Published May 6, 2016

Legume finishing provides beef with positive human dietary fatty acid ratios and consumer preference comparable with grain-finished beef[1]

A. Chail,* J. F. Legako,*[2] L. R. Pitcher,† T. C. Griggs,‡ R. E. Ward,* S. Martini,* and J. W. MacAdam†

*Department of Nutrition, Dietetics, & Food Sciences, Utah State University, Logan 84322; †Department of Plants, Soils, & Climate, Utah State University, Logan 84322; and ‡Division of Plant & Soil Sciences, West Virginia University, Morgantown 26506

ABSTRACT: Consumer liking, proximate composition, pH, Warner–Bratzler shear force, fatty acid composition, and volatile compounds were determined from the LM (longissimus thoracis) of cattle ($n = 6$ per diet) finished on conventional feedlot (USUGrain), legume, and grass forage diets. Forage diets included a condensed tannin-containing perennial legume, birdsfoot trefoil (*Lotus corniculatus*; USUBFT), and a grass, meadow brome (*Bromus riparius* Rehmann; USUGrass). Moreover, representative retail forage (USDA Certified Organic Grass-fed [OrgGrass]) and conventional beef (USDA Choice, Grain-fed; ChGrain) were investigated ($n = 6$ per retail type). The ChGrain had the greatest ($P < 0.05$) intramuscular fat (IMF) percentage followed by USUGrain, the IMF percentage of which was greater ($P < 0.05$) than that of USUGrass and OrgGrass. The IMF content of USUBFT was similar ($P > 0.05$) to that of both USUGrain and USUGrass. Both grain-finished beef treatments were rated greater ($P < 0.05$) for flavor, tenderness, fattiness, juiciness, and overall liking compared with USUGrass and OrgGrass. Consumer liking of USUBFT beef tenderness, fattiness, and overall liking were comparable ($P > 0.05$) with that of USUGrain and ChGrain. Flavor liking was rated greatest ($P < 0.05$) for USUGrain and ChGrain, and that of USUBFT was intermediate ($P > 0.05$) to those of ChGrain, USUGrass, and OrgGrass. Cumulative SFA and MUFA concentrations were greatest ($P < 0.05$) in ChGrain and USUGrain, whereas USUGrass and OrgGrass had lower ($P < 0.05$) concentrations. Concentrations of cumulative SFA and MUFA in USUBFT were intermediate and similar ($P > 0.05$) to those of USUGrain and USUGrass. Each forage-finished beef treatment, USUGrass, OrgGrass, and USUBFT, had lower ($P < 0.001$) ratios of n-6:n-3 fatty acids. Hexanal was the most numerically abundant volatile compound. The concentration of hexanal increased with increasing concentrations of total PUFA. Among all the lipid degradation products (aldehydes, alcohols, furans, carboxylic acids, and ketones) measured in this study, there was an overall trend toward greater quantities in grain-finished products, lower quantities in USUGrass and OrgGrass, and intermediate quantities in USUBFT. This trend was in agreement with IMF content, fatty acid concentrations, and sensory attributes. These results suggest an opportunity for a birdsfoot trefoil finishing program, which results in beef comparable in sensory quality with grain-finished beef but with reduced n-6 and SFA, similar to grass-finished beef.

Key words: beef, birdsfoot trefoil, fatty acids, grass finished, legumes, volatile compounds

J. Anim. Sci. 2016.94:2184–2197
doi:10.2527/jas2015-0241

INTRODUCTION

Beef quality is impacted by the cattle finishing diet (Reagan et al., 1977; Bidner et al., 1981, 1986; McIntyre and Ryan, 1984; Morris et al., 1997; Maughan et al., 2012). The nutrient composition of

[1]This project was supported by the Utah Agricultural Experiment Station, Utah State University, and approved as journal paper number 8866.

[2]Corresponding author: jerrad.legako@usu.edu

Received December 22, 2015.
Accepted February 26, 2016.

the feed along with the amount of feed energy available to the animal can modify beef carcass composition (Muir et al., 1998). This carcass modification can impact the amount of intramuscular fat (**IMF**) and the fatty acid composition, and the result of these variances is an altered volatile flavor profile on cooking (Mills et al., 1992; Elmore et al., 1999, 2004; French et al., 2000, 2001). Ultimately, diet influences the perceived eating quality and flavor of beef (Melton, 1990; Tansawat et al., 2013). Grain-finished beef is considered to have a more acceptable flavor compared with forage-finished beef (Larick et al., 1987; Medeiros et al., 1987; French et al., 2001; Corbin et al., 2015; O'Quinn et al., 2016).

Variances in fatty acid composition with cattle finishing diet may also impact beef nutritional quality. Diets having greater ratios of PUFA to SFA (>0.45) and lower ratios of *n*-6:*n*-3 (<4.0) may reduce the incidence of coronary artery disease (Simopoulos, 2004). Forage-finished beef has reduced *n*-6:*n*-3 fatty acid ratios and greater PUFA:SFA ratios (Enser et al., 1998; Elmore et al., 2004) and has been concluded to have comparatively greater nutritional value (Manner et al., 1984; Muir et al., 1998; Warren et al., 2008).

Birdsfoot trefoil is a perennial legume that is productive and persistent in the Intermountain West of the United States. The condensed tannin concentration of birdsfoot trefoil is generally low (10 to 30 g/kg herbage DM) but sufficient to prevent bloat even when this legume is grazed in pure stands (Barry and McNabb, 1999). Previous work indicated that birdsfoot trefoil–finished animals had greater ADG than grass-finished cattle but less ADG compared with grain-finished cattle (Pitcher, 2015). In a preliminary consumer evaluation, beef from birdsfoot trefoil–finished steers was found to be similar to purchased grain-finished beef and preferred over purchased grass-finished beef (unpublished data). The objective of the present study was to compare the consumer acceptability and chemical properties of conventionally finished and forage-finished beef and to further explore the unique properties of birdsfoot trefoil–finished beef.

MATERIALS AND METHODS

Animal Care and Use

All animal procedures and protocols in this study were approved by the Utah State University (**USU**) Animal Care and Use committee (Institutional Animal Care and Use Committee number 1493).

Table 1. Composition of diets on a DM basis

	Finishing diet[1]		
Component, %	USUGrain	USUBFT	USUGrass
CP	15.4	24.4	18.2
ADF	16.5	26.8	32.2
NDF	31.0	28.9	50.4
Ash	8.5	7.0	10.8
Crude fat	2.4	2.0	3.4
Lignin	3.2	4.4	3.3
Nonfibrous carbohydrate	42.7	39.8	19.3

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

Cattle Finishing, Harvest, and Carcass Evaluation

Eighteen spring-born (March 2012) and fall-weaned (2012) Angus steers with similar initial weights (416–490 kg) were selected from the USU beef herd. From weaning until the end of May 2013, cattle were fed a mixture of corn silage and alfalfa hay. Six grass-finished steers were put on tall fescue for 6 wk from 1 June 2013 and then moved onto meadow brome until slaughter (meadow brome [*Bromus riparius* Rehmann; **USUGrass**]). Six of the 18 steers were put on birdsfoot trefoil from 1 June 2013 until slaughter (perennial legume, birdsfoot trefoil [*Lotus corniculatus*; **USUBFT**]). The remaining 6 steers were feedlot finished on a concentrate diet of high-starch cereal grain from 1 June 2013 until slaughter (conventional feedlot [**USUGrain**]). The composition of finishing diets was determined on a DM basis (Table 1). Cattle in this study were not implanted with growth hormones or treated with other growth-stimulating inputs.

Animals were slaughtered at the USU Matthew Hillyard Animal, Teaching, and Research Center (Wellsville, UT) at approximately 18 mo of age. Carcasses were chilled for 24 h at 2 to 4°C and the quality and yield grade were determined based on USDA protocols (USDA, 1997). Lean maturity (A^{00} to A^{100}), skeletal maturity (A^{00} to A^{100}), fat thickness (cm), LM area (cm^2), HCW (kg), and KPH were determined. Carcass marbling scores were determined by comparison of visual marbling of the LM at the 12th and 13th ribs with official USDA marbling photographs (National Cattlemen's Beef Association, Centennial, CO).

