Chemical, Fatty Acid and Sensory Characteristics of Beef from Cattle Grazing Forages Supplemented with Soyhulls vs. USDA Choice and Select Beef

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Story in Brief

Increased concerns for a healthier diet have spurred interests in forage-fed beef due to proportions of fatty acids that have exhibited a healthy impact when incorporated into a dietary regimen. Supplementing concentrates to cattle on a forage ration can improve palatability, but can negatively impact the healthier fatty acid profile associated with a forage ration. Therefore, over two consecutive years, steaks from cattle (n = 107) grazing three cool season grazing systems consisting of either orchardgrass pasture or fescue pasture, each with soyhull supplementation, or fescue pasture with no supplementation for a control were compared with USDA Choice and Select steaks obtained from area supermarkets for chemical, fatty acid and sensory characteristics. Steaks from all three forage treatments had more ($P < 0.05$) longissimus conjugated linoleic acid (CLA; 18:2*cis*-9, trans-11) and lower ($P < 0.05$) n-6 to n-3 fatty acid ratios than USDA Choice or Select steaks. Supplementing soyhulls did not decrease ($P > 0.05$) longissimus CLA, and sensory evaluation revealed that the supplemented treatments had improved ($P < 0.05$) beef/brothy and reduced ($P < 0.05$) grassy characteristics when compared to the control. These results suggest supplementing soyhulls to cattle on forage can improve the sensory characteristics of the beef without dramatically hindering the fatty acid profile associated with forage-fed beef.

Introduction

Forage-fed beef has taken a "healthy" role as a marketing strategy due to an increased awareness for a healthier human diet. Typically, beef from cattle on a forage diet has been considered healthy due to either its leanness or a healthier fatty acid profile. In human health, certain fatty acid interests are increased levels of conjugated linoleic acid (CLA), which has exhibited anticarcinogenic properties, and lowering the ratio of n-6 to n-3 fatty acids, which can aid in cardiovascular health (Lee et al., 1989; Whigham et al., 2000). However, forage-fed beef can experience decreased consumer acceptance due to differences in juiciness or tenderness (Muir et al., 1998), and most commonly differing flavor characteristics when compared to grain-fed beef (Melton et al., 1983). Increasing the portion of grain in the diet can allow for improved flavor desirability (Smith et al., 1983).

Supplementation of forage-fed beef can allow for increased gains, enhanced carcass quality, and improved palatability; however, increased incorporation of concentrates in the diet can decrease forage utilization and deleteriously affect the fatty acid profile associated with the healthier aspects of forage-fed beef (French et al., 2000; Griebenow et al., 1997). Therefore, the objectives of this study were to determine if supplementation of soyhulls, a highly digestible fiber source, could allow for improved sensory characteristics without negatively affecting the perceived healthier fatty acid profile commonly present in forage-fed beef.

Experimental Procedures

Animals. For this study, British and British x Continental fall- and spring-born beef steers and heifers (n = 107) were selected from a commercial cowherd at the University of Tennessee Experiment Station, Springhill, TN. Cattle were assessed and chosen based on three divergent biological types for a separate trial. This study was replicated over two consecutive years consisting of 54 animals utilized each year. One heifer was removed from the first year's study due to chronic illness.

After weaning, the randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture (n = 35) supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture (n =36) with soyhull supplementation (Fescue), or fescue pasture (n = 36) with no supplementation (Control). Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring, and 1 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 days when the cattle were reweighed. Grazing continued into the summer months (mean days of age = 555), until forage availability started to diminish and cattle had attained a relative degree of finish determined by visual appraisal, whereupon all cattle, within a year, were sent to a commercial slaughtering facility.

After carcasses had chilled for 48 h, a three-rib section (10th to 12th ribs) of the wholesale rib from the right side of each carcass was removed, vacuum-sealed, transported back to the University of Arkansas and aged for an additional 5 days before subsequent analyses.

For comparison to the forage-fed beef, USDA Choice (Choice) and Select (Select) ribeye steaks were randomly chosen from area supermarkets or purveyors to be representative of those typically available to consumers. Unless otherwise specified, the number of USDA Choice and Select steaks were equal in number to those from the forage-fed treatments for individual analyses.

Warner-Bratzler shear force and cooking loss. For Warner-Bratzler shear force (WBS) analysis, rib steaks (1 in thick) were cooked in a convection oven until the internal temperature of each steak was 158°F. After cooking, steaks were allowed to cool to room temperature for approximately 2 h, and upon cooling, five 0.5-in diameter cores were removed from the longissimus muscle from each steak for WBS. Each core was sheared with a Warner-Bratzler shear (WBS) attachment using an Instron (Canton, MA) Universal Testing Machine.

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Cooking loss of the steaks was determined during the cooking process for WBS. After steaks were removed from the vacuum-sealed pouches, each steak was weighed on a balance prior to cooking. Upon completion of cooking, a final weight was obtained for cooking loss calculations.

Chemical analyses. For fatty acid, lipid, and moisture analyses a sub-sample consisting of 14 Choice and 14 Select steaks was utilized. Samples from the forage treatments consisted of the total number of observations in each treatment (n = 36 each).

Percent moisture was obtained by dicing the longissimus muscle of a steak and utilizing approximately a 50-g sample to represent a homogenous portion. Samples were freeze-dried for approximately 96 h. After drying, percentage moisture was calculated, and samples were placed in a commercial blender, ground and stored in a freezer at - 20°F for later determination of total lipids and fatty acid profiles.

Total lipids were obtained using the method as described by Rule (1997). Tissue samples weighing 200 mg were utilized, and lipid extraction was performed with chloroform-methanol, followed by chloroform removal and evaporation to yield the lipid fraction.

For fatty acid analysis, total lipids were extracted by the same method previously described. Fatty acid methyl esters (FAME) were prepared by transmethylation utilizing methanol and HCl as described by Murrieta et al. (2003). Tridecanoic acid (13:0; 1 mg) was used as the internal standard for all samples. Fatty acid methyl esters were analyzed using a Hewlett-Packard 5890 series II gas chromatograph (Hewlett-Packard, Avondale, PA) equipped with a flame ionization detector and a 60-m x 0.25-mm fused silica capillary column (SP-2380; Supelco, Bellefonte, PA).

Taste-panel. Sensory characteristics of the longissimus steaks were obtained by a professional taste-panel at Texas A & M University, College Station, TX. A sub-sample consisting of 24 steaks per forage treatment and 14 Choice and 14 Select steaks (n = 100) was utilized for determination of sensory characteristics. A six-member taste panel was utilized to determine aromatic, feeling-factor, taste and aftertaste, and textural sensory characteristics. The aromatic, feeling factor, taste and aftertaste sensory characteristics were scored on a 15-point scale (0 = not detected; 15 = extremely intense). Textural sensory characteristics were scored on an 8-point scale (1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense).

