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KANSAS STATE UNIVERSITY CATTLEMEN'S DAY

A Preliminary Investigation of the Contribution of Different Tenderness Factors to Beef Loin, Tri-tip, and Heel Tenderness

C.K.Y. Chun, W. Wu, A.A. Welter, T.G. O'Quinn, G. Magnin-Bissel, D.L. Boyle, and M.D. Chao

Abstract

The objective of this study was to identify the relative contribution of tenderness factors for three beef muscles with similar tenderness ratings. Longissimus lumborum (loin), tensor fascia latae (tri-tip), and gastrocnemius (heel) were collected from 10 U.S. Department of Agriculture choice beef carcasses, fabricated into steaks and assigned to a 5 or 21 day aging period (n = 60). Tri-tip had the longest sarcomere, followed by heel and loin (3.01, 2.59, and 1.71 μm, respectively; $P < 0.01$). Heel had the greatest relative troponin-T degradation percentage, followed by tri-tip and loin (68.10, 53.42, and 35.01%, respectively; $P < 0.01$). As expected, heel had the greatest collagen content, followed by tri-tip and loin (0.61, 0.40, and 0.28%, respectively; $P < 0.01$). Out of the three cuts, heel had the highest overall collagen crosslink density (0.20 mol/mol collagen; $P < 0.05$), while loin and tri-tip did not differ (0.13 and 0.15 mol/mol collagen, respectively; $P > 0.05$). Heel had lower lipid content than the others (2.68%; $P < 0.01$), while tri-tip and loin did not differ in lipid content (8.24 vs. 6.99 %; $P > 0.05$). Loin was ranked by the trained panel to have the highest overall tenderness, while tri-tip and heel did not differ in overall tenderness ($P > 0.05$). A multivariate regression analysis was conducted to quantify the relative contribution of each of the tenderness factors to overall tenderness evaluated by trained panelists. The equations indicated that each beef cut had a unique profile of tenderness contributors. Loin tenderness was driven by lipid content ($P < 0.05$); tri-tip tenderness was driven by collagen content ($P < 0.05$). Heel tenderness was driven by proteolysis ($P < 0.01$). Only collagen content may be casually used as an overall tenderness predictor for all three cuts.

Introduction

Beef tenderness is a complex palatability trait with many tenderness-contributing components. The overall perception of beef tenderness is dependent on all the tenderness-contributing components as well as the interaction among these components. Evaluating one or two tenderness components does not provide the whole picture of these interactions. One beef cut may excel in one or two of these tenderness compo-

nents, but still fail to be perceived as tender due to failing one single tenderness component. Therefore, the objective of this study is to understand the relative contribution of each tenderness component to beef muscles.

Experimental Procedures

Boneless beef strip loin (Institutional Meat Purchasing Specifications #180), heel (Institutional Meat Purchasing Specifications #171F), and tri-tip (Institutional Meat Purchasing Specifications #185C) were collected from 10 U.S. Department of Agriculture Choice beef carcasses from a commercial beef processing facility in the Midwest and transported back to Kansas State University's Meat Laboratory, Manhattan, KS. Steaks were fabricated from the anterior to the posterior end of each strip loin and dorsal to the ventral end of each tri-tip and heel after 2 and 21 days of aging. Steaks from each aging period from each subprimal were assigned to one of three assays: 1) trained sensory analysis; 2) objective tenderness evaluation (Warner-Bratzler shear force); or 3) physiochemical analysis (sarcomere length, proteolysis, intramuscular fat content, collagen crosslink densities and content). Sensory panelists were trained according to the American Meat Science Association sensory guidelines (AMSA, 2015). Steaks were cooked to medium doneness (160°F). Sensory panelists evaluated myofibril tenderness, connective tissue amount, lipid flavor intensity, and overall tenderness of the steak samples. Objective tenderness was evaluated using Warner-Bratzler shear force. Procedures were conducted according to sensory guidelines (AMSA, 2015). Steaks were also cooked to medium doneness. Grilled steaks were cooled at 39°F overnight, and then cored. Six cores were measured for each sample. Sarcomeres were imaged with a confocal microscope using a 100 × 1.4/f objective. Thirty sarcomeres were measured for each sample. Myofibrillar proteins were isolated and the degree of proteolysis was measured by troponin-T degradation using gel electrophoresis and western blotting. Intact and degraded forms of troponin-T were found at 35 and 28 kDa, respectively. Percent troponin-T degraded was measured by band intensities of degraded bands divided by band intensities of all bands in a specific lane. Fat content was measured by extracting lipid from samples via chloroform, methanol, and water. The chloroform layer was evaporated leaving lipid content. Percent lipid was calculated by dividing the lipid weight over the sample weight. Collagen content was determined by measuring hydroxyproline concentration. Hydroxyproline concentrations of the samples were determined using a spectrophotometer. A conversion factor of 7.14 for hydroxyproline to collagen ratio was used to determine collagen content of each sample. Mature collagen crosslinks pyridinoline and deoxypyridnoline were measured by an ultra-high-pressure liquid chromatography unit. Finally, a correlation analysis was conducted to quantify the relative contribution of each of the tenderness factors to overall tenderness evaluated by trained panelists.