Product Collection and Fabrication

Rib-eye rolls (Institutional Meat Purchasing Specification number 112; North American Meat Processors Association, 2010) were collected from each carcass (*n* = 6 per treatment). In addition to the 3 university treatments, rib-eye rolls from retail forage-fed beef (USDA Certified Organic Grass-fed [**OrgGrass**]) were purchased from a Whole Foods Market Inc. (Austin, TX) retail store in Salt Lake City, UT, and feedlot-finished rib-eye rolls were purchased at a Sam's Club (Sam's West, Inc., Bentonville, AR) store in Logan, UT (Member's Mark, USDA Choice, grain-fed ChGrain). Retail products were purchased the day they were received by stores. Box dates were used to estimate product postmortem age based on the common industry practice of a 24-h duration between harvest and boxing. All rib-eye rolls were wet-aged under vacuum for a total of 14 d, or an estimated total of 14 d for retail products, at 2 to 4°C before being frozen (−20°C) and producing retail steaks. Rib-eye steaks (Institutional Meat Purchasing Specification number 1112A; North American Meat Processors Association, 2010) were produced by slicing frozen rib-eye rolls using a band saw (Butcher boy; model number SA-16; American Meat Equipment, LLC, Selmer, TN) into 2.5-cm-thick steaks. All steaks were vacuum-packaged and stored at −20°C for further analysis.

Sample Preparation for Proximate, pH, and Fatty Acid Analysis

Raw steaks were thawed for 24 h at 4 to 6°C. All exterior muscles, heavy connective tissue, and external fat were removed, leaving only the LM. Samples were cubed, submerged in liquid nitrogen, placed in a blender (Vita-Mix Corp., Cleveland, OH; model number VM0100A), and pulverized to form beef homogenates. Powdered samples were double packed in VWR sample bags (BPR-4590 VW1; VWR International, Radnor, PA) and stored at −80°C for subsequent analysis (Martin et al., 2013).

Proximate Analysis

A chloroform:methanol extraction method was used for determination of total IMF, similar to Folch et al. (1957). One gram of each homogenized sample was weighed into 50-mL centrifuge tubes (VWR International; North American catalog number 89039-656) along with 3.2 mL of distilled water and vortexed. Eight milliliters each of methanol and chloroform were added and vortexed for 2 min. Four milliliters of water was added to samples, which were vortexed for an additional 30 sec. This mixture was centrifuged at 2,360 × g for 10 min at 25°C. Four milliliters of the chloroform layer was pipetted into labeled and preweighed disposable 50-mL culture tubes. Chloroform extracts were evaporated to dryness through an initial 10-min heating on an electric dry heating block before finishing evaporation in an oven (101°C) to a constant weight. Tubes were cooled in a desiccator and weighed. The total fat percentage was calculated as fat (%) = (weight of fat residue/sample weight) × 2 × 100.

An AOAC International oven-drying method was used to determine total moisture (method 950.46b; AOAC, 1995). Percentage of moisture was calculated as moisture (%) = [(wet weight − dry weight)/(wet weight)] × 100. Percent ash was determined through heating in a muffle furnace at 550 to 600°C for at least 24 h (method 920.153; AOAC, 1995). Incinerated samples were removed from the furnace and allowed to cool in a desiccator before weighing. The percentage of ash was calculated as ash (%) = (ash weight/initial weight) × 100. Protein percent was determined by a dye-binding method (method 2011.04; AOAC, 2011) using a CEM Sprint Protein Analyzer (CEM Corporation, Matthews, NC) as described by Moser and Herman (2011).

pH Analysis

A benchtop pH meter (Orion 3 Star; Thermo Electron Corporation, Beverly, MA) was used to determine the pH of homogenized samples. Five grams of homogenized sample was weighed into 50 mL (VWR International) disposable culture tubes. Forty-five milliliters of distilled water was added to the culture tube, which was vortexed until all meat was dispersed. A filter paper (VWR International; North American catalog number 28320-085) folded in the form of a cone was immersed in the culture tube and then the pH electrode was immersed in the solution that seeped into the filter paper cone (John et al., 2004).

Fatty Acid Analysis

Fatty acid methyl esters (**FAME**) were prepared by the method described by O'Fallon et al. (2007). One gram of raw meat homogenate was weighed into a screw-cap glass vial along with an internal standard solution of tridecanoic acid (0.5 mg/mL in methanol; T-135; Nu-Chek Prep, Inc., Elysian, MN), and the vial was sealed with a polypropylene-lined cap (ThermoFisher Scientific, Waltham, MA). Vials were placed in a water bath (catalog number 67120; Precision Scientific, Chicago, IL) for incubation at 55°C. Hexane was used to extract FAME before analysis by gas chromatography (**GC**).

Separation of FAME was performed by a Shimadzu GC-2010 (Shimadzu Corporation; Kyoto, Japan) equipped with a HP-88 capillary column (100 m by 0.25 mm by 0.20 μm; Agilent Technologies, Palo Alto, CA) and a flame ionization detector (**FID**). The gas chromatograph was operated based on the conditions described by Tansawat et al. (2013). The column head pressure was 195.6 kPa and the total flow rate was 129.1 mL/min (column flow: 2.47 mL/min; purge flow: 3.0 mL/min). One microliter of sample was injected with a split ratio of 50:1. The oven method was as follows: 35°C held for 2 min, then increased to a temperature of 170°C at a rate of 4°C/min, then held for 4 min, then increased to a temperature of 240°C at a rate of 3.5°C/min, and then held for 7 min. Hydrogen was used as the carrier gas. The injector and FID were operated at 250°C. Fatty acids were identified based on the similarity of retention times with GC reference standards (Nu-Chek Prep, Inc.). Fatty acid concentrations were calculated relative to initial wet sample weight (mg/g).

Consumer Sensory Evaluation

Sensory evaluation was conducted at the USU Department of Nutrition, Dietetics, and Food Sciences (Logan, UT) as per an approved human subject protocol (USU Institutional Review Board number 4760), similar to the protocols of Maughan et al. (2012). Six replicates comprising the 5 treatments were conducted with 120 panelists in each replicate. Each replicate occurred on separate days and only 1 animal replicate or purchased rib-eye roll was represented within each sensory panel replicate. Before consumer evaluation, steaks were thawed for 24 h at 4°C. Steaks were cooked using Presto Tilt'n Drain electric griddles (42096US; National Presto Industries, Inc., Eau Claire, WI) to a medium degree of doneness (70°C) determined with a digital thermometer (Atkins Temp tech digital thermometer; Cooper-Atkins Corporation, Middlefield, CT) equipped with a fast responding microneedle probe. The temperature was read by inserting the probe parallel to the surface of the griddle to the geometric center of the steak. Immediately after cooking, all remaining external fat, connective tissues, and exterior muscles were removed from the cooked steaks, leaving the LM for evaluation. Steaks were cut into 8 to 12 cubes (2.5 by 2.5 cm by cooked thickness), placed in covered aluminum dishes, and held for no more than 5 min in a warming oven (65 ± 3°C). One cube per sample was served warm to consumers under red lighting. Consumers were provided with toothpicks, a napkin, a cup of water, and palate cleansers (unsalted crackers).

Each sample was evaluated for aroma, flavor, tenderness, juiciness, fattiness, and overall liking on a hedonic scale of 9, with 1 being "dislike extremely" and 9 being "like extremely." For aroma, panelists were instructed to uncover samples and sniff the cooked sample. All other attributes were evaluated during mastication of samples. A 4-point hedonic scale was used for quality where 1 = unsatisfactory, 2 = everyday quality, 3 = better than everyday quality, and 4 = premium quality. Additionally, consumers were asked for anonymous demographic information along with consumption and preference information for beef. Preference data was collected using a 10-mm continuous line scale where 0 = extremely unimportant and 10 = extremely important.

Warner–Bratzler Shear Force Analysis

Objective tenderness was determined by Warner–Bratzler shear force (**WBSF**) according to American Meat Science Association guidelines (AMSA, 2015). Steaks were thawed for 24 h until an internal temperature of 4 to 6°C was reached and then cooked as previously described. Cooked steaks were cooled overnight (4–6°C) and tempered 3 h at room temperature (24–26°C) before coring. Six 1.27-cm cores per steak sample were removed parallel to the longitudinal orientation of the muscle fiber of the LM. Each core was sheared once on a TMS-Pro Texture Analyzer (FTC 500N ILC; Food Technology Corporation, Sterling, VA) with a WBSF attachment using 200 mm/min crosshead speed and a 50-kg load cell.