Statistical analysis. Comparisons of steaks from the three forage treatments and USDA Choice and Select steaks by one-way analysis of variance blocked by year were performed using PROC GLM in SAS (SAS Inst., Inc., Cary, NC.). Mean generation and separation was executed using LSMEANS with the PDIFF and STDERR options of SAS.

Results and Discussion

Least squares means for longissimus steak cooking loss, percentage lipid and moisture, and WBS are reported in Table 1. Choice steaks had the highest ($P < 0.05$) lipid percentage and the lowest ($P < 0.05$) moisture percentage compared to all other treatments. Fescue and Orchard steaks had higher ($P < 0.05$) lipid percentages than Control or Select steaks. Control steaks had lesser ($P < 0.05$) cooking losses than Choice steaks, but did not differ ($P > 0.05$) from the other treatments. The WBS force values for Choice were lowest ($P < 0.05$), indicating improved tenderness; however, steaks from all treatments had less than 13.2 lb (6 kg) shear force, an index of tenderness, indicating all treatments could be classified as tender.

Longissimus fatty acid least squares means are reported in Table 2. Choice and Select steaks had increased ($P < 0.05$) 18:2cis- 9,12 percentages, and had decreased ($P < 0.05$) 18:2*cis*- 9, trans-11 (CLA) and 18:3*cis*- 9,12,15 percentages compared to the forage treatments. In fact, forage treatments had greater than twice the CLA content than Choice or Select steaks. There were no differences ($P > 0.05$) between forage treatments for CLA, but the Control steaks did have increased ($P < 0.05$) 18:3*cis*- 9,12,15 percentages. This increase could be due to increased forage ingestion associated with no supplemented feed. Therefore, the increased 18:3*cis*- 9,12,15 percentages in Control lean tissue is probably a result of increased ingestion of fescue forage, which typically has a high percentage of 18:3*cis*- 9,12,15. The Control steaks also had higher ($P < 0.05$) percentages of 20:5*cis*- 5,8,11,14,17 and 22:5*cis*- 7,10,13,16,19 than all other treatments; thus allowing the Control steaks to have a lower ($P < 0.05$), more desirable, n-6 to n-3 fatty acid ratio than all other treatments. However, the Fescue and Orchard longissimus steaks did have a lower ($P < 0.05$) n-6 to n-3 ratio than Choice or Select steaks.

Sensory profile characteristics are reported in Table 3. Although Control longissimus steaks had the lowest ($P < 0.05$) beef/brothy sensory characteristic, there were no differences ($P > 0.05$) between Choice, Fescue, Orchard or Select longissimus steaks, indicating an improved beef flavor with soyhull supplementation. Furthermore, longissimus steaks from Fescue and Orchard had lower ($P < 0.05$) grassy sensory values than the Control, and did not differ ($P > 0.05$) from Choice or Select steaks. There were no differences ($P > 0.05$) between treatments for juiciness, and even though longissimus steaks from Choice were rated more tender ($P < 0.05$) for overall tenderness, there were no differences ($P > 0.05$) between forage treatments or Select steaks.

Implications

Implementing soyhull supplementation on a forage-feeding regimen can allow for improved flavor characteristics to levels similar to Choice steaks while maintaining heightened CLA concentrations and a more acceptable n-3 fatty acid profile compared to typical supermarket steaks available to the consumer.

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Table 1. Least-squares means for longissimus cooking loss, lipid percentage, moisture percentage and Warner-Bratzler shear force (WBS) by treatment[a].

	Treatment				
Item	Control	Fescue	Orchard	Choice	Select
Cooking loss[b]	27.54 ± 0.77^{x}	27.13 ± 0.78^{x}	28.77 ± 0.79^{wx}	30.14 ± 0.78^{w}	29.28 ± 0.78^{wx}
Lipid %[c]	2.56 ± 0.27^{y}	4.72 ± 0.27^{x}	5.00 ± 0.27^{x}	6.93 ± 0.42^{w}	3.29 ± 0.43^{y}
Moisture %[d]	74.43 ± 0.26^{w}	71.92 ± 0.26^{x}	71.70 ± 0.27^{x}	69.38 ± 0.42^{y}	72.38 ± 0.42^{x}
Shear (lb)	10.23 ± 0.20^{xy}	11.46 ± 0.20^{w}	11.42 ± 0.20^{wx}	8.12 ± 0.44^{z}	9.88 ± 0.20^{y}

[a] **Cooking loss and WBS: Choice, Control, Fescue, Orchard and Select (n = 36 each; n = 179 total)**
Lipid and moisture %: Control, Fescue and Orchard (n = 36 each); Choice and Select (n = 14 each)
Total sample (n = 135)
[b] Cooking loss calculated as: (Fresh weight – Cooked weight) / Fresh weight x 100
[c] Lipid percentage calculated as: Lipid weight / Tissue weight x (100 – percent moisture)
[d] Moisture percentage calculated as: (Wet weight – Dry weight) / Wet weight x 100
[wxyz] Within a row, means without a common superscript letter differ ($P < 0.05$)

Table 2. Least-squares means for individual fatty acids of longissimus muscle by treatment (n = 135)[a].

