ILL Lending Request

Borrowings Library: OKS
Max Cost: $50.00IFM
Patron: Mateescu, Raluca 672154 lw
Request Date: 3/24/2011 02:10:19 PM

Journal Title: The Professional animal scientists.
Volume: 26
Issue: 6
Month/Year: 2010
Pages: 579-586
Article Author:
Article Title: A. J. Garmyn, G. G. Hilton, R. G. Mateescu, and D. L. VanOverbeke; Effects of Concentrate- Versus Forage-Based Finishing Diet on Carcass Traits, Beef
Imprint: Champaign, Il ; American Registry of Pro

Evans Original TN #: 2008760

ILL Number: 75527867

[redacted]

CIRCLE ONE:
IFM EFTS INVOICE NO CHARGE $_____
Comments:_____

Rev 8.13.04

Location: **IMPORT TIFF FROM DRIVE K:\MSLLending (75527867) & ARIEL.**
Process: **Regular**
Delivery Method: **ARIEL? Yes 139.78.49.61 OR TRY 139.78.50.143**
Billing Category: Exempt
Charge: **$0.00**
Payment Method:
IFM:
EFTS: No
INVOICE: Billing Address If Invoicing:

607-OKC Texpress
Oklahoma State University
Interlibrary Services
Stillwater, OK 74078-1071

Circle one:

Scanned & Arieled, Faxed or Mailed by: CM 3.24.11
Unable to Pull or Scan because : (initial & date)

NOS_____ Bnd too Tight _____

Exceeds 50 pgs_____

Other_____

THIS REQUEST HAS BEEN FILLED BY:

OCLC: TMV
DOCLINE: TXUTAMU

Medical Sciences Library, Texas A&M University

Phone: 979-845-7428
Fax: 979-845-0923
Ariel: 165.91.58.23
Email: docdel@medlib.tamu.edu

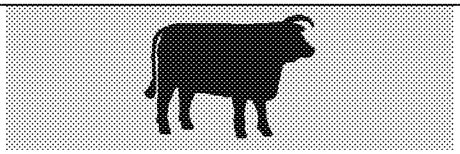
* THIS IS NOT AN INVOICE

(any charges will be Invoiced seperately at the end of the Billing Quarter)

REQUESTING RESENDS:

We prefer **FAX** but will accept by phone, email, or Ariel

The Professional Animal Scientist 26 (2010):579–586



Effects of Concentrate- Versus Forage-Based Finishing Diet on Carcass Traits, Beef Palatability, and Color Stability in Longissimus Muscle from Angus Heifers

A. J. Garmyn,[1] G. G. Hilton, R. G. Mateescu, and D. L. VanOverbeke[2]
Department of Animal Science, Oklahoma State University, Stillwater 74078

ABSTRACT

The objective was to determine the effects of finishing diet on carcass traits, beef palatability, and color stability of LM from Angus heifers. Half-siblings were obtained from a herd selected for increased intramuscular fat, ribeye area, and percentage of retail product, and decreased backfat and were randomly assigned to a forage- or concentrate-based finishing diet. Longissimus muscle samples (n = 155) were obtained and fabricated into steaks for trained sensory panel, Warner-Bratzler shear force, thiobarbituric acid-reactive substances (TBARS), and simulated retail display evaluation. Data were analyzed using the MIXED procedures of SAS using slaughter age as a covariate. Carcasses from concentrate-finished heifers had greater adjusted fat thickness (1.86 vs. 0.87 cm), greater percentage of KPH (2.14 vs. 1.35%), greater numerical YG (3.38 vs. 2.25), and greater marbling scores (modest 90 vs. traces 70) than forage-finished heifers ($P < 0.05$). Steaks from concentrate-fed heifers had lesser Warner-Bratzler shear force values (3.67 vs. 5.05 kg), greater tenderness ratings, greater beef flavor intensity, lesser grassy/cowy flavor intensity, and greater painty/fishy flavor intensity than steaks from forage-fed heifers ($P < 0.05$). Initial TBARS were greater ($P < 0.05$) in steaks from concentrate-fed heifers when compared with grass-fed heifers, but TBARS were not different ($P > 0.05$) between diets after 7 d in retail display. Of the color measurements, only L^* values differed between diets; they were greater (38.36 vs. 32.25; $P < 0.05$) for steaks from concentrate-fed heifers. This study points to several differences in beef palatability resulting from finishing diet composition.