Volatile Compound Analysis

Volatile analysis was performed using a similar protocol, as outlined by Legako et al. (2015). Cooking protocols were the same as those previously described. Immediately after cooking, five 1.27-cm cores were extracted by coring perpendicular to the surface of the steak cut surface. Cores were then minced for 10 s in a coffee-bean grinder (KRUPS, Medford, MA; type number F203). Five grams of the minced sample were weighed into 20-mL glass vials (093640-036-00; GERSTEL, Inc., Linthicum, MD) and closed with a polytetrafluoroethylene septa and screw cap (093640-092-00; GERSTEL, Inc.). Ten microliters of internal standard (1,2-dicholorobenzene; 0.801 mg/mL) was added and the vial was loaded by a Gerstel MPS automated sampler for a 5-min incubation period at 65°C in the Gerstel agitator (500 rotations per min) followed by 20 min of extraction where volatile compounds were collected from the headspace of cooked samples by solid phase microextraction using an 85-μm film thickness carboxen polydimethylsiloxane fiber (Supelco Inc., Bellefonte, PA). Extracted volatile compounds were injected on a VF-5 ms capillary column (30 m × 0.25 mm × 1.00 μm; Agilent J&W GC Column; Agilent Technologies, Santa Clara, CA). Authentic standards were purchased from Sigma-Aldrich (St. Louis, MO) and used to validate compound identities through comparison of retention times and ion fragmentation patterns. Quantitation was performed by an internal standard calibration with the same authentic standards.

Statistical Analysis

A generalized linear mixed model using the PROC GLIMMIX procedure of SAS (version 9.3; SAS Inst. Inc., Cary, NC) was used for statistical analysis. One-way ANOVA was used to determine the effect of diet. Carcass served as the experimental unit. Denominator degrees of freedom were calculated by the Kenward–Rogers approximation. Perceived quality level was analyzed by the GLIMMIX procedure of SAS using the ILINK option of the LSMEANS statement for the calculation of least squares means of proportions. All treatment mean separation was conducted using a protected *t* test by the LSMEANS/PDIFF option of the GLIMMIX procedure. Statistical significance was determined at $P \leq 0.05$.

Table 2. Final BW and carcass characteristics of cattle ($n = 6$ per diet) finished on different dietary treatments

	Finishing diet[1]				
Characteristic	USUGrain	USUBFT	USUGrass	SEM[2]	*P*-value
Final BW, kg	644.6[a]	556.8[b]	511.1[c]	13.7	<0.001
HCW, kg	370.3[a]	346.0[a]	291.0[b]	9.3	<0.001
Marbling score[3]	493.3	438.3	406.7	34.3	0.227
12th–rib fat thickness, cm	1.1[a]	1.0[a]	0.5[b]	0.1	<0.001
LM area, cm^2	83.3[a]	72.3[b]	66.7[b]	3.5	0.012
KPH, %	3.0[a]	2.6[a]	1.8[b]	0.2	0.004
Calculated yield grade[4]	3.2[a]	3.4[a]	2.5[b]	0.2	0.020

[a–c]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]Pooled (largest) SE of least squares means.

[3]Marbling assessed at LM surface between the 12th and 13th ribs by comparison with official USDA marbling photographs (National Cattlemen's Beef Association, Centennial, CO). Marbling score units: 200 = Traces^{00}; 300 = Slight^{00}; 400 = Small^{00}; 500 = Modest^{00}; 600 = Moderate^{00}; 700 = Slightly Abundant^{00}; and 800 = Moderately abundant^{00}.

[4]Calculated yield grade = 2.5 + (0.984252 × cm BF) + (0.2 × % KHP) + (0.008378 × kg HCW) − (0.0496 × cm^2 LM area).

RESULTS

Final BW and Carcass Characteristics

Final BW and carcass data of USU cattle are summarized in Table 2. Final BW was affected by diet ($P < 0.001$). Feedlot-finished animals weighed the most ($P < 0.05$) followed by USUBFT animals, and the USUGrass cattle were the lightest ($P < 0.05$). Fat thickness, HCW, KPH, and calculated yield grade of USUGrain and USUBFT cattle were similar ($P > 0.05$) and were both greater ($P < 0.05$) than those of USUGrass cattle. Longissimus muscle area was greater ($P < 0.05$) among USUGrain carcasses compared with USUBFT and USUGrass carcasses, which were similar ($P < 0.05$) and smaller. Diet did not influence marbling score ($P = 0.227$).

Proximate Composition and pH

Beef moisture, ash, IMF, and protein percentages were affected by diet ($P \leq 0.009$; Table 3). Moisture was greater ($P < 0.05$) in USUGrass and OrgGrass compared with ChGrain and USUGrain. Moisture content of USUBFT beef was similar ($P > 0.05$) with all forage treatments and USUGrain. The ChGrain had the greatest ($P < 0.05$) IMF but the lowest ($P < 0.05$) moisture. Although ChGrain had the greatest ($P < 0.05$) IMF, it was followed by USUGrain, in which the IMF was greater ($P < 0.05$) than that in USUGrass and OrgGrass. The IMF content of USUBFT was similar ($P > 0.05$) to that of both USUGrain and USUGrass. In this study, protein was also affected ($P = 0.008$) by diet, where ChGrain and OrgGrass had greater ($P < 0.05$) values than the 3 university-finished treatments, USUBFT, USUGrain, and USUGrass, which were similar ($P > 0.05$) to each other. Ash was greater ($P = 0.009$) in forage-finished beef, with the exception of USUBFT, which had values comparable ($P > 0.05$) with USUGrain. Dietary regimen had no effect ($P = 0.080$) on pH.

Fatty Acids

Concentrations of beef fatty acids (mg/g wet sample) are tabulated in Table 4. The concentrations of all fatty acids were affected ($P \leq 0.004$) by diet except ($P = 0.398$) docosanoic acid (22:0). Cumulative SFA and MUFA concentrations were greatest ($P < 0.05$) in ChGrain and USUGrain, whereas USUGrass and OrgGrass had comparably lower ($P < 0.05$) concentrations. Concentrations of cumulative SFA and MUFA in USUBFT were intermediate and similar ($P > 0.05$) to both USUGrain and USUGrass. Concentration of cumulative PUFA was greatest ($P < 0.05$) in ChGrain compared with all other treatments.

Among individual fatty acids, palmitic acid (16:0) and stearic acid (18:0) were the major contributors to the overall concentration of SFA, each of which was greater ($P < 0.05$) in grain-finished beef compared with grass-finished beef. The concentration of 16:0 and 18:0 in USUBFT was intermediate and similar

Table 3. The effects of dietary treatments on the least squares means for percentage of moisture, ash, intramuscular fat (IMF), protein, and pH of raw beef LM (longissimus thoracis)

	Finishing diet[1] and retail product[2]						
Measurement	USUGrain	ChGrain	USUBFT	USUGrass	OrgGrass	SEM[3]	*P*-value
Moisture, %	71.87[b]	69.98[c]	73.33[ab]	74.91[a]	74.69[a]	0.57	<0.001
Ash, %	1.02[bc]	0.99[c]	1.01[bc]	1.04[ab]	1.06[a]	0.01	0.009
IMF, %	5.84[b]	7.94[a]	4.43[bc]	2.91[cd]	2.21[d]	0.67	<0.001
Protein, %	22.68[b]	23.95[a]	22.93[b]	22.84[b]	24.01[a]	0.31	0.008
pH	5.71	5.72	5.78	5.91	5.87	0.06	0.080

[a–d]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]ChGrain = USDA Choice, Grain-fed; OrgGrass = USDA Certified Organic Grass-fed.

[3]Pooled (largest) SE of least squares means.

($P > 0.05$) to that in USUGrain and USUGrass but lower ($P < 0.05$) than that in ChGrain and greater ($P < 0.05$) than that in OrgGrass. Oleic acid (18:1*n*-9), the most prominent fatty acid, had greater ($P < 0.05$) concentrations in grain-finished beef compared with forage-finished beef. Long-chain omega-3 fatty acid ecosapentanoic acid (20:5*n*-3) and docosohexaenoic acid (22:6*n*-3) were each affected by dietary treatment ($P < 0.001$). Although 22:6*n*-3 concentration was lower ($P < 0.05$) in ChGrain compared with all others, 20:5*n*-3 was greatest ($P < 0.05$) in OrgGrass followed by USUBFT, USUGrass, USUGrain, and ChGrain in decreasing order ($P < 0.05$). In addition to individual fatty acids, dietary treatment impacted the ratio of *n*-6:*n*-3 ($P < 0.001$), where ChGrain was greatest ($P < 0.05$) followed by USUGrain, being greater ($P < 0.05$) than all forage-finished beef having the lowest ratios.

Description of Consumer Participants

Demographic data are presented in Table 5. Age and gender percentages were similar to previous USU studies (Lance, 2011). A large percentage of consumers were between 18 and 29 yr of age because sensory testing recruitment occurred on the university campus. Among participants, 41.25% selected beef as their preferred meat product and 48.61% reported consuming beef once a week or more often (Table 6). Participants further rated flavor (55.28%) to be the most important palatability trait, in greater relative proportion to tenderness (32.08%) and juiciness (12.64%).