	Treatment				
Fatty acid[a]	Control	Fescue	Orchard	Choice	Select
12:0	0.29 ± 0.05	0.30 ± 0.06	0.26 ± 0.06	0.35 ± 0.08	0.28 ± 0.08
14:0	1.20 ± 0.07^{x}	1.41 ± 0.08^{wx}	1.33 ± 0.08^{wx}	1.61 ± 0.13^{w}	1.56 ± 0.13$_{w}$
14:1*cis*-9	0.54 ± 0.11^{y}	0.99 ± 0.11^{w}	0.86 ± 0.11^{wx}	0.56 ± 0.18^{xy}	0.45 ± 0.18^{xy}
15:0	2.58 ± 0.11^{w}	1.44 ± 0.11^{y}	1.83 ± 0.11^{x}	1.89 ± 0.18^{x}	2.04 ± 0.18^{x}
15:1*cis*-9	0.33 ± 0.02^{w}	0.18 ± 0.02^{x}	0.28 ± 0.02^{w}	0.16 ± 0.03^{x}	0.18 ± 0.03^{x}
16:0	22.80 ± 0.29^{x}	25.28 ± 0.29^{w}	24.50 ± 0.30^{w}	25.09 ± 0.47^{w}	22.90 ± 0.47^{x}
16:1*cis*-9	2.75 ± 0.09	3.13 ± 0.09	2.97 ± 0.09	3.06 ± 0.15	2.98 ± 0.15
16:1*trans*-9	0.94 ± 0.03^{w}	0.68 ± 0.03^{x}	0.72 ± 0.04^{x}	0.45 ± 0.06^{y}	0.50 ± 0.06^{y}
17:0	2.00 ± 0.14^{w}	1.51 ± 0.13^{x}	2.09 ± 0.14^{w}	1.76 ± 0.22^{wx}	1.76 ± 0.22^{wx}
17:1*cis*-9	1.01 ± 0.03^{x}	0.93 ± 0.03^{xy}	0.84 ± 0.03^{y}	0.87 ± 0.05^{y}	1.13 ± 0.05^{w}
18:0	13.70 ± 0.23^{w}	13.01 ± 0.23^{x}	12.91 ± 0.23^{x}	11.68 ± 0.37^{y}	11.49 ± 0.37^{y}
18:1*cis*-9	30.97 ± 0.47^{z}	34.98 ± 0.47^{w}	34.61 ± 0.47^{wx}	32.88 ± 0.75^{xy}	31.90 ± 0.75^{yz}
18:2*cis*-9,12	7.15 ± 0.32^{y}	6.47 ± 0.32^{y}	6.85 ± 0.32^{y}	9.85 ± 0.55^{x}	11.52 ± 0.53^{w}
18:2*cis*-9, *trans*-11 (CLA)	0.69 ± 0.02^{w}	0.70 ± 0.02^{w}	0.63 ± 0.02^{w}	0.25 ± 0.03^{x}	0.26 ± 0.03^{x}
18:3*cis*-6,9,12	0.04 ± 0.01^{x}	0.06 ± 0.00^{w}	0.05 ± 0.01^{wx}	0.03 ± 0.02^{x}	0.04 ± 0.01^{wx}
18:3*cis*-9,12,15	2.12 ± 0.07^{w}	1.28 ± 0.07^{x}	1.17 ± 0.07^{x}	0.39 ± 0.12^{y}	0.58 ± 0.12^{y}
20:4*cis*-5,8,11,14	3.55 ± 0.15^{w}	2.54 ± 0.16^{x}	2.61 ± 0.16^{x}	3.60 ± 0.26^{w}	3.79 ± 0.25^{w}
20:5*cis*-5,8,11,14,17	1.27 ± 0.04^{w}	0.38 ± 0.04^{y}	0.50 ± 0.04^{x}	0.28 ± 0.06^{y}	0.61 ± 0.06^{x}
22:0	0.98 ± 0.06^{w}	0.70 ± 0.06^{x}	0.86 ± 0.06^{wx}	0.90 ± 0.13^{wx}	0.92 ± 0.11^{wx}
22:5*cis*-7,10,13,16,19	1.53 ± 0.05^{w}	0.80 ± 0.05^{yz}	1.01 ± 0.05^{x}	0.64 ± 0.08^{z}	0.99 ± 0.08^{xy}
22:6*cis*-4,7,10,13,16,19	0.16 ± 0.01^{w}	0.08 ± 0.01^{x}	0.09 ± 0.01^{x}	0.08 ± 0.01^{x}	0.14 ± 0.01^{w}
PUFA	15.07 ± 0.46^{w}	10.03 ± 0.46^{y}	12.95 ± 0.46^{x}	12.90 ± 0.69^{x}	14.77 ± 0.69^{wx}
SFA	43.08 ± 0.37	43.40 ± 0.37	42.95 ± 0.37	43.48 ± 0.55	42.05 ± 0.55
PUFA / SFA	0.35 ± 0.01^{w}	0.23 ± 0.01^{y}	0.30 ± 0.01^{x}	0.30 ± 0.02^{x}	0.35 ± 0.02^{w}
n - 3	4.90 ± 0.13^{w}	2.21 ± 0.13^{y}	2.81 ± 0.13^{x}	1.46 ± 0.19^{z}	2.37 ± 0.19^{xy}
n - 6	9.37 ± 0.41^{x}	7.03 ± 0.41^{y}	9.42 ± 0.41^{x}	11.16 ± 0.62^{w}	12.09 ± 0.62^{w}
n - 6 / n - 3	1.92 ± 0.32^{z}	3.19 ± 0.32^{y}	3.38 ± 0.32^{y}	8.24 ± 0.48^{w}	5.69 ± 0.48^{x}

[a] Control, Fescue and Orchard (n = 36 each); Choice and Select (n = 14 each)
[b] Fatty acid percents expressed as proportion of all peaks observed by GLC
PUFA = Fatty acids with 2 or more double bonds; SFA = Fatty acids with no double bonds;
n-3 = 18:3*cis*- 9,12,15; 20:5*cis*-5,8,11,14,17; 22:5*cis*-7,10,13,16,19; 22:6*cis*-4,7,10,13,16,19
n-6 = 18:2*cis*-9,12; 18:3*cis*-6,9,12; 20:4*cis*-5,8,11,14
[wxyz] Within a row, means without a common superscript letter differ ($P < 0.05$)

Table 3. Least-squares means for sensory characteristics of longissimus muscle by treatment (n = 100)[a].