Key words: beef, color stability, concentrate finishing, forage finishing, palatability

INTRODUCTION

Beef can be classified as a fatty protein source, with certain health risks associated with its consumption. This stems from the total fat content, saturated fatty acid composition, and cholesterol found in beef and their relationship with obesity, certain types of cancer, and cardiovascular diseases (Fernandez-Gines et al., 2005). Therefore, considerable attention has been given to improving the nutritional value of beef, particularly through the diet and genetic selection of cattle.

Fatty acid profiles of intramuscular fat (**IMF**) can be altered and enhanced for human nutrition by incorporating forages in the beef cattle diet (French et al., 2000; Realini et al., 2004). Increased grass intake can decrease the concentration of saturated fatty acids while increasing the ratio of PUFA to saturated fatty acids and the concentration of beneficial conjugated linoleic acid.

Although forage-based finishing systems can enhance the nutritional

[1] Present address: Texas Tech University, Lubbock 79409.
[2] Corresponding author: deb.vanoverbeke@okstate.edu

value of beef, their effect on carcass characteristics, palatability traits, and color stability remains unclear. In addition to increasing IMF in the LM (Faucitano et al., 2008), grain feeding can also increase carcass weight and backfat (Mandell et al., 1998; Realini et al., 2004). French et al. (2001) found no differences in color, tenderness, or sensory traits between diets of varying levels of grass and concentrates. However, Faucitano et al. (2008) reported decreased sensory panel tenderness scores for grain-fed cattle, although Schroeder et al. (1980) found that grain finishing increased scores for palatability-determining traits while reducing shear force values. The effect of diet on color stability and lipid oxidation varies, depending on the processed state of the muscle (Realini et al., 2004).

Results in these types of studies can be confounded by backfat finish or slaughter age. Moreover, cattle have typically not been related, which can increase the difficulty of detecting differences truly explained by the diet. Therefore, the purpose of this study was to examine the effects of concentrate versus forage finishing of genetically related heifers on carcass characteristics, beef palatability, and color stability while statistically accounting for slaughter age.

MATERIALS AND METHODS

The Oklahoma State University Institutional Review Board approved the experimental protocol used in the present study.

Animal Resources and Diets

Angus heifers (n = 204) used in this study were obtained from a herd in South Carolina that has been selected for increased IMF, ribeye area (LMA), and retail product and decreased backfat since 1993. Heifers were born between December 2006 and January 2007. Paternal half-siblings were randomly assigned to a concentrate- or forage-based finishing diet so that each sire had offspring represented in both finishing diet types. All heifers were backgrounded on wheat pasture in central Oklahoma until March 2008, when heifers were assigned to a finishing diet. After backgrounding, concentrate-finished heifers (n = 102; initial BW = 266.2 ± 28.5 kg) were fed in a single pen to follow a natural program (no implants, nonimplant metabolic modifiers, or antibiotics) at a commercial feedlot in McLean, Texas, for approximately 140 d from March 2008 to July 2008. Heifers received a starter ration for the first 24 d and were transitioned to a finishing diet at d 25. On d 34, the finishing ration was changed from Sweet Bran (Cargill Inc., Blair, NE) to a blend of 60% Sweet Bran and 40% distillers dried grains. Composition of the starter and finishing diets fed is shown in Table 1. Heifers were fed 3 times daily.

Forage-finished heifers (n = 104; initial BW = 261.5 ± 31.0 kg) were rotated between grass and wheat pasture with an antibiotic-free mineral supplement until July 2009. The number of times per week the cool season pastures were grazed was adjusted to compensate for available forage. Heifers had access to pasture consisting of wheat pasture and annual grass (ryegrass) mix during winter months and bermudagrass and native pasture dominated by blue grama, bluestem, and buffalograss (*Bouteloua dactyloides*) during the warm seasons.

Table 1. Ingredient and nutrient composition (% of DM, unless stated otherwise) of starting and finishing diets fed to heifers

	Diet[1]		
Item	1	2	3
Ingredient			
Flaked corn	42.96	63.30	57.74
Sweet Bran[2]	20.30	22.32	26.37
Hay blend	30.80	8.53	9.97
Supplement 1[3]	5.94	5.85	5.92
Nutrient composition,[4] %			
DM, % of as-fed	74.3	73.3	72.4
CP	14.8	14.4	15.1
NPN	3.08	1.96	1.99
NDF	33.0	21.3	23.6
NE_m, Mcal/kg	0.81	0.93	0.92
NE_g, Mcal/kg	0.52	0.62	0.61
Calcium	0.89	0.72	0.75
Magnesium	0.31	0.23	0.24
Phosphorus	0.34	0.39	0.41
Potassium	0.92	0.73	0.76
Sulfur	0.18	0.18	0.19

[1]Diet 1 = starter diet fed for the first 24 d; diet 2 = finishing diet fed from d 25 to 34; diet 3 = diet fed for the remainder of the finishing phase.