In response to preference for a type of beef, participants had no clear partiality, selecting "doesn't matter" most frequency (62.50%) whereas "grass-fed" (20.42%) and "grain-fed" (17.08%) were selected about equally. Consumers also rated the importance of factors such as brand, country of origin, natural or organic claims, price, and USDA grade of beef (Table 7). Price was rated most important ($P < 0.05$) followed by USDA grade, country of origin, natural or organic claims, and brand of the product, each differing ($P < 0.05$) from others in the stated order.

Consumer Sensory Evaluation and Warner–Bratzler Shear Force

Consumer evaluation and WBSF results are presented in Table 8. All sensory attributes were affected by diet type ($P \leq 0.009$), except aroma ($P = 0.120$). Grain-finished beef (USUGrain and Grain) was rated greater ($P < 0.05$) for flavor, tenderness, fattiness, juiciness, and overall liking compared with USUGrass and OrgGrass beef. Consumer preference for USUBFT beef tenderness, fattiness, and overall liking were comparable ($P > 0.05$) with USUGrain and Grain beef. Flavor liking was rated greatest ($P < 0.05$) for USUGrain and Grain beef, whereas USUBFT beef flavor was intermediate and similar ($P > 0.05$) to Grain, USUGrass, and OrgGrass beef.

Despite differences in consumer perception of tenderness ($P = 0.001$) among dietary treatments, there was no treatment effect ($P = 0.880$) on WBSF. It is unclear if this is meaningful or if instrumental measures of tenderness are less sensitive than consumer perceptions. It should be noted that all products were considered to have WBSF values below previous thresholds for a tender product (4.6 kg; Shackelford et al., 1991).

In addition to assessment of liking, consumers were asked to rate the quality level of each beef type (Table 9). Among all treatments, USUGrain beef was rated "unsatisfactory" with lesser ($P < 0.05$) frequency compared with beef from all other treatments. Both USUGrass and OrgGrass beef had similar ($P > 0.05$) percentages of consumer ratings for "good everyday quality." All other treatments were lower ($P < 0.05$) for ratings of "good everyday quality" compared with USUGrass beef; however, OrgGrass beef was rated similar ($P > 0.05$) to beef from all treatments. Ratings

Table 4. The effects of dietary treatment on concentration (mg/g wet sample) of individual fatty acids and fatty acid categories (SFA, MUFA, and PUFA) from raw beef LM (longissimus thoracis)

Fatty acids, mg/g wet sample	Finishing diet[1] and retail product[2]					SEM[3]	*P*-value
	USUGrain	ChGrain	USUBFT	USUGrass	OrgGrass		
SFA	27.32^{ab}	37.41^{a}	21.42^{bc}	14.66^{cd}	8.14^{d}	3.81	<0.001
10:0	0.03^{b}	0.04^{a}	0.03^{cb}	0.02^{cd}	0.01^{d}	<0.01	<0.001
12:0	0.03^{b}	0.05^{a}	0.03^{b}	0.02^{cb}	0.01^{c}	0.01	0.002
14:0	1.46^{b}	2.34^{a}	1.21^{bc}	0.81^{cd}	0.40^{d}	0.25	<0.001
15:0	0.23^{b}	0.38^{a}	0.23^{b}	0.17^{bc}	0.11^{c}	0.03	<0.001
16:0	16.77^{ab}	21.33^{a}	12.45^{bc}	8.31^{cd}	4.27^{d}	2.38	0.001
17:0	0.63^{b}	0.94^{a}	0.48^{bc}	0.32^{cd}	0.22^{d}	0.07	<0.001
18:0	8.02^{b}	12.03^{a}	6.82^{bc}	4.89^{cd}	3.02^{d}	1.14	<0.001
19:0	0.07^{c}	0.21^{a}	0.11^{b}	0.07^{cb}	0.06^{c}	0.01	<0.001
20:0	0.06^{b}	0.08^{a}	0.06^{ab}	0.04^{bc}	0.03^{c}	0.01	0.004
22:0	0.01	0.01	0.02	0.01	0.01	<0.01	0.398
MUFA	28.24^{ab}	35.59^{a}	18.35^{bc}	12.07^{cd}	6.65^{d}	4.04	<0.001
14:1 *cis*-9	0.32^{b}	0.48^{a}	0.21^{bc}	0.15^{c}	0.07^{c}	0.06	<0.001
16:1 *trans*-9	0.17^{b}	0.35^{a}	0.18^{b}	0.14^{b}	0.11^{b}	0.04	0.002
16:1 *cis*-9	2.15^{ab}	2.55^{a}	1.45^{bc}	1.00^{cd}	0.52^{d}	0.30	<0.001
18:1 *trans*-11	0.29^{b}	3.18^{a}	0.82^{b}	0.53^{b}	0.44^{b}	0.51	<0.001
18:1 *n*-9	24.45^{a}	28.15^{a}	15.21^{b}	9.89^{bc}	5.30^{c}	3.29	<0.001
18:1 *n*-7	0.88^{a}	0.89^{a}	0.47^{b}	0.36^{b}	0.21^{b}	0.10	<0.001
PUFA	2.04^{b}	4.05^{a}	2.25^{b}	1.67^{b}	1.41^{b}	0.39	<0.001
18:2 *n*-6	1.22^{b}	3.06^{a}	1.06^{b}	0.84^{b}	0.63^{b}	0.32	<0.001
18:3 *n*-6	0.02^{a}	0.02^{a}	0.01^{b}	0.01^{c}	0.01^{c}	<0.01	<0.001
18:3 *n*-3	0.23^{b}	0.20^{b}	0.52^{a}	0.27^{b}	0.26^{b}	0.04	<0.001
20:2 *n*-6	0.03^{b}	0.06^{a}	0.03^{b}	0.02^{b}	0.01^{b}	0.01	<0.001
20:3 *n*-6	<0.01^{b}	<0.01^{b}	0.03^{a}	0.01^{b}	0.01^{b}	<0.01	<0.001
20:4 *n*-6	0.38^{ab}	0.40^{a}	0.34^{c}	0.35^{bc}	0.29^{d}	0.01	<0.001
20:5 *n*-3	0.04^{d}	0.02^{e}	0.09^{b}	0.07^{c}	0.12^{a}	<0.01	<0.001
22:6 *n*-3	0.02^{a}	0.01^{b}	0.02^{a}	0.02^{a}	0.02^{a}	<0.01	<0.001
CLA *cis*-9, *trans*-11	0.08^{b}	0.28^{a}	0.16^{b}	0.08^{b}	0.06^{b}	0.03	<0.001
Total unknown	2.05^{b}	3.14^{a}	1.85^{bc}	1.42^{cd}	1.12^{d}	0.23	<0.001
PUFA:SFA	0.08^{c}	0.10^{b}	0.11^{b}	0.12^{b}	0.19^{a}	0.01	<0.001
n-6:*n*-3 ratio	5.74^{b}	15.21^{a}	2.41^{c}	3.44^{c}	2.33^{c}	0.46	<0.001

$^{a–e}$Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]ChGrain = USDA Choice, Grain-fed; OrgGrass = USDA Certified Organic Grass-fed.

[3]Pooled (largest) SE of least squares means.

for "better than everyday quality" were greater ($P < 0.05$) for USUGrain, ChGrain, and USUBFT beef compared with USUGrass beef. Meanwhile, OrgGrass beef was rated as "better than everyday quality" with frequency similar ($P > 0.05$) to USUBFT and ChGrain beef. Consumers rated USUGrain beef as "premium quality" with greater ($P < 0.05$) frequency compared with ChGrain, USUGrass, and OrgGrass beef. Meanwhile, USUBFT beef was similar ($P > 0.05$) to USUGrain beef for selection of "premium quality" by consumers.