	Treatment				
Item	Control	Fescue	Orchard	Choice	Select
Aromatics[b]					
Beef/brothy	4.46 ± 0.08[x]	4.73 ± 0.08[w]	4.80 ± 0.08[w]	4.94 ± 0.10[w]	4.86 ± 0.10[w]
Beef fat	1.42 ± 0.06[y]	1.58 ± 0.06[xy]	1.61 ± 0.06[x]	1.82 ± 0.08[w]	1.59 ± 0.08[xy]
Serumy/bloody	1.49 ± 0.09	1.61 ± 0.09	1.58 ± 0.09	1.47 ± 0.12	1.51 ± 0.12
Grainy/cowy	0.0	0.0	0.0	0.0	0.0
Cardboard	0.11 ± 0.03	0.08 ± 0.03	0.10 ± 0.03	0.06 ± 0.04	0.10 ± 0.04
Painty	0.0	0.0	0.0	0.0	0.0
Fishy	0.0	0.0	0.0	0.0	0.0
Liver	0.27 ± 0.07	0.21 ± 0.07	0.26 ± 0.07	0.47 ± 0.09	0.25 ± 0.09
Soured	0.0	0.0	0.0	0.0	0.0
Browned/burnt	0.73 ± 0.10	0.83 ± 0.10	0.94 ± 0.10	0.80 ± 0.13	0.89 ± 0.13
Grassy	1.11 ± 0.08[w]	0.80 ± 0.08[x]	0.78 ± 0.08[x]	0.60 ± 0.11[x]	0.71 ± 0.11[x]
Milky/oily	0.61 ± 0.06	0.64 ± 0.06	0.69 ± 0.06	0.52 ± 0.08	0.48 ± 0.08
Old/putrid	0.10 ± 0.03	0.02 ± 0.03	0.05 ± 0.03	0.04 ± 0.03	0.02 ± 0.03
Feeling factors[b]					
Metallic	2.68 ± 0.04	2.81 ± 0.04	2.76 ± 0.04	2.71 ± 0.05	2.73 ± 0.05
Astringent	2.37 ± 0.03[wx]	2.45 ± 0.03[x]	2.42 ± 0.03[x]	2.28 ± 0.04[w]	2.39 ± 0.04[wx]
Tastes[b]					
Salt	1.98 ± 0.02	2.03 ± 0.02	2.00 ± 0.02	2.02 ± 0.02	2.01 ± 0.02
Sour	2.51 ± 0.05	2.52 ± 0.05	2.60 ± 0.05	2.48 ± 0.06	2.51 ± 0.06
Bitter	2.45 ± 0.05	2.43 ± 0.05	2.39 ± 0.05	2.29 ± 0.07	2.35 ± 0.07
Sweet	0.40 ± 0.04	0.50 ± 0.04	0.43 ± 0.04	0.59 ± 0.05	0.47 ± 0.05
Aftertastes[b]					
Sour	0.99 ± 0.07	0.92 ± 0.07	1.00 ± 0.07	1.08 ± 0.09	1.09 ± 0.09
Acid	1.27 ± 0.10	1.28 ± 0.10	1.19 ± 0.10	1.09 ± 0.14	1.26 ± 0.14
Bitter	0.90 ± 0.08	0.94 ± 0.08	0.82 ± 0.08	0.68 ± 0.11	0.83 ± 0.11
Liver	0.09 ± 0.03	0.03 ± 0.03	0.07 ± 0.03	0.14 ± 0.04	0.06 ± 0.04
Browned/burnt	0.14 ± 0.07	0.14 ± 0.07	0.20 ± 0.07	0.18 ± 0.08	0.25 ± 0.08
Metallic	1.72 ± 0.06[x]	1.89 ± 0.06[wx]	1.91 ± 0.06[w]	1.79 ± 0.08[wx]	2.02 ± 0.08[w]
Grassy	0.26 ± 0.05[w]	0.11 ± 0.05[x]	0.10 ± 0.05[x]	0.04 ± 0.06[x]	0.13 ± 0.06[x]
Milky/oily	0.30 ± 0.06	0.38 ± 0.06	0.37 ± 0.06	0.24 ± 0.08	0.23 ± 0.08
Lipburn	0.38 ± 0.03	0.33 ± 0.03	0.30 ± 0.03	0.34 ± 0.04	0.36 ± 0.03
Chemical	0.01 ± 0.02	0.03 ± 0.02	0.0	0.04 ± 0.02	0.01 ± 0.02
Serumy/bloody	0.25 ± 0.06	0.25 ± 0.06	0.25 ± 0.06	0.18 ± 0.07	0.13 ± 0.07
Sweet	0.01 ± 0.02	0.07 ± 0.02	0.0	0.04 ± 0.03	0.01 ± 0.03
Old/putrid	0.0	0.0	0.0	0.0	0.0
Textures[c]					
Juiciness	4.95 ± 0.11	5.05 ± 0.11	5.02 ± 0.11	5.26 ± 0.15	5.10 ± 0.15
Myofibrillar tenderness	5.35 ± 0.17[x]	5.36 ± 0.17[x]	5.37 ± 0.17[x]	6.49 ± 0.22[w]	5.80 ± 0.22[x]
Connective tissue	6.19 ± 0.17[xy]	6.23 ± 0.17[xy]	6.01 ± 0.17[y]	7.14 ± 0.22[w]	6.60 ± 0.22[wy]
Overall tenderness	5.36 ± 0.17[x]	5.36 ± 0.17[x]	5.35 ± 0.17[x]	6.51 ± 0.22[w]	5.79 ± 0.22[x]

[a] Sample consisted of sub-sample: Control, Fescue and Orchard (n = 24 each); Choice and Select (n = 14 each)
[b] 0 to 15: 0 = absent, 15 = extremely intense
[c] 1 to 8: 1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense
[wxy] Within treatment or biological type, within a row, means with different superscripts differ ($P < 0.05$)

Carcass and Color Characteristics of Three Biological Types of Cattle Grazing Cool-Season Forages Supplemented with Soyhulls

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Story in Brief

Soyhull supplementation to divergent biological types of cattle on forage-based systems was studied to determine the impact on carcass and color characteristics. Weaned calves (n = 107) biologically classified as large-, medium-, or small-framed and intermediate maturing rates were allocated to three cool season grazing systems consisting of either orchardgrass pasture or fescue pasture, each with soyhull supplementation, or fescue pasture with no supplementation for a control. Supplementing cattle with soyhulls allowed for heavier ($P < 0.05$) live and carcass weights; larger ($P < 0.05$) loin eyes; increased ($P < 0.05$) backfat; kidney, pelvic and heart fat, and yield grades; and increased ($P < 0.05$) marbling scores, and quality grades. Utilizing cattle biologically classified as large- or medium-framed allowed for heavier ($P < 0.05$) carcass weights without reducing ($P > 0.05$) marbling scores or quality grades when compared to small-framed cattle. Instrumental color analysis of lean and adipose tissue revealed improved ($P < 0.05$) lightness (L*) in lean color for supplemented carcasses as compared to the control. There were no differences ($P > 0.05$) between dietary treatments for L*, a* or b* values of adipose tissue. Other than adipose b* values being lower ($P < 0.05$) for medium-framed cattle, there were no differences ($P > 0.05$) between biological types for instrumental color values. These results indicate that supplementing forage-grazing cattle with soyhulls can improve carcass merit, and utilizing large- or medium-framed cattle can allow for increased carcass weights without decreasing carcass quality. Both of these factors could be beneficial in forage-based finishing systems.