[2]Sweet Bran (Cargill Inc., Blair, NE); diet 3 consists of a blend of 60% Sweet Bran and 40% dried distillers grains.

[3]Pelleted supplement contained the following (DM basis): 40.35% ground corn, 19.73% wheat middlings, 21.42% limestone, 4.39% dicalcium phosphate, 5.79% salt, 0.05% manganous oxide, 1.14% Availa-Zn 100 (Zinpro, Eden Prairie, MN), 0.07% zinc sulfate, 4.56% potassium chloride, 1.93% magnesium oxide, 0.06% vitamin A (30,000 IU/g), 0.04% vitamin E (50%), 0.31% Rumensin 80 (Elanco Animal Health, Indianapolis, IN), and 0.17% Tylan 40 (Elanco Animal Health).

[4]Based on laboratory results.

Slaughter and Data Collection

After approximately 140 d on feed, concentrate-fed heifers were slaughtered at a commercial slaughter facility in Fort Worth, Texas. Grain-finished heifers were slaughtered when heifers reached an average final BW of 545 kg. After a grazing period of approximately 505 d, forage-finished heifers were slaughtered at a commercial slaughter facility in Booker, Texas. Forage-fed heifers were slaughtered when heifers reached an average final BW of 454 kg. Neither plant used electrical stimulation; both plants operated at similar processing speeds. At 48 h postmortem, trained personnel from Oklahoma State University obtained carcass measurements, including hot carcass weight (**HCW**), LMA, percentage of KPH, adjusted fat thickness, marbling score, skeletal maturity, calculated USDA YG, and USDA QG. The scale used for data entry of marbling score was 10 = practically devoid, 20 = traces, 30 = slight, 40 = small, 50 = modest, 60 = moderate, 70 = slightly abundant, and 80 = moderately abundant. Skeletal maturity was recorded, but degrees were not assessed within grade A maturity. Insufficient lighting prevented accurate assessment of lean maturity, so it was not evaluated or recorded in the plants.

Sample Collection and Preparation

Carcasses were fabricated according to Institutional Meat Purchasing Specifications (**IMPS**; USDA, 1996). Strip loins (IMPS 180) were collected, vacuum packaged, boxed, and transported to the Oklahoma State University Food and Agricultural Products Center in Stillwater. Strip loins (n = 155) were aged 10 d postmortem at 2°C. Some carcasses were excluded because of improper identification to verify parentage. After aging, an approximately 1.27-cm steak was removed from the anterior end of the strip loin to level the cut surface. The steak was trimmed of all external connective tissue and external fat to be used as the initial thiobarbituric acid-reactive substances (**TBARS**) steak. Three 2.54-cm steaks were removed for Warner-Bratzler shear force (**WBSF**), sensory analysis, and simulated retail display. Sensory, WBSF, and TBARS steaks were vacuum packaged and placed in a freezer at −20°C for subsequent analysis.

Retail Display

The steaks were placed on a white Styrofoam tray with a white soaker pad and overwrapped with a polyvinyl chloride film. To simulate retail display, trays were placed in an open-topped, coffin-chest display case (M1-8EB, Hussman, Bridgeton, MO) maintained between 2 and 4°C, and were displayed under continuous 1,600 lx of cool-white fluorescent lighting (Bulb No. F40 T12, Promolux, British Columbia, Canada).

Visual Color

Beginning at 0 h under display conditions and every 12 h thereafter for 7 d, each steak was subjectively evaluated by a 6-member trained panel. Trained panelists passed the Farnsworth 100 Hue Test (Macbeth, Newsburgh, NY) with an error score <60 before participating on a color panel. Trays were rotated daily to be exposed to all possible light angles and intensities, as well as to decrease potential environmental effects associated with the defrost cycle and location within the case. Panelists assigned scores to each steak for subjective muscle color, surface discoloration, and overall appearance at each evaluation time. Muscle color was characterized on an 8-point scale (1 = extremely dark red, and 8 = extremely bright cherry red) as outlined in the Guidelines for Meat Color Evaluation (American Meat Science Association, 1991). Scores for surface discoloration caused by metmyoglobin were assigned based on a 7-point scale [1 = no (0%) discoloration, and 7 = total (100%) discoloration]. Overall appearance was scored on an 8-point scale (1 = extremely undesirable, and 8 = extremely desirable).