Volatile Compounds

Volatile compound results are summarized in Table 10. Among lipid-derived compounds, hexanal was determined to be greatest ($P < 0.05$) in ChGrain followed by USUGrain, which was similar ($P > 0.05$) to USUBFT, OrgGrass, and USUGrass; USUGrass had the lowest ($P < 0.05$) levels of hexanal. In addition to hexanal, decanal was affected ($P = 0.028$) by dietary treatment, where ChGrain had greater ($P < 0.05$) concentrations of decanal compared with all others. Alcohols, such as 1-hexanol, 1-heptanol, and 2-pentyl-furan, have each been found to result from degradation of unsaturated fatty acids (Back, 2007), specifically linoleic acid (Grosch, 1987). Quantities

Table 5. Consumer participant's demographic information

Demographic category	Selection options	Percentage
Age	18–29 yr	69.31
	30–39 yr	13.33
	40–49 yr	8.19
	50–60 yr	5.69
	over 60 yr	3.47
Gender	Male	56.53
	Female	43.47
Ethnic origin	African–American	0.42
	Asian	13.47
	Caucasian/White	81.39
	Hispanic	2.78
	Native American	0.14
	Other	1.81
Income	Under $25,000	49.31
	$25,000–$34,999	13.89
	$35,000–$49,999	10.28
	$50,000–$74,999	12.50
	$75,000–$100,000	8.89
	More than $100,000	5.14
Education level	Non-high school graduate	0.14
	High school graduate	3.19
	Some college/technical school	17.64
	College bachelor	39.58
	Master degree	22.36
	Professional degree (e.g., MD, JD)	2.50
	Doctorate	14.58

of 2-pentyl furan, 1-hexanol, and 1-heptanol were observed to diverge in the study treatments, being greater ($P < 0.05$) in USUGrain and ChGrain beef compared with USUGrass and OrgGrass beef. Meanwhile, quantities of 2-pentyl furan in USUBFT were intermediate and similar ($P > 0.05$) to ChGrain, USUGrass, and OrgGrass. In the same manner, 1-hexanol from USUBFT was similar ($P > 0.05$) to all of the grain- and forage-finished products. Quantities of 1-heptanol from USUBFT were similar ($P > 0.05$) to those from USUGrain, USUGrass, and OrgGrass.

Among carboxylic acids, concentrations of pentanoic acid, octanoic acid, and hexanoic acid were impacted ($P \leq 0.009$) by dietary treatment. Pentanoic acid was found to be lower ($P < 0.05$) in grass-finished beef but not USUBFT beef, which had greater ($P < 0.05$) pentanoic acid, comparable ($P > 0.05$) with grain-finished beef. The concentration of hexanoic acid was greater ($P < 0.05$) in USUGrain and ChGrain and lower in USUGrass and OrgGrass, with USUBFT having an intermediate quantity. Octanoic acid quantity was the greatest ($P < 0.05$) in ChGrain but similar in USUBFT, USUGrass, OrgGrass, and USUGrain ($P > 0.05$).

Table 6. Consumer participant's beef consumption frequency, most important palatability trait, preferred type of beef, and preferred meat product

Beef consumption inquiry	Selection options	Percentage
Frequency of consumption of beef	Less often than once a year	0.14
	Once or twice a year	1.39
	Once every 4–6 mo	2.78
	Once every 2–3 mo	5.69
	Once a month/every 4 wk	10.14
	Once every 2–3 wk	31.25
	Once a week or more often	48.61
Most important palatability trait	Flavor	55.28
	Tenderness	32.08
	Juiciness	12.64
Preferred type of beef	Grain fed	17.08
	Grass fed	20.42
	Doesn't matter	62.50
Preferred meat product	Beef	41.25
	Chicken	16.53
	Fish	6.94
	Lamb	9.86
	Pork	14.31
	Shellfish	2.78
	Turkey	4.17
	Veal	1.25
	Venison (deer)	2.92

Additional lipid degradation products, 2-propanone and 2-heptanone, were determined to differ by dietary treatment ($P \leq 0.007$). Quantity of 2-propanone was greater ($P < 0.05$) in USUGrain and ChGrain compared with USUBFT and USUGrass, whereas the quantity of 2-propanone from OrgGrass was similar ($P > 0.05$) to both the USUGrain and the forage-finished diets (USUBFT and USUGrass). The quantity of 2-heptanone was greatest ($P < 0.05$) in the USUGrain treatment compared with all other dietary treatments. The forage-finished products (USUBFT, USUGrass, and OrgGrass) were similar ($P > 0.05$) in the quan-

Table 7. Consumer rating of importance for various factors related to beef

Factor	Importance[1]
Brand name	3.56^{e}
Country of origin	4.65^{c}
Natural or organic claims	4.02^{d}
Price	7.58^{a}
USDA grade	6.37^{b}
SEM[2]	0.10
P-value	<0.001

[1]Factor importance was determined using a 10-mm continuous line scale where 0 = extremely unimportant and 10 = extremely important. Superscript letters indicate order of importance.

[2]Pooled (largest) SE of least squares means.

Table 8. The effects of dietary treatments on consumer liking of aroma, flavor, tenderness, fattiness, juiciness, overall liking, quality rating, and Warner–Bratzler shear force (WBSF) of beef LM (longissimus thoracis)

	Finishing diet[1] and retail product[2]						
Attribute[3]	USUGrain	ChGrain	USUBFT	USUGrass	OrgGrass	SEM[4]	*P*-value
Aroma	6.53	6.41	6.32	6.35	6.33	0.08	0.120
Flavor	6.50^{a}	6.23^{ab}	6.15^{bc}	6.10^{bc}	6.01^{c}	0.11	0.005
Tenderness	6.56^{a}	6.39^{ab}	6.58^{a}	6.12^{bc}	6.08^{c}	0.12	0.001
Fattiness	6.35^{a}	6.18^{abc}	6.26^{ab}	5.93^{c}	6.01^{bc}	0.12	0.009
Juiciness	6.28^{a}	5.88^{b}	6.20^{a}	5.81^{b}	5.75^{b}	0.12	0.005
Overall liking	6.45^{a}	6.20^{ab}	6.24^{a}	5.93^{bc}	5.92^{c}	0.11	0.001
WBSF, kgf	2.91	2.99	2.74	3.02	3.03	0.22	0.880

[a–c]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]ChGrain = USDA Choice, Grain-fed; OrgGrass = USDA Certified Organic Grass-fed.

[3]Evaluated on a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely).

[4]Pooled (largest) SE of least squares means.

tity of 2-heptanone, whereas ChGrain was similar ($P > 0.05$) to both USUBFT and OrgGrass.

Intermediate products of the Maillard reaction, 3-hydroxy-2-butanone and 2,3-butanedione (Dashdorj et al., 2015), were impacted by dietary treatment ($P \leq 0.044$). The ChGrain, OrgGrass, and USUGrain had similar ($P > 0.05$) concentrations of 3-hydroxy-2-butanone, which were greater ($P < 0.05$) than USUBFT and USUGrass. In the case of 2,3-butanedione, USUGrass and ChGrain had similar ($P > 0.05$) quantities, which were all greater ($P < 0.05$) than OrgGrass, USUGrain, and USUBFT. Carbon disulfide, derived from participation of sulfur-containing AA in the Maillard reaction (Boylston et al., 2012), was in the greatest ($P < 0.05$) concentration in OrgGrass, and the values of ChGrain and USUGrain were comparable ($P > 0.05$) and greater ($P < 0.05$) than USUBFT and USUGrass.

Pyrazines are nitrogen-containing compounds and the end products of the Maillard reaction (Back, 2007). Pyrazines contribute to the roasted flavor of meat and have low odor thresholds (Buttery and Ling, 1997). In this study, 2-ethyl-3,5-dimethyl pyrazine was found to be affected ($P = 0.036$) by dietary treatment. This pyrazine was greater ($P < 0.05$) in USUBFT and USUGrain compared with ChGrain, whereas ChGrain was similar ($P > 0.05$) to USUGrass and OrgGrass.

DISCUSSION

Carcass measures indicated that USUGrain and USUBFT animals had increased subcutaneous and perinephric fat deposition and overall heavier BW and carcasses compared with grass-finished cattle. In previous studies, fat thickness and HCW were determined to be greater for carcasses of concentrate-finished steers compared with mixed grass-legume pasture–finished steers (Realini et al., 2004). However, grazing of an annual legume species (cowpea) resulted in greater carcass fat thickness than grass grazing (Schmidt

Table 9. The effects of dietary treatments on the percentage of beef LM (longissimus thoracis) rated at different quality levels by consumers

	Finishing diet[1] and retail product[2]						
Quality level[3]	USUGrain	ChGrain	USUBFT	USUGrass	OrgGrass	SEM[4]	*P*-value
Unsatisfactory	10.3^{b}	14.0^{a}	14.5^{a}	15.6^{a}	17.8^{a}	1.7	0.002
Good everyday quality	44.2^{b}	45.1^{b}	44.0^{b}	53.5^{a}	48.6^{ab}	2.0	<0.001
Better than everyday quality	33.7^{a}	32.6^{ab}	31.8^{ab}	25.1^{c}	28.3^{bc}	1.8	0.002
Premium quality	11.7^{a}	8.0^{bc}	9.6^{ab}	5.7^{cd}	5.1^{d}	0.9	<0.001

[a–c]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]ChGrain = USDA Choice, Grain-fed; OrgGrass = USDA Certified Organic Grass-fed.