Introduction

Retaining cattle after weaning and even up to a finished weight, and allocating different types of beef cattle to specific forages can allow for increased productivity and profit to producers. However, on a similar time scale, forage-fed cattle typically do not have the same degree of finish as grain-fed cattle due to the decreased energy available in the forage. Although typical forage-fed beef is lean and warrants an acceptable USDA yield grade, it is often inferior to traditional grain-fed beef in terms of both USDA quality grade and forage-fed beef's darker lean and more yellow fat color. The color of the lean and external fat of cuts of meat has been shown to be influential on the purchasing ability and visual acceptability by the consumer (Dikeman, 1990; Kropf, 1980)

Supplementing cattle on forage can provide sufficient additional energy to obtain a desirable degree of finish. However, concentrate supplementation can cause decreased forage utilization, and because the objective of forage-feeding cattle is to maximize utilization of available forages, alternative forms of supplementation could be considered to achieve a desirable production system. Utilization of appropriate biological types of cattle with the proper dietary regimen could allow for superior end product either in carcass weight or carcass quality. Therefore, the objectives of this study were to determine the effects of the supplementation of soyhulls, a highly digestible fiber source, to different biological types of forage-fed cattle on carcass quality and adipose and lean color.

Experimental Procedures

Animals. British and British x Continental fall- and spring-born beef steers and heifers from two consecutive years (n = 108) of small (SI), medium (MI), or large (LI) frame size and intermediate maturing rate were selected from a commercial cow herd at the University of Tennessee Experiment Station, Springhill, TN, to be utilized in this study. Biological types were estimated using the equation set forth by McCurley et al. (1980). This study was replicated over two consecutive years consisting of 54 animals utilized each year. One small-framed intermediate maturing heifer was removed from the first year's study due to chronic illness.

After weaning in October of each year, all calves chosen for the study were backgrounded for 2 weeks, receiving orchardgrass hay ad libitum and were started on pelleted soyhulls before being allocated to the trial. The randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture with pelleted soyhull supplementation (Fescue), or tall fescue pasture with no supplementation (Control). A commercial salt and mineral mix was available to all animals throughout the study.

Six animals (two from each biological type) were allocated to each paddock. There were three paddocks of each forage allowing for three replications each year (n = 36 per treatment). Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring and 1 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 days when the cattle were reweighed. Grazing continued into the summer months (mean days of age = 555) until forage availability started to diminish and cattle had attained a relative degree of finish determined by visual appraisal, whereupon all cattle, within a year, were sent to a commercial slaughtering facility.

Carcass. Carcasses were chilled for 48 h before carcass data were obtained by a USDA Grader. Carcass data obtained included 12th rib backfat, maturity score, hot carcass weight, marbling score, percent kidney, pelvic and heart fat (KPH), loin eye area, quality grade and yield grade.

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Instrumental color. Instrumental color data were obtained by a qualified technician using a Minolta chromatographer (Model CR-300; Minolta Corp., Ramsey, NJ). Instrumental color data included lean and adipose CIE L*, a* and b* values. The lean values were obtained at the central, medial and lateral areas of the exposed longissimus at the 12th rib. Adipose values were obtained at the external fat located between the 10th and 12th rib region.

Statistical analysis. The experiment was set up as a split-plot design with random effects of year and replicate within year, and fixed effects of treatment and biological type. The whole plot consisted of treatment and the sub-plot consisted of biological type. The three-way interaction of year x replicate x treatment was the error term for the whole plot, and the four-way interaction year x replicate x treatment x biological type was the error term for the sub-plot and for the interaction of treatment x biological type. Although year is generally considered to have a significant effect on performance, it is likely due to temporary environmental effects causing pasture conditions to vary between years (Vallentine, 1990). Due to this, and that year was considered a random effect, no interactions pertaining to year were included in the final model. Days of age of individual animals was included in the final model as a covariate for all traits analyzed. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC.). Means were generated using the LSMEANS option and separation was performed using the PDIFF option.

Results and Discussion

Main effect results for carcass traits, by treatment and biological type, are reported in Table 1. The live weights prior to slaughter and the carcass weights of the cattle supplemented with soyhulls were heavier ($P < 0.05$) than cattle without supplementation, although there were no differences ($P > 0.05$) between the Orchard and Fescue supplemented cattle. Similarly, loin eye area was larger ($P < 0.05$), and KPH, marbling score and quality grade were greater ($P < 0.05$) for the soyhull supplemented cattle than the Control, although the soyhull supplemented treatments did not differ ($P > 0.05$). Soyhull supplementation of cattle grazing fescue and orchardgrass allowed carcasses to obtain USDA Choice quality grades compared to USDA Standard quality grades for traditional grazing cattle. The LI cattle had heavier ($P < 0.05$) live and carcass weights and larger ($P < 0.05$) loin eye areas than SI, whereas there were no differences ($P > 0.05$) between the biological types for marbling score or quality grade.

The treatment x biological type interaction ($P < 0.05$) on carcass backfat means is reported in Table 2. Carcasses from the three biological types within the Control treatment had less ($P < 0.05$) backfat than biological types within either the Fescue or Orchard treatments. Excluding Fescue-MI carcasses, the LI carcasses within the Orchard treatment had more ($P < 0.05$) backfat than all other biological types represented within each treatment. There were no differences ($P > 0.05$) for backfat between the LI, MI and SI carcasses within the Fescue treatment and MI and SI within the Orchard treatment. An interaction of treatment x biological type was also found to be significant for yield grade of the carcasses (Table 3). Similar to backfat, Control carcasses from the three biological types did not differ ($P > 0.05$) in numerical values for yield grade, but were lower ($P < 0.05$) than carcasses from the three biological types within both soyhull-supplemented treatments. There were no differences ($P > 0.05$) for yield grade between biological types within the Fescue treatment, and the LI carcasses from the Orchard treatment had a higher ($P < 0.05$) yield grade than all other biological types within treatments except the MI carcasses within the Fescue treatment.

Typically, increased forage ingestion allows for carcasses with a darker lean appearance or fat that is yellow in appearance. The darker lean can be attributed to increased myoglobin, decreased muscle glycogen, or both, and the yellow fat is due to forages having increased carotenoids compared to concentrates (Priolo et al., 2001). The instrumental color results from the present study are reported in Table 4. The lean L* values, corresponding to degrees of lightness or darkness, resulted in the Control carcasses having a lower ($P < 0.05$) L* value, indicating a darker lean than the soyhull supplemented treatments. The lean b* values, indicating degree of yellow appearance, revealed the Control carcasses had a lower lean b* value ($P < 0.05$), indicating a less yellow appearance than the Fescue or Orchard carcasses. However, the lean b* values reported did not reveal a drastically yellow appearance, as the values were below the mean values from a survey from 1,000 carcasses evaluated at commercial processing plants (Page et al., 2001). There were no differences ($P > 0.05$) between feeding treatments for adipose instrumental values. Instrumental color results for biological type revealed no differences ($P > 0.05$) for lean characteristics, but MI carcasses had lower ($P < 0.05$) adipose b* values than LI or SI carcasses. Even though the mean b* values between biological types were statistically different, the numerical difference was not drastic

Table 1. Least-squares means for carcass traits by treatment and biological type (n = 107).

	Treatment			Biological type[a]		
Trait	Control	Fescue	Orchard	LI	MI	SI
Live weight (lb)	847 ± 13[x]	1192 ± 13[w]	1203 ± 13[w]	1144 ± 13[w]	1065 ± 13[x]	1034 ± 13[x]
Hot carcass weight (lb)	438 ± 11[x]	671 ± 11[w]	680 ± 11[w]	629 ± 11[w]	596 ± 11[x]	561 ± 5[y]
Loin eye area (in^2)	9.63 ± 0.25[x]	11.81 ± 0.25[w]	11.79 ± 0.26[w]	11.69 ± 0.26[w]	11.09 ± 0.25[wx]	10.46 ± 0.27[x]
KPH	1.52 ± 0.06[x]	2.26 ± 0.06[w]	2.32 ± 0.06[w]	2.06 ± 0.06	2.01 ± 0.06	2.03 ± 0.06
Maturity[b]	164.72 ± 3.67	157.49 ± 3.65	156.70 ± 3.72	159.41 ± 3.79	162.01 ± 3.65	157.48 ± 3.83
Marbling score[c]	178.62 ± 16.07[x]	473.85 ± 15.99[w]	446.94 ± 16.27[w]	367.34 ± 16.59	368.77 ± 15.98	363.30 ± 16.78
Quality grade[d]	535.02 ± 8.51[x]	718.03 ± 8.46[w]	704.26 ± 8.61[w]	653.06 ± 8.78	657.05 ± 8.46	647.20 ± 8.89

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

[b] 100 to199 = A maturity

[c] PD = 100 to 199, Tr = 200 to 299, Sl = 300 to 399, Sm = 400 to 499, Mt = 500 to 599, Md = 600 to 699

[d] Standard = 500 to 599, Select = 600 to 699, Choice = 700 to 799

[wxy] Within treatment or biological type, within a row, means without a common superscript letter differ ($P < 0.05$)

and probably would not have been visually influential in terms of the degree of yellowness. Therefore, supplementing soyhulls to cattle on forage may slightly improve lean color, but overall does not seem to largely affect lean or adipose color. Biological type within these feeding conditions does not seem to be an influential source of variation in lean or adipose color as well.

Implications

These results illustrate that supplementing forage-fed cattle with soyhulls can improve carcass merit in terms of increased weights and quality grade values, but can negatively affect leanness due to higher yield grades. Utilizing cattle with potential for a larger mature size could allow for increased carcass weights without negatively impacting quality. Future studies utilizing different supplementation rates and cattle types might be necessary to achieve maximal production and carcass merit.

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Table 2. Least-squares means for the treatment x biological type interaction on 12th rib backfat (in).

	Biological Type[a]		
Treatment	LI	MI	SI
Control	0.11 ± 0.04[z]	0.10 ± 0.04[z]	0.08 ± 0.04[z]
Fescue	0.35 ± 0.04[xy]	0.42 ± 0.04[wx]	0.39 ± 0.04[x]
Orchard	0.51 ± 0.04[w]	0.36 ± 0.04[xy]	0.26 ± 0.04[y]

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

[wxyz] Means without a common superscript letter differ (P < 0.05)

Table 3. Least squares means for the treatment x biological type interaction on yield grade.

	Biological type[a]		
Treatment	LI	MI	SI
Control	1.52 ± 0.12[z]	1.62 ± 0.11[z]	1.65 ± 0.11[z]
Fescue	2.60 ± 0.11[xy]	2.85 ± 0.11[wx]	2.61 ± 0.11[xy]
Orchard	3.01 ± 0.11[w]	2.52 ± 0.11[y]	2.58 ± 0.12[xy]

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

[wxyz] Means without a common superscript letter differ (P < 0.05)

Table 4. Least-squares means for carcass instrumental color by treatment and biological type (n = 107).

	Treatment			Biological type[a]		
Item	Control	Fescue	Orchard	LI	MI	SI
Lean						
L *	30.51 ± 0.47[x]	32.98 ± 0.47[w]	32.58 ± 0.47[w]	32.03 ± 0.48	32.00 ± 0.47	32.03 ± 0.49
a *	19.34 ± 0.35	20.47 ± 0.35	19.92 ± 0.35	19.80 ± 0.36	19.91 ± 0.35	20.03 ± 0.36
b *	7.71 ± 0.35[x]	9.65 ± 0.35[w]	9.47 ± 0.35[w]	8.77 ± 0.36	9.03 ± 0.35	9.01 ± 0.36
Adipose						
L*	73.83 ± 1.08	70.12 ± 1.07	71.56 ± 1.08	72.35 ± 0.84	71.49 ± 0.81	71.68 ± 0.85
a *	1.36 ± 0.55	2.80 ± 0.54	2.56 ± 0.53	1.83 ± 0.43	2.55 ± 0.42	2.34 ± 0.43
b *	18.37 ± 0.77	20.97 ± 0.77	18.94 ± 0.64	21.37 ± 1.05[w]	19.44 ± 0.63[x]	21.10 ± 0.62[w]

[a] LI = large-framed, intermediate maturing; MI = medium-framed, intermediate maturing; SI = small-framed, intermediate maturing

[wx] Within treatment or biological type, within a row, means without a common superscript letter differ (P < 0..05).

Sensory Characteristics of Beef from Three Biological Types of Cattle Grazing Cool-Season Forages Supplemented with Soyhulls

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Story In Brief

The effects of soyhull supplementation to divergent biological types of cattle on forage-based dietary regimens were studied to observe the impact on sensory beef palatability. Over two consecutive years, weaned calves (n = 107) classified as large-, medium-, or small-framed, and of intermediate rate of maturing were allocated to fescue without supplementation (Control), or fescue or orchardgrass pasture with soyhull supplementation. Sensory evaluation of longissimus steaks from the cattle revealed that soyhull supplementation reduced ($P < 0.05$) the grassy flavor intensity compared to the Control. There were no differences ($P > 0.05$) among dietary treatments for juiciness or tenderness; however, beef from all three dietary regimens was rated "slightly tender" on the sensory scale. Biological type revealed little influence on sensory flavor or palatability characteristics under these dietary regimens. These results indicate that although soyhull supplementation may not greatly impact beef flavor, it can aid in reduction of the grassy flavor characteristic commonly associated with forage-fed beef.

