PROJECT SUMMARY
PRODUCT QUALITY

BEEF
RESEARCH

A Preliminary Study to Investigate the Contribution of Different Tenderness Factors to Beef Loin, Tri-Tip and Heel Tenderness

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Background

Tenderness, in its simplest form, is described as how much force is required to bite through a piece of meat, but yet, it is complex because it is influenced by many contributing components. Overall perception of beef tenderness is dependent on all the tenderness contributing components as well as the interaction among them, and evaluating 1 or 2 tenderness components does not provide the whole picture. One beef cut may excel in 1 or 2 of the tenderness components, but still fail to be perceived as tender due to the failure of one single tenderness component. Countless studies over the past three decades have evaluated the impact of various individual tenderness contributing components on meat tenderness, such as proteolysis, sarcomere length, muscle fiber cross-sectional area, fat content and fatty acid profile, collagen content and collagen crosslinks, just to name a few. All of the tenderness components described above have been shown to influence beef tenderness, but how much do these components individually contribute to a beef muscle's overall perception of tenderness?

In a beef tenderness ranking study supported by the Beef Checkoff, *longissimus lumborum*, *gastrocnemius* and *tensor fascia latae* received similar ratings in tenderness, but their overall tenderness is known to be contributed by varying levels of tenderness-contributing components. Based on their functionalities and known properties, we know *longissimus lumborum* (loin) is a muscle of support that exhibits high intramuscular fat, low collagen density and great aging response. *Gastrocnemius* (heel) is a muscle of locomotion which exhibits low intramuscular fat, high collagen content and unknown response to aging. *Tensor fascia latae* (tri-tip) functions in both roles of support and locomotion, with limiting information on its biochemical properties. As these 3 cuts are categorized in the same tenderness group, but with distinct properties, they serve as the ideal model to evaluate the relative contributions of the proposed tenderness components on overall perception of beef tenderness.

Objective

The objective of this study was to obtain preliminary data to better understand the contribution of each tenderness factor to the perception of tenderness of three specific beef muscles with similar tenderness rating.

Methods

Boneless beef striploin (NAMP #180), heel (NAMP #171F) and tri-tip (NAMP #185C) were collected from 10 USDA Choice beef carcasses (n=30) from a commercial beef processing facility in the Midwest and transported back to KSU Meat Laboratory. Steaks were from the anterior to the posterior end of each striploin and dorsal to the ventral end of each tri-tip and heel after 2 and 21 d of aging. Steaks from each aging period, from each subprimal, were assigned to one of 3 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 and content).

All data were analyzed as a split-plot using PROC GLIMMIX of SAS (version 9.4, Cary, NC). The model included the whole-plot factor of meat cut, the sub-plot factors of aging time and the cut × aging time interaction. To determine the significance of the correlation between the tenderness contributors and overall tenderness (from trained panel) of each muscle, a multivariate regression model was constructed using PROC REG and the stepwise selection procedure, with variable required to be significant ($P < 0.05$) to remain in the final model.

Important Findings

Biochemical composition of the 3 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 d of post-mortem storage (2.49 vs 2.70 µm; $P < 0.05$). Heel had the greatest relative troponin-T degradation %, 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 (6.06, 3.98 and 2.76 mg/g of muscle tissue, respectively; $P < 0.01$). It was also worth noting that collagen content decreased for all cuts from 5 to 21 d of post-mortem storage (4.64 vs 3.90 mg/g muscle tissue; $P < 0.05$). Out of the 3 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 over aging, total mature crosslinks maintained its concentration, resulting in an increase in mature collagen crosslink density from 5 to 21 d of post-mortem 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).

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; table 2). A multivariate regression analysis was conducted to quantify the relative contribution of each of the tenderness factors to overall tenderness evaluated by trained panelists (Table 2). 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). Surprisingly, heel tenderness was driven by proteolysis (P< 0.01). Only collagen content may be casually used as an overall tenderness predictor for all 3 cuts.

Implications

Results indicate that loin is an inherently tender cut with moderate proteolytic activity, high fat content, low collagen levels, but short sarcomere length. Tri-tip had long sarcomere length, great proteolytic activity, high fat content, and a moderate level of collagen. Finally, heel had long sarcomere length, great proteolytic activity, but low-fat content and a high level of collagen. Yet, tri-tip and heel were both rated to have similar overall tenderness. The one biochemical trait that could explain this phenomenon was that tri-tip had a greater level of a specific mature collagen crosslink - deoxypyridioline compared to heel. The collagen characteristic is the least studied tenderness factor, but it may play the greatest role in meat tenderness regardless of cut. More research is needed to characterize collagen and collagen crosslinks to continue to improve overall meat tenderness.

Tables

Table 1. Sarcomere length, troponin-T (TNT) degradation, lipid content, collagen content, Warner-Bratzler shear force (WBSF), and collagen crosslink density of 3 retail beef cuts aged for 5 or 21 days (n=60).

		Treatment				
	Age	[1]Loin	[2]Tri-tip	[3]Heel	SEM	P-value
Items						
[4]TNT, % 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					.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^{b}	2.68^{b}	0.56	< .01
Collagen, mg/g of wet tissue		2.76^{c}	3.98^{b}	6.06^{a}	0.39	< .01
[5]WBSF, Kgf		2.51^{c}	3.61^{b}	4.38^{a}	0.12	< .01
[6]PYD + [7]DPD/Collagen, mol/mol		0.14^{b}	0.16^{b}	0.21^{a}	0.02	= .01
PYD/Collagen, mol/mol		0.13^{b}	0.15^{b}	0.20^{a}	0.01	< .01
DPD/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*, [4] Troponin-t degradation,
[5] Warner-Bratzler shear force, [6] Pyridinoline, [7] Deoxypyridinoline

Table 2. Regression equation and coefficient between tenderness factors and retail beef cuts.

Responses	Regression equations	R^2
All cuts	Overall tenderness = 87.686-1.759 x collagen content -6.843 x sarcomere length	0.295
Loin	Overall tenderness = 91.988-2.58 x lipid content	0.285
Tri-tip	Overall tenderness = 72.798-3.461 x collagen content	0.208
Heel	Overall tenderness = 14.466+0.631 x degraded TNT%	0.533

Stepwise procedure used require all variables in the model to be significant (P < 0.05).

Figures

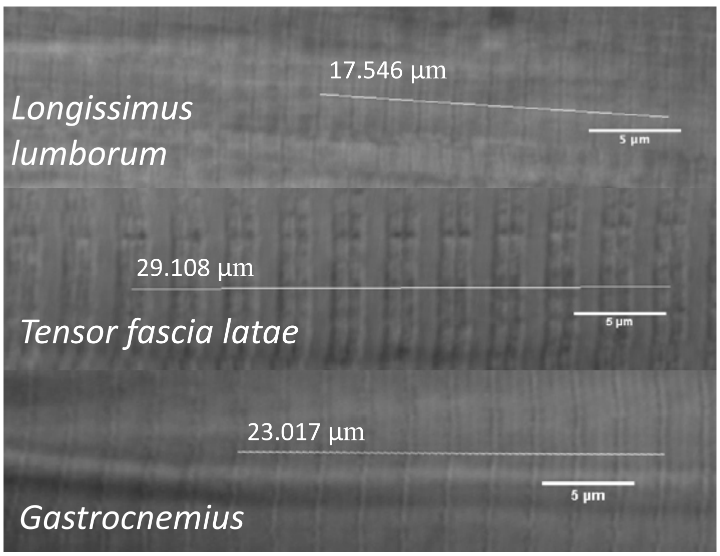

Figure 1. Representative images of sarcomere length for individual retail cuts.