[3]Evaluated on a 4-point hedonic scale (1 = unsatisfactory, 2 = good everyday quality, 3 = better than everyday quality, and 4 = premium quality).

[4]Pooled (largest) SE of least squares means.

Table 10. The effects of dietary treatments on concentrations (ng/g of cooked sample) of volatile compounds of beef LM (longissimus thoracis)

	Finishing diet[1] and retail product[2]						
Volatile compound	USUGrain	ChGrain	USUBFT	USUGrass	OrgGrass	SEM[3]	*P*-value
n-Aldehydes							
Acetaldehyde	10.36	8.99	9.13	8.09	7.54	1.11	0.457
2-Methyl-propanal	4.06	3.26	3.52	3.22	3.99	0.47	0.588
Hexanal	27.88[b]	42.58[a]	29.53[ab]	13.49[c]	16.23[bc]	4.85	0.002
Heptanal	2.37	3.01	2.45	1.90	1.84	0.48	0.445
Octanal	2.77	3.36	2.36	2.73	2.17	0.58	0.654
Nonanal	3.18	3.22	2.61	2.92	2.14	0.66	0.760
Decanal	0.10[b]	0.44[a]	0.08[b]	0.14[b]	0.10[b]	0.10	0.028
Strecker aldehydes							
3-Methyl-butanal	11.92	8.75	11.78	10.29	9.70	1.42	0.467
2-Methyl-butanal	4.05	2.83	4.54	3.69	3.53	0.72	0.548
Benzaldehyde	2.04	1.82	2.32	1.84	2.32	0.17	0.118
Benzeneacetaldehyde	0.48	0.46	0.49	0.40	0.43	0.02	0.056
Ketones							
3-Hydroxy-2-butanone	234.26[abc]	368.78[a]	82.07[c]	135.26[bc]	249.95[ab]	54.96	0.011
2-Propanone	15.85[ab]	19.72[a]	9.85[c]	10.21[c]	13.47[bc]	1.92	0.007
2,3-Butanedione	9.63[ab]	14.51[a]	4.47[b]	11.49[a]	9.79[ab]	2.16	0.044
2-Butanone	11.55	10.23	9.75	8.43	11.01	1.22	0.438
2-Pentanone	1.18	1.17	1.02	0.83	0.97	0.09	0.064
2-Heptanone	3.51[a]	2.22[b]	1.86[bc]	1.20[c]	1.37[bc]	0.30	<0.001
Sulfur containing							
Dimethyl sulfide	2.10	2.10	2.03	1.66	2.05	0.24	0.654
Dimethyl disulfide	0.42	0.41	0.36	0.34	0.39	0.03	0.297
Carbon disulfide	6.60[ab]	6.17[ab]	3.17[b]	3.45[b]	9.63[a]	1.36	0.016
Methional	1.55	1.43	1.65	1.21	1.44	0.13	0.179
Furans							
2-Pentyl-furan	1.22[a]	1.17[ab]	1.12[bc]	1.04[c]	1.05[c]	0.03	0.003
Carboxylic acids							
Butanoic acid	3.85	5.23	4.26	3.20	1.99	0.89	0.150
Pentanoic acid	1.07[a]	1.12[a]	1.07[a]	0.95[b]	0.94[b]	0.04	0.012
Hexanoic acid	1.56[a]	1.43[a]	1.22[ab]	0.81[bc]	0.74[c]	0.14	0.001
Heptanoic acid	0.59	0.61	0.58	0.57	0.58	0.01	0.146
Octanoic acid	0.32[b]	0.39[a]	0.39[a]	0.34[b]	0.34[b]	0.02	0.007
Pyrazines							
Methyl-pyrazine	0.38	0.35	0.37	0.35	0.34	0.01	0.208
2,5-Dimethyl-pyrazine	0.51	0.44	0.50	0.46	0.44	0.02	0.051
Trimethyl-pyrazine	0.42	0.38	0.42	0.39	0.39	0.01	0.087
2-Ethyl-3,5-dimethyl-pyrazine	1.21[ab]	1.14[c]	1.22[a]	1.15[bc]	1.16[bc]	0.02	0.036
Esters							
Acetic acid, methyl ester	2.04	1.59	3.27	4.94	3.91	1.54	0.543
Butanoic acid, methyl ester	1.31	1.46	1.66	1.25	1.23	0.18	0.406
Octanoic acid, methyl ester	0.23	0.26	0.37	0.33	0.26	0.05	0.326
Alcohols							
1-Hexanol	0.64[a]	0.55[a]	0.52[ab]	0.38[b]	0.38[b]	0.05	0.006
1-Heptanol	0.82[ab]	0.89[a]	0.75[bc]	0.65[c]	0.67[c]	0.05	0.003
1-Octen-3-ol	1.93[a]	1.02[b]	1.11[b]	0.69[b]	0.67[b]	0.18	<0.001

[a–c]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to diet.

[1]USUGrain = conventional feedlot; USUBFT = perennial legume, birdsfoot trefoil (*Lotus corniculatus*); USUGrass = meadow brome (*Bromus riparius* Rehmann).

[2]ChGrain = USDA Choice, Grain-fed; OrgGrass = USDA Certified Organic Grass-fed.

[3]Pooled (largest) SE of least squares means.

et al., 2013). Similarly, LM area was determined in earlier studies to be greater for concentrate-finished steers compared with grass-finished steers (Realini et al., 2004). In the present study, the marbling scores of USU-finished cattle did not statistically differ regardless of treatment. This result is in contrast to previous works showing that marbling is altered with diet (Muir et al., 1998). However, visual assessment of marbling is a subjective measure and other indicators of carcass fatness (fat thickness and KPH) revealed that diet did have an impact on carcass fatness in this study.

Evidence of dietary impact on carcass fatness was further revealed through gravimetric analysis of IMF content. The present study is in agreement with past works demonstrating that IMF is greater for grain-finished beef than for grass-finished beef (French et al., 2001; Nuernberg et al., 2005). However, among the USU-finished beef treatments, the IMF of USUBFT was intermediate to USUGrain and USUGrass. The elevated IMF concentration of birdsfoot trefoil–finished beef is of interest due to the well documented impact of IMF content on palatability (Smith et al., 2004).

Accumulation of IMF occurs through preferential metabolism of glucose for fatty acid synthesis within intramuscular adipocytes (Smith and Crouse, 1984). Provision of dietary glucose, or precursors to glucose such as starch, to cattle at earlier stages has been demonstrated to impact marbling or IMF (Meyer et al., 2005). In this study, the quantity of nonfibrous carbohydrates (**NFC**) within foodstuffs appeared to influence provision of glucose and, thus, IMF accumulation. Cattle finished within the USU feedlot and on birdsfoot trefoil pastures were provided similar amounts of NFC, which was double the amount present in grass pastures.

Change in IMF content occurs primarily through increases in triglycerides during animal fattening (Wood et al., 2008). Furthermore, there is a propensity for greater accumulation of SFA and MUFA within beef triglycerides as overall IMF increases, in comparison with PUFA (Scollan et al., 2006; Wood et al., 2008). This accumulation of SFA and MUFA and proportional decrease in PUFA is related to overall IMF accumulation, irrespective of diet (De Smet et al., 2004). This phenomenon was evident in the present study, where grain-finished beef had greater IMF, cumulative SFA, and MUFA compared with grass-finished beef. Similar to overall IMF content, cumulative SFA and MUFA of USUBFT was intermediate to the USUGrain and USUGrass treatments.

Content of SFA and MUFA is of further interest to sensory perception. Concentrations of 16:0 have been positively correlated with desirable beef flavors (Baublits et al., 2009), and oleic acid is positively related to beef flavor desirability (Dryden and Maechello, 1970). In contrast, increased proportion of omega-3 fatty acids have been shown to increase undesirable off-flavors in beef (French et al., 2000; Wood et al., 2004).

Although relative increases of omega-3 fatty acids may negatively influence sensory perception, maintaining lower ratios of n-6:n-3 fatty acids can have positive health impacts. Simopoulos (2004) stated that human diets maintaining n-6:n-3 fatty acid ratios below 4.0 may decrease chances of coronary diseases and cancer. Ratios in the forage-finished beef treatments, including USUBFT, were all less than 4.0, whereas the grain-finished beef ratios each exceeded 4.0, particularly the purchased beef, ChGrain, which had an n-6:n-3 fatty acid ratio greater than 15. This result indicates that although USUBFT shared SFA and MUFA similarities with grain-finished beef, the n-6:n-3 ratios of USUBFT were at a positive dietary level.