Introduction

Utilizing a forage-based feeding regimen potentially allows for beef with a more admirable fatty acid profile and improved leanness, thereby potentially providing a healthier beef product to consumers. However, forage-feed beef often is inferior to concentrate-fed beef in terms of carcass muscling and quality grade. Additionally, forage-fed beef can impart different flavor characteristics, particularly a more intense grassy flavor. Often, these flavor differences are partly due to volatiles from fat oxidation and from chlorophyll derivatives (Griebenow et al., 1997). Supplementing concentrates to cattle on a forage-based feeding regimen can improve gains, increase carcass weights, and improve quality grades. Additionally, supplementing concentrates can also reduce the grassy flavor intensity. However, concentrate supplementation can cause decreased forage utilization (Dixon and Stockdale, 1999), and since maximal utilization of available forages is one objective of a forage-based feeding program, alternative supplemental feedstuffs could be considered. In addition, allocating appropriate types of cattle to forage-based feeding regimens can allow for improved performance and carcass characteristics, and the rate of growth exhibited by cattle has been stated to influence tenderness (Aberle et al., 1981). The impact of cattle biological type on flavor characteristics is less clear. Therefore, the objective of this study was to observe the effects of supplementing soyhulls, a highly digestible fiber source, to divergent biological types of forage-fed cattle on sensory taste characteristics.

Experimental Procedures

Animals. British, and British x Continental fall- and winter-born beef steers and heifers from two consecutive years (n = 108) of small (n = 35; SI), medium (n = 36; MI), or large (n = 36; LI) frame size and intermediate maturing rate were selected from a commercial cow herd at the University of Tennessee Experiment Station, Springhill, Tenn., be utilized in this study. Biological types were estimated using the equation set forth by McCurley et al. (1980). This study was replicated over two consecutive years with 54 animals utilized each year. One small-framed intermediate maturing heifer was removed from the first year's study due to chronic illness.

The randomly chosen calves were stratified across either orchardgrass (*Dactylis glomerata*) predominated pasture supplemented with pelleted soyhulls (Orchard), tall fescue (*Festuca arundinacea* Schreb.) pasture with soyhull supplementation (Fescue), or fescue pasture with no supplementation, for the control (Control). A commercial salt and mineral mix was available to all animals throughout the study. Six animals (two from each biological type) were allocated to a paddock, replicated three times within each treatment, each year (n = 36 per treatment). There were equal numbers of steer and heifer calves represented within each biological type, within each treatment. Utilizing a rotational system, each paddock allowed for 0.5 acre/calf in the fall and spring, and 1.0 acre/calf in the winter. Pelleted soyhulls were fed to the supplemented treatments and were allocated at 1% BW/calf/day. Adjustments to supplementation were performed every 28 d when the cattle were reweighed. Grazing continued into the summer months (mean days-of-age = 555), until forage availability started to diminish, whereupon all cattle, within a year, were sent to a commercial slaughtering facility (carcass results from these cattle were reported by Baublits et al., 2003).

After carcasses had chilled for 48 h, a three-rib section (10th – 12th ribs) of the wholesale rib from the right side of each carcass was removed, vacuum-sealed, transported back to the University of Arkansas and aged for an additional 5 d before subsequent analyses.

Taste-panel. Sensory characteristics of longissimus steaks were obtained by a professional six-member descriptive taste-panel at Texas A & M University, College Station, Texas. A sub-sample consisting of 24 steaks per treatment (72 steaks total) was utilized for determination of sensory characteristics. A six-member taste panel determined aromatic, feeling-factor, taste and aftertaste, and textural sensory characteristics. The aromatic, feeling factor, taste and aftertaste sensory characteristics were scored on a 15-point scale (0 = not

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detected; 15 = extremely intense). Textural sensory characteristics were scored on an 8-point scale (1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense).

Statistical analysis. The experiment was set up as a split-plot design with random effects of year and replicate within year, and fixed effects of treatment and biological type. The whole plot consisted of forage treatment, and the sub-plot consisted of biological type. The three-way interaction of year x replicate x treatment was the error term for the whole plot, and the four-way interaction year x replicate x treatment x biological type was the error term for the sub-plot and for the interaction of treatment x biological type. Although year is generally considered to have a significant effect on performance, it is likely due to temporary environmental effects causing pasture conditions to vary between years (Vallentine, 1990). Due to this, and that year was considered a random effect, all interactions pertaining to year were not included in the final model. Days-of-age of individual animals was included in the final model as a covariate for all variables analyzed. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.). Means were generated using LSMEANS and separation was performed using the PDIFF option.

Results and Discussion

The treatment x biological type interaction was not significant for any of the sensory characteristics. Therefore, sensory results of longissimus samples by treatment and biological type are reported in Table 1. The Control samples exhibited a more intense ($P < 0.05$) grassy aroma than the supplemented groups, indicating a reduced grassy intensity associated with soyhull supplementation. The exact cause of this is unknown; however, it could be related to differences in phyt-2-ene, a volatile derivative of chlorophyll oxidation. Larick et al. (1987) reported a positive correlation between phyt-2-ene and grassy flavor intensity. Although not measured in the present study, the Control cattle could have deposited more chlorophyll in the fat depots due to increased forage ingestion with the exclusion of soyhull supplementation at 1 % / BW that the other groups received. The differences in the grassy flavor intensity could also be related to differences in fatness between the carcasses from the dietary regimens. Smith et al. (1983) discussed a minimal threshold fat thickness value of 0.3 in, to attenuate the grassy flavor characteristic. This could possibly explain the observed differences in the grassy descriptor in the present study. Although a treatment x biological type interaction was significant for fat thickness, all biological types in the Control treatment had less than 0.3 in backfat, whereas all biological types in the Fescue and Orchard treatments had greater than 0.3 in backfat (except Orchard-SI, which had 0.26 in backfat; Baublits et al., 2003). Biological type did not have a significant influence on flavor except for differences in the sweet sensory descriptor. Beef from the SI cattle had a more intense ($P < 0.05$) sweet characteristic than beef from MI. The exact cause of this is unknown. There were no significant differences between biological types for marbling, and although the treatment x biological type interaction was significant for fat thickness, SI generally did not differ from MI within each dietary regimen or LI within the Control and Fescue dietary regimens (Baublits et al., 2003). Interestingly, there were no differences in juiciness between dietary regimens, even though beef from the two supplemented treatments had significantly more marbling than the Control (Small vs. Practically Devoid marbling scores, respectively; Baublits et al., 2003). There were no differences ($P > 0.05$) in sensory tenderness ratings between treatments or biological types. Overall tenderness sensory ratings illustrated that longissimus samples from all three treatments were scored in approximately the “slightly tender” category, which is slightly above the median value on the sensory evaluation scale.