Instrumental Color

Steaks were evaluated for instrumental color beginning at 0 h under display conditions and every 12 h thereafter for 7 d. The color of each steak was measured using a HunterLab Miniscan XE Plus Spectrophotometer (2.50-cm aperture, 10° standard observer, Illuminant D65, HunterLab Associates Inc., Reston, VA) to determine color coordinate values for L* (brightness; 0 = black, and 100 = white), a* (redness/greenness; positive values = red, and negative values = green), and b* (yellowness/blueness; positive values = yellow, and negative values = blue) according to the procedures of the Commission Internationale de l'Éclairage (1976). At each time of evaluation, 3 independent readings for L*, a*, and b* values were taken for each steak and averaged.

Warner-Bratzler Shear Force

The frozen steaks were allowed to thaw at 4°C for 24 h before cooking. Steaks were broiled in an impingement oven (XLT Impinger, Model 3240-TS, BOFI Inc., Wichita, KS, or Lincoln Impinger, Model 1132-000-A, Lincoln Foodservice Products, Fort Wayne, IN) at 200°C to an internal temperature of 68°C. An Atkins AccuTuff 340 thermometer (Atkins Temtec, Gainesville, FL) was used to measure the temperature of steaks as they exited the oven. If they had not yet reached 68°C, they were returned to the conveyor until they reached 68°C. After cooking, steaks were cooled at 4°C for 18 to 24 h. Six cores, 1.27 cm in diameter, were removed parallel to the muscle fiber orientation and sheared once, using a Warner-Bratzler head attached to an Instron Universal Testing Machine (Model 4502, Instron Corporation, Canton, MS). The Warner-Bratzler head moved at a crosshead speed of 200 mm/min. Peak load (kg) of each core was recorded by an IBM

PS2 computer (Model 55 SX, IBM, Armonk, NY) using software provided by the Instron Corporation. Mean peak load (kg) was analyzed for each sample.

Sensory Analysis

Steaks were assigned a randomized number for sensory sessions and then assigned to sensory sessions in numerical order of the randomized number. Steaks were allowed to thaw at 4°C for 24 h before cooking, cooked to 68°C as described above for WBSF, sliced into 2.54 × 1.27 × 1.27 cm samples, and served warm to panelists.

Sensory attributes were evaluated by an 8-member trained panel consisting of Oklahoma State University personnel. Panelists were trained for evaluating tenderness, juiciness, and 4 specific flavor attributes (Cross et al., 1978). Flavor terminology used by Berry et al. (1980) was adopted for use in the study. Livery/metallic flavor was classified as "serum, blood, or liver-like." Grassy flavor was classified as "animal, chemical, medicinal, or iodine-like." Johnson and Civille (1986) noted that cowy was the aromatic associated with cow meat, and painty and fishy were aromatics associated with rancid fats and oils. Various products and steaks, some similar to those used in the study, were used to establish flavor notes. Sensory sessions were conducted once or twice per day and contained 12 samples each. Bohnenkamp and Berry (1987) reported that 8 to 12 samples per meeting were ideal for trained sensory ground beef panels; however, trained panelists could evaluate up to 18 ground beef samples in a satisfactory manner for the evaluation of texture and juiciness. Even so, panelists were limited to 12 samples/session to minimize panelist fatigue in the current study. Samples were evaluated using a standard ballot from the American Meat Science Association (1995). Panelists evaluated samples in duplicate for initial and sustained juiciness, initial and overall tenderness, and amount of connective tissue. Panelists evaluated cooked beef flavor, grassy/cowy flavor, painty/fishy flavor, and livery/metallic flavor intensity. Panelists used an 8-point scale to evaluate juiciness (1 = extremely dry; 2 = very dry; 3 = moderately dry; 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy; 7 = very juicy; 8 = extremely juicy), tenderness (1 = extremely tough; 2 = very tough; 3 = moderately tough; 4 = slightly tough; 5 = slightly tender; 6 = moderately tender; 7 = very tender; 8 = extremely tender), and connective tissue (1 = abundant; 2 = moