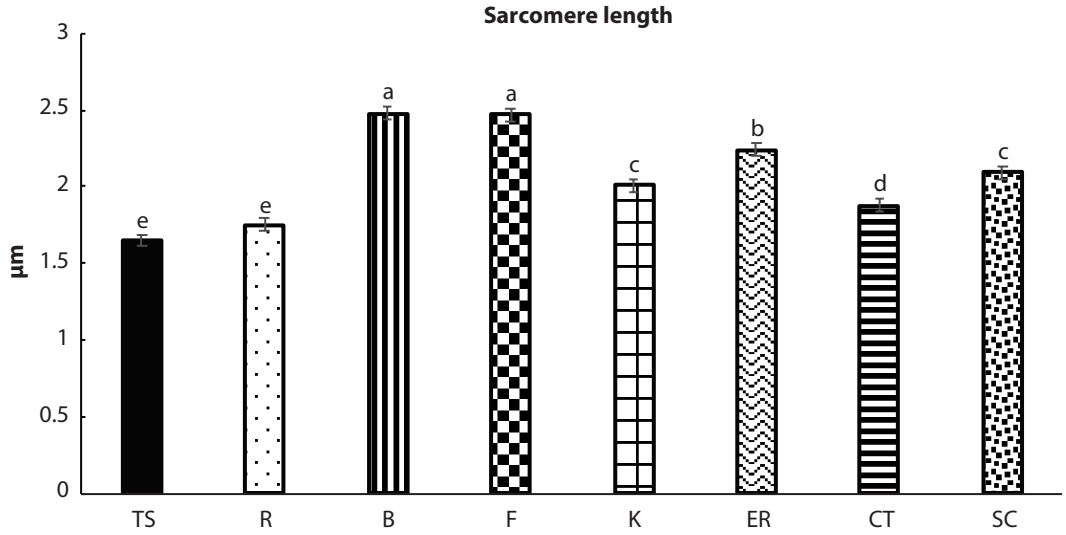

Figure 3. Sarcomere length of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

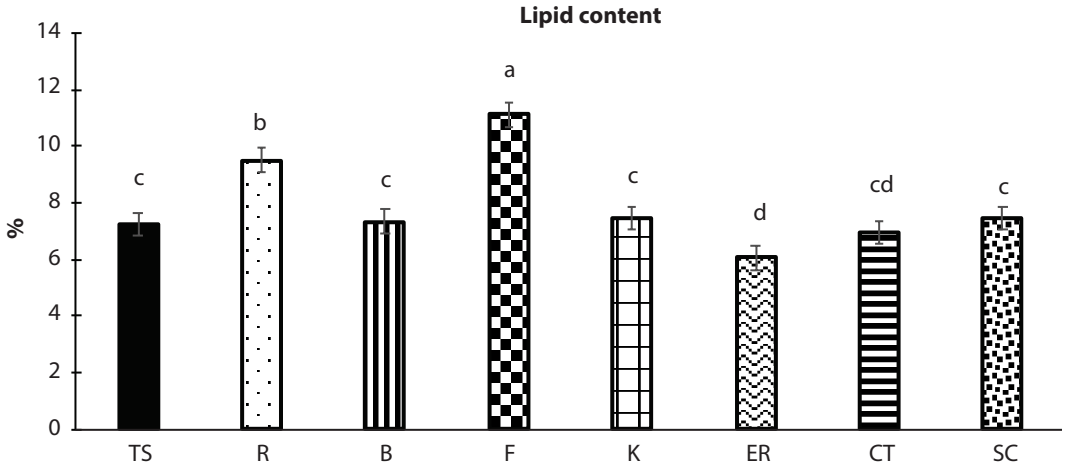

Figure 4. Lipid Content of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.

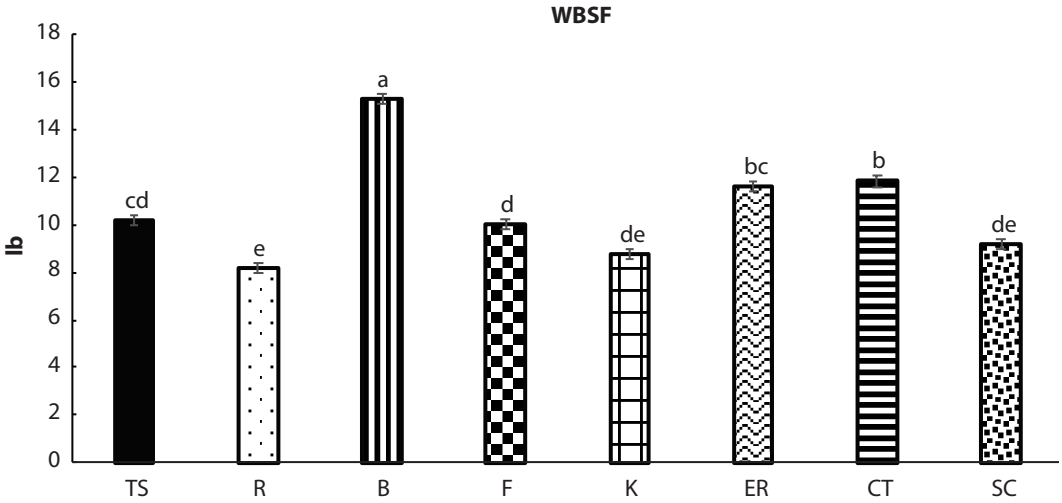

Figure 5. Warner-Bratzler Shear Force (WBSF) of eight retail beef cuts (n = 160). TS = Top sirloin butt; R = Ribeye; B = Brisket; F = Flank; K = Knuckle; ER = Eye of round; MT = Mock tender; SC = Shoulder clod.