Implications

Supplementing forage-fed cattle soyhulls did not seem to greatly influence beef flavor or tenderness, but can decrease grassy flavor intensity. Biological type, within these types of production systems does not seem to have substantial influence on beef flavor or palatability.

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Table 1. Least squares means for sensory characteristics of longissimus muscle by treatment and biological type(n = 72)[a].

	Treatment[b]			Biological Type[c]		
Item	Control	Fescue	Orchard	LI	MI	SI
Aromatics [d]						
Beef/brothy	4.46 ± 0.10	4.73 ± 0.10	4.80 ± 0.10	4.66 ± 0.08	4.66 ± 0.08	4.68 ± 0.09
Beef fat	1.42 ± 0.07	1.58 ± 0.07	1.62 ± 0.07	1.50 ± 0.06	1.51 ± 0.06	1.61 ± 0.07
Serumy/bloody	1.49 ± 0.10	1.62 ± 0.10	1.60 ± 0.10	1.47 ± 0.10	1.59 ± 0.10	1.65 ± 0.11
Grainy/cowy	0.09 ± 0.03	0.04 ± 0.03	0.03 ± 0.03	0.04 ± 0.03	0.03 ± 0.02	0.09 ± 0.03
Cardboard	0.11 ± 0.03	0.07 ± 0.03	0.10 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.10 ± 0.03
Painty	0.00	0.00	0.00	0.00	0.00	0.00
Fishy	0.00	0.00	0.00	0.00	0.00	0.00
Liver	0.27 ±0.06	0.21 ± 0.06	0.27 ± 0.06	0.28 ± 0.06	0.18 ± 0.06	0.28 ± 0.06
Soured	0.00	0.00	0.00	0.00	0.00	0.00
Browned/burnt	0.73 ± 0.10	0.82 ± 0.10	0.93 ± 0.10	0.93 ± 0.10	0.84 ± 0.10	0.71 ± 11
Grassy	1.11 ± 0.09[w]	0.80 ± 0.09[x]	0.77 ± 0.09[x]	0.92 ± 0.09	0.99 ± 0.09	0.77 ± 0.10
Milky/oily	0.62 ± 0.07	0.63 ± 0.07	0.68 ± 0.07	0.71 ± 0.07	0.70 ± 0.07	0.52 ± 0.08
Old/Putrid	0.09 ± 0.03	0.02 ± 0.03	0.05 ± 0.03	0.03 ± 0.03	0.06 ± 0.03	0.08 ± 0.03
Feeling Factors [d]						
Metallic	2.68 ± 0.04	2.81 ± 0.04	2.76 ± 0.04	2.74 ± 0.04	2.74 ± 0.04	2.76 ± 0.05
Astringent	2.37 ± 0.04	2.45 ± 0.04	2.42 ± 0.04	2.42 ± 0.03	2.42 ± 0.03	2.41 ± 0.04
Tastes [d]						
Salt	1.99 ± 0.02	2.04 ± 0.02	2.00 ± 0.02	1.99 ± 0.02	2.02 ± 0.02	2.01 ± 0.03
Sour	2.51 ± 0.06	2.52 ± 0.06	2.51 ± 0.05	2.51 ± 0.05	2.57 ± 0.05	2.55 ± 0.06
Bitter	2.45 ± 0.06	2.42 ± 0.06	2.39 ± 0.06	2.47 ± 0.06	2.39 ± 0.06	2.39 ± 0.06
Sweet	0.40 ± 0.04	0.50 ± 0.04	0.45 ± 0.04	0.44 ± 0.04[wx]	0.38 ± 0.04[x]	0.53 ± 0.04[w]
Aftertastes [d]						
Sour	1.01 ± 0.07	0.93 ± 0.07	1.01 ± 0.07	0.94 ± 0.07	1.01 ± 0.07	1.01 ± 0.08
Acid	1.27 ± 0.10	1.26 ± 0.10	1.15 ± 0.10	1.39 ± 0.09	1.19 ± 0.09	1.10 ± 0.11
Bitter	0.90 ± 0.09	0.94 ± 0.09	0.82 ± 0.09	0.97 ± 0.09	0.83 ± 0.09	0.86 ± 0.10
Liver	0.09 ± 0.03	0.03 ± 0.03	0.06 ± 0.03	0.08 ± 0.03	0.06 ± 0.03	0.04 ± 0.03
Browned/Burnt	0.14 ± 0.06	0.14 ± 0.06	0.20 ± 0.06	0.19 ± 0.06	0.17 ± 0.06	0.11 ± 0.06
Metallic	1.72 ± 0.10	1.89 ± 0.10	1.91 ± 0.10	1.86 ± 0.08	1.89 ± 0.08	1.76 ± 0.08
Grassy	0.26 ± 0.09	0.11 ± 0.09	0.10 ± 0.09	0.10 ± 0.06	0.22 ± 0.06	0.15 ± 0.06
Milky/Oily	0.30 ± 0.07	0.38 ± 0.07	0.37 ± 0.07	0.33 ± 0.07	0.37 ± 0.07	0.36 ± 0.07
Textures [e]						
Juiciness	4.93 ± 0.13	5.11 ± 0.13	5.07 ± 0.13	5.01 ± 0.13	4.96 ± 0.13	5.14 ± 0.14
Myofibrillar Tenderness	5.29 ± 0.21	5.44 ± 0.22	5.42 ± 0.22	5.32 ± 0.21	5.28 ± 0.21	5.56 ± 0.23
Connective Tissue	6.10 ± 0.22	6.26 ± 0.23	6.01 ± 0.23	6.06 ± 0.22	5.96 ± 0.22	6.35 ± 0.24
Overall Tenderness	5.29 ± 0.21	5.44 ± 0.22	5.40 ± 0.22	5.32 ± 0.21	5.24 ± 0.21	5.58 ± 0.23

[a] Sample consisted of sub-sample (n = 24 for each treatment or biological type).
[b] LI = large-framed, intermediate-maturing; MI = medium-framed, intermediate-maturing; SI = small framed, intermediate-maturing.
[c] 0 to 15: 0 = absent, 15 = extremely intense.
[d] 1 to 8: 1 = extremely dry, extremely tough, abundant, extremely bland; 8 = extremely juicy, extremely tender, none, extremely intense.
[wx] Within treatment or biological type, and within row, means without a common superscript differ ($P < 0.05$).