The consumer participants of this study rated monetary factors (Price) and expectations of eating quality (USDA grade) more important than production claims or brand name. Of importance for the interpretation of these results is that participants also valued factors related to palatability (USDA grade). Furthermore, among palatability factors, flavor had the greatest proportion of importance to these consumers. As previously stated, flavor of forage-finished beef is known to differ from conventional feedlot–finished beef. Therefore, based on the high ranking of flavor and factors related to eating satisfaction, it may be assumed that the participants in this study were discerning of the beef attributes of interest in this study.

Sensory evaluation revealed a clear difference between grain- and grass-finished beef, supported by numerous previous investigations (Larick et al., 1987; Medeiros et al., 1987; French et al., 2001; Corbin et al., 2015; O'Quinn et al., 2016). Furthermore, results indicated that beef from birdsfoot trefoil–finished and grain-finished animals were comparable for most sensory attributes and perceived quality level. As previously described, USUBFT tenderness, fattiness, overall preference, and flavor were similar to ChGrain, whereas the flavor was also not different from other forage-finished beef (USUGrass and OrgGrass), although the flavor was liked less than that of USU grain-finished beef. This intermediate perception of USUBFT is in alignment with previously described results for IMF content and fatty acid composition, supporting the dual influence of fat content and fatty acid composition on sensory perception.

The primary mechanisms for the formation of the measured volatile compounds were through the degradation of lipids or the Maillard reaction, occurring during cooking (Dashdorj et al., 2015). Among lipid degradation products, aldehydes are formed as a result of thermal oxidation of oleic acid, linoleic acid, and linolenic acid (Cerny, 2007). Hexanal, which is formed via the oxidation of linoleic acid (Grosch, 1987), was the most numerically abundant aldehyde across all dietary treatments. Previously, Elmore et al. (1999) noted that highly unsaturated fatty acids enter free radical reactions and may break down to form smaller molecules that, in turn, form flavor-contributing volatile compounds. In alignment with this, the concentration of hexanal increased with increasing concentrations of total PUFA. Alcohols, such as 1-hexanol, 1-heptanol, and 2-pentyl-furan, have all been found to result from degradation of unsaturated fatty acids (Back, 2007), specifically linoleic acid (Grosch, 1987). Previously, each of these volatile compounds was reported to be greater in grain-finished beef (Elmore et al., 2004). Among all the lipid degradation products (aldehydes, alcohols, furans, carboxylic acids, and ketones) measured in this study, there was an overall trend toward greater quantities in grain-finished products, lower quantities in USUGrass and OrgGrass, and intermediate quantities in USUBFT. This trend was in agreement with previously described IMF content, fatty acid concentrations, and sensory attributes. Although very few studies have determined direct relationships between volatile compounds and flavor, the results of this study revealed that consumers preferred beef having greater lipid-derived volatile compounds.

Trends were less clear among Maillard reaction products. However, this was no surprise because, for the most part, development of Maillard products is not directly influenced by lipid components, the primary variant in this study. Each of the described Maillard products is of interest with regard to beef flavor. However, it was unclear if any viable relationship was present between Maillard products and the dietary treatments of this study. It should be noted that Maillard reaction products are greatly impacted by cooking method, duration, and temperature; in this study, all of these variables were held constant. It is yet unclear if compositional differences in fat, as in this study, greatly influence Maillard product development.

The results of this study support the conclusion that cattle finishing diets impact beef quality, where grass-finished beef is generally lower in fat and less liked by consumers compared with grain-finished beef. However, this study reveals that not all forages are equal. The relatively high concentration of NFC in the legume birdsfoot trefoil compared with meadow brome appears to have increased IMF and altered consumer perceptions. The tenderness, fattiness, overall liking, and quality level of birdsfoot trefoil–finished beef was equivalent to grain-finished beef. Meanwhile, the important dietary characteristic of n-6:n-3 ratios for birdsfoot trefoil–finished beef was more favorable compared with grain-finished beef and comparable with grass-finished beef. These results demonstrate an opportunity for producers to follow a forage-finishing program while maintaining beef eating quality comparable with grain finishing programs.

LITERATURE CITED

American Meat Science Association (AMSA). 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurement of fresh meat. AMSA, Champaign, IL.

AOAC. 1995. Official methods of analysis. 16th ed. AOAC International, Arlington, VA.

AOAC. 2011. Official methods of analysis. 18th ed. AOAC International, Arlington, VA.

Back, H. H. 2007. Handbook of meat, poultry and seafood quality. Blackwell Publishing, Ames, IA.

Barry, T. N., and W. C. McNabb. 1999. The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. Br. J. Nutr. 81:263–272.

Baublits, R. T., F. W. Pohlman, A. H. Brown, Z. B. Johnson, D. C. Rule, D. O. Onks, C. M. Murrieta, C. J. Richards, B. A. Sandelin, H. D. Loveday, and R. B. Pugh. 2009. Correlations and prediction equations for fatty acids and sensory characteristics of beef longissimus rib steaks from forage-fed and retail USDA Choice and Select rib steaks. J. Muscle Foods 20:1–17. doi:10.1111/j.1745-4573.2008.00129.x

Bidner, T. D., A. R. Schupp, A. B. Mohamad, N. C. Rumore, R. E. Montgomery, C. P. Bagley, and K. W. McMillin. 1986. Acceptability of beef from Angus Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high energy diet. J. Anim. Sci. 62:381–387.

Bidner, T. D., A. R. Schupp, R. E. Montgomery, and J. C. Carpenter Jr. 1981. Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. J. Anim. Sci. 53:1181–1187.

Boylston, T., F. Chen, P. Coggins, G. Hydlig, L. H. McKee, and C. Kerth. 2012. Handbook of meat, poultry and seafood quality. John Wiley & Sons, New York, NY.

Buttery, R. G., and L. C. Ling. 1997. 2-Ethyl-3,5-dimethylpyrazine and 2-ethyl-3,6-dimethylpyrazine: Odor thresholds in water solution. LWT-Food Sci. Technol. 30:109–110.

Cerny, C. 2007. Sensory evaluation of beef flavors In: L. M. L. Nollet, editor, Handbook of meat, poultry and seafood quality. Blackwell Publishing, Ames, IA. p. 311–326.

Corbin, C. H., T. G. O'Quinn, A. J. Garmyn, J. F. Legako, M. R. Hunt, T. T. N. Dinh, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Sci. 100:24–31. doi:10.1016/j.meatsci.2014.09.009

Dashdorj, D., T. Amna, and I. Hwang. 2015. Influence of specific taste-active components on meat flavor as affected by intrinsic and extrinsic factors: An overview. Eur. Food Res. Technol. 241:157–171. doi:10.1007/s00217-015-2449-3

De Smet, S., K. Raes, and D. Demeyer. 2004. Meat fatty acid composition as affected by fatness and genetic factors: A review. Anim. Res. 53:81–98. doi:10.1051/animres:2004003

Dryden, F. D., and J. A. Maechello. 1970. Influence of total lipid and fatty acid composition upon the palatability of three bovine muscles. J. Anim. Sci. 31:36–41.

Elmore, J. S., E. W. Helen, D. S. Mottram, D. S. Nigel, M. Enser, R. Richardson, and J. D. Wood. 2004. A comparison of the aroma volatiles and fatty acid compositions of grilled beef muscle from Aberdeen Angus and Holstein-Friesian steers fed diets based on silage or concentrates. Meat Sci. 68:27–33. doi:10.1016/j.meatsci.2004.01.010

Elmore, J. S., D. S. Mottram, M. Enser, and J. D. Wood. 1999. Effect of the polyunsaturated fatty acid composition of beef muscle on the profile of aroma volatiles. J. Agric. Food Chem. 47:1619–1625. doi:10.1021/jf980718m

Enser, M., K. G. Hallett, B. Hewett, G. A. J. Fursey, J. D. Wood, and G. Harrington. 1998. Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. Meat Sci. 49:329–341. doi:10.1016/S0309-1740(97)00144-7

Folch, J., M. Lees, and G. H. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497–509.

French, P., E. G. O. Riordan, F. J. Monahan, P. J. Caffrey, M. T. Mooney, D. J. Troy, and A. P. Moloney. 2001. The eating quality of meat of steers fed grass and/or concentrates. Meat Sci. 57:379–386. doi:10.1016/S0309-1740(00)00115-7

French, P., C. Stanton, F. Lawless, E. G. O. Riordan, F. J. Monahan, P. J. Caffrey, and A. P. Moloney. 2000. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets. J. Anim. Sci. 78:2849–2855.

Grosch, W. 1987. Reactions of hydroperoxides – Products of low molecular weight. In: H. W. S. Chan, editor, Autoxidation of unsaturated lipids. Academic Press, London, UK. p. 95–135.