Results and Discussion

Biochemical composition and objective tenderness of the three beef cuts are displayed in Table 1. Tri-tip had the longest sarcomere, followed by heel and loin (3.01, 2.59, and 1.71 μm, respectively; $P < 0.01$). It was interesting to note that heel increased in sarcomere length from 5 to 21 days of postmortem storage (2.49 vs. 2.70 μm; $P < 0.05$). Heel had the greatest relative troponin-T degradation percentage, followed by tri-tip and loin (68.10, 53.42, and 35.01%, respectively; $P < 0.01$). As expected, heel had the

greatest collagen content, followed by tri-tip and loin (0.61, 0.40, and 0.28%, respectively; $P < 0.01$). It is also worth noting that collagen content decreased for all cuts from 5 to 21 days of postmortem storage (0.46 vs. 0.39%; $P < 0.05$). Out of the three cuts, heel had the highest total mature collagen crosslink density (0.20 mol/mol collagen; $P < 0.05$), while loin and tri-tip did not differ (0.13 and 0.15 mol/mol collagen, respectively; $P > 0.05$). It is important to note there was also an aging effect for collagen crosslinks. As collagen content decreased with aging, total mature crosslinks maintained their concentration, resulting in an increase in mature collagen crosslink density from 5 to 21 days of postmortem storage (0.14 vs. 0.20; $P < 0.01$). Heel had lower lipid content than the others (2.68%; $P < 0.01$), while tri-tip and loin did not differ in lipid content (8.24 vs. 6.99%; $P > 0.05$). As expected, loin had the lowest Warner-Bratzler shear force value followed by tri-tip and heel (5.53, 7.96, and 9.66 lb, respectively; $P < 0.01$).

Trained panel analysis of the three beef cuts are displayed in Table 2. Loin was ranked by the trained panel to have the highest overall tenderness, while tri-tip and heel did not differ in overall tenderness ($P > 0.05$). Biochemical measurements showed tri-tip to have all the attributes of a tender cut, yet panelists rated it similar to heel in overall tenderness. This leads us to speculate about the results of our mature crosslink data. More research is required to characterize collagen and collagen crosslinks to provide a better understanding of meat tenderness. Table 3 shows that each beef cut had a unique profile of tenderness contributors. Loin tenderness was driven by lipid content ($P < 0.05$); tri-tip tenderness was driven by collagen content ($P < 0.05$). Heel tenderness was driven by proteolysis ($P < 0.01$). Only collagen content may be casually used as an overall tenderness predictor for all three cuts.

Implications

Each muscle showed a unique tenderness factor profile. Loin is inherently tender, and tri-tip has the attributes for a tender cut as shown by our biochemical analysis, yet panelists rated tri-tip to have similar overall tenderness as heel, an inherently tough muscle. Collagen characteristics are the least studied tenderness factors, but may play the greatest role in meat tenderness regardless of cut.

References

American Meat Science Association. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

Table 1. Physiochemical analysis and Warner-Bratzler shear force of three retail beef cuts aged for 5 or 21 days

		Treatment			Standard error of the means	
Items	**Age**	**[1]Loin**	**[2]Tri-tip**	**[3]Heel**		***P*-value**
Troponin-T, % degraded					3.44	< .01
	5	29.99^{Aa}	38.83^{Aa}	60.36^{Ab}		
	21	40.04^{Bb}	68.00^{Ba}	75.84^{Ba}		
Sarcomere length, μm					0.08	< .05
	5	1.79^{Ac}	3.07^{Aa}	2.49^{Ab}		
	21	1.63^{Ac}	2.96^{Aa}	2.70^{Bb}		
Lipid content, %		6.99^{a}	8.24^{a}	2.68^{b}	0.56	< .01
Collagen, %		0.28^{c}	0.40^{b}	0.61^{a}	0.39	< .01
Warner-Bratzler shear force, lb		5.53^{c}	7.96^{b}	9.66^{a}	0.12	< .01
Pyridinoline + deoxypyridinoline/collagen, mol/mol		0.14^{b}	0.16^{b}	0.21^{a}	0.02	= .01
Pyridinoline/collagen, mol/mol		0.13^{b}	0.15^{b}	0.20^{a}	0.01	< .01
Deoxypyridinoline/collagen, mol/mol					0.002	< .01
	5	0.018^{aA}	0.016^{aA}	0.007^{bA}		
	21	0.002^{bB}	0.014^{aA}	0.008^{abA}		

[a-c]Within a row, means without a common superscript differ at $P < 0.05$.
[A-B]Within a column, means without a common superscript differ at $P < 0.05$.
[1]Loin = Longissimus lumborum.
[2]Tri-tip = Tensor facia latae.
[3]Heel = Gastrocnemius.

Table 2. Trained panel ratings[1] of three retail beef cuts aged for 5 or 21 days

	Treatment			Standard error of the means	
Items	**Loin**	**Tri-tip**	**Heel**		***P*-value**
Myofibril tenderness	75.82^{a}	63.00^{b}	63.48^{b}	1.91	<.01
Connective tissue	6.08^{b}	14.15^{a}	18.22^{a}	1.57	<.01
Lipid flavor	23.21^{b}	28.07^{a}	21.88^{b}	0.784	<.01
Overall tenderness	73.95^{a}	59.04^{b}	57.44^{b}	2.36	<.01

[a-b]Within a row, means without a common superscript differ at $P < 0.05$.
[1] Sensory scores: 0 = extremely tough/none/bland; 50 = neither tough nor tender; 100 = extremely tender/abundant/intense.

Table 3. Correlation coefficient (r) of overall tenderness with different tenderness components of three retail beef cuts

	Correlation coefficient (r) to overall tenderness			
Tenderness components	**All cuts**	**Loin**	**Tri-tip**	**Heel**
Collagen content	-0.423***	0.352	-0.456**	-0.143
Pyridinoline density	-0.094	0.317	0.089	0.050
Deoxypyridinoline density	-0.114	-0.267	0.056	-0.126
Lipid content	0.104	-0.534**	-0.069	-0.012
Degraded troponin-T%	-0.237	-0.102	0.145	0.730***
Sarcomere length	-0.452***	0.276	0.099	0.387*

* $P < 0.10$.
** $P < 0.05$.
*** $P < 0.01$.