John, L., D. Cornforth, C. E. Carpenter, O. Sorheim, B. C. Pettee, and D. R. Whittier. 2004. Comparison of color and thiobarbituric acid values of cooked hamburger patties after storage of fresh beef chubs in modified atmospheres. J. Food Sci. 69:C608–C614. doi:10.1111/j.1365-2621.2004.tb09908.x

Lance, R. M. 2011. Effects of adjunct cultures, sodium gluconate, and ripening temperature on low-fat cheddar cheese flavor. MS Thesis, Utah State University, Logan, UT.

Larick, D. K., H. B. Hedrick, M. E. Bailey, J. E. Williams, D. L. Hancock, G. B. Garner, and R. E. Morrow. 1987. Flavor constituents of beef as Influenced by forage- and grain-feeding. J. Food Sci. 52:245–251. doi:10.1111/j.1365-2621.1987.tb06585.x

Legako, J. F., J. C. Brooks, T. G. O'Quinn, T. D. J. Hagan, R. Polkinghorne, L. J. Farmer, and M. F. Miller. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat Sci. 100:291–300. doi:10.1016/j.meatsci.2014.10.026

Manner, W., R. J. Maxwell, and J. E. Williams. 1984. Effects of dietary regimen and tissue site on bovine fatty acid profiles. J. Anim. Sci. 59:109–121.

Martin, J. N., J. C. Brooks, L. D. Thompson, J. W. Savell, K. B. Harris, L. L. May, A. N. Haneklaus, J. L. Schutz, K. E. Belk, T. Engle, D. R. Woener, J. F. Legako, A. M. Luna, L. W. Douglas, S. E. Douglas, J. Howe, M. Duvall, K. Y. Patterson, and J. L. Leheska. 2013. Nutrient database improvement project: The influence of U.S.D.A. quality and yield grade on the separable components and proximate composition of raw and cooked retail cuts from the beef rib and plate. Meat Sci. 95(3):486–494. doi:10.1016/j.meatsci.2013.05.031

Maughan, C., R. Tansawat, D. Cornforth, R. Ward, and S. Martini. 2012. Development of a beef flavor lexicon and its application to compare the flavor profile and consumer acceptance of rib steaks from grass- or grain-fed cattle. Meat Sci. 90:116–121. doi:10.1016/j.meatsci.2011.06.006

McIntyre, B. L., and W. J. Ryan. 1984. The influence of type of diet and electrical stimulation on the eating quality of beef. Proc. Aust. Soc. Anim. Prod. 15:468–471.

Medeiros, L. C., R. A. Field, D. J. Menkhaus, and W. C. Russel. 1987. Evaluation of range-grazed and concentrate-fed beef by a trained sensory panel, a household panel and a laboratory test market group. J. Sens. Stud. 2:259–272. doi:10.1111/j.1745-459X.1987.tb00421.x

Melton, S. L. 1990. Effects of feeds on flavor of red meat: A review. J. Anim. Sci. 68:4421–4435.

Meyer, D. L., M. S. Kerley, E. L. Walker, D. H. Keisler, V. L. Pierce, T. B. Schmidy, C. A. Stahl, M. L. Linville, and E. P. Berg. 2005. Growth rate, body composition, and meat tenderness in early vs. traditionally weaned beef calves. J. Anim. Sci. 83:2752–2761.

Mills, E. W., J. W. Comerford, R. Hollendert, H. W. Harpster, B. House, and W. R. Henning. 1992. Meat composition and palatability of Holstein and beef steers as influenced by forage type and protein source. J. Anim. Sci. 70(8):2446–2451.

Morris, S. T., R. W. Purchas, and D. L. Burnham. 1997. Short-term grain feeding and its effect on carcass and meat quality. Proc. N.Z. Soc. Anim. Prod. 57:275–277.

Moser, C., and K. Herman. 2011. Method for the rapid determination of protein in meats using the CEM Sprint protein analyzer: Collaborative study. J. AOAC Int. 94:1555–1561. doi:10.5740/jaoacint.CS2011_04

Muir, P. D., J. M. Deaker, and M. D. Bown. 1998. Effects of forage- and grain-based feeding systems on beef quality: A review. N. Z. J. Agric. Res. 41:623–635. doi:10.1080/00288233.1998.9513346

North American Meat Processors Association. 2010. The meat buyer's guide. 6th ed. North American Meat Processors Association, Reston VA.

Nuernberg, K., D. Dannenberger, G. Nuernberg, K. Ender, J. Voigt, N. D. Scollan, J. D. Wood, G. R. Nute, and R. I. R. Ichardson. 2005. Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of longissimus muscle in different cattle breeds. Livest. Prod. Sci. 94:137–147. doi:10.1016/j.livprodsci.2004.11.036

O'Fallon, J. V., J. R. Busboom, M. L. Nelson, and C. T. Gaskins. 2007. A direct method for fatty acid methyl ester synthesis: Application to wet meat tissues, oils, and feedstuffs. J. Anim. Sci. 85:1511–1521. doi:10.2527/jas.2006-491

O'Quinn, T. G., D. R. Woerner, T. E. Engle, P. L. Chapman, J. F. Legako, J. C. Brooks, K. E. Belk, and J. D. Tatum. 2016. Identifying consumer preferences for specific beef flavor characteristics in relation to cattle production and postmortem processing parameters. Meat Sci. 112:90–102. doi:10.1016/j.meatsci.2015.11.001

Pitcher, L. R. 2015. Beef average daily gain and enteric methane emissions on birdsfoot trefoil, cicer milkvetch and meadow brome pastures. MS Thesis, Utah State University, Logan, UT.

Reagan, J. O., J. A. Carpenter, F. T. Bauer, and R. S. Lowrey. 1977. Packaging and palatability characteristics of grass and grass-grain fed beef. J. Anim. Sci. 45:716–721.

Realini, C. E., S. K. Duckett, G. W. Brito, M. Dalla Rizza, and D. De Mattos. 2004. Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. Meat Sci. 66:567–577. doi:10.1016/S0309-1740(03)00160-8

Schmidt, J. R., M. C. Miller, J. G. Andrae, S. E. Ellis, and S. K. Duckett. 2013. Effect of summer forage species grazed during finishing on animal performance, carcass quality, and meat quality. J. Anim. Sci. 91:4451–4461. doi:10.2527/jas.2012-5405

Scollan, N., J.-F. Hocquette, K. Nuernberg, D. Dannenberger, I. Richardson, and A. Moloney. 2006. Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Sci. 74:17–33. doi:10.1016/j.meatsci.2006.05.002

Shackelford, S. D., J. B. Morgan, H. R. Cross, and J. W. Savell. 1991. Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J. Muscle Foods 2:289–296. doi:10.1111/j.1745-4573.1991.tb00461.x

Simopoulos, A. P. 2004. Omega-6/omega-3 essential fatty acid ratio and chronic diseases. Food Rev. Int. 20(1):77–90. doi:10.1081/FRI-120028831

Smith, S. B., and J. D. Crouse. 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J. Nutr. 4:792–800.

Smith, S. B., D. R. Smith, and D. K. Lunt. 2004. Chemical and physical characteristics of meat: Adipose tissue. In: W. Jensen, C. Devine, and M. Dikemann, editors, Encyclopedia of meat sciences. Elsevier Science, Oxford, UK. p. 225–238.

Tansawat, R., C. A. J. Maughan, R. E. Ward, S. Martini, and D. P. Cornforth. 2013. Chemical characterisation of pasture- and grain-fed beef related to meat quality and flavour attributes. Int. J. Food Sci. Technol. 48:484–495. doi:10.1111/j.1365-2621.2012.03209.x

USDA. 1997. United States standards for grades of carcass beef. USDA, Agricultural Marketing Service, Livestock and Seed Division, Washington, DC.

Warren, H. E., N. D. Scollan, M. Enser, S. I. Hughes, R. I. Richardson, and J. D. Wood. 2008. Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. I: Animal performance, carcass quality and muscle fatty acid composition. Meat Sci. 78:256–269. doi:10.1016/j.meatsci.2007.06.008

Wood, J. D., M. Enser, A. V. Fisher, G. R. Nute, P. R. Sheard, R. I. Richardson, S. L. Hughes, and F. M. Whittington. 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78:343–358. doi:10.1016/j.meatsci.2007.07.019

Wood, J., R. Richardson, G. Nute, A. Fisher, M. Campo, E. Kasapidou, P. Sheard, and M. Enser. 2004. Effects of fatty acids on meat quality: A review. Meat Sci. 66:21–32. doi:10.1016/S0309-1740(03)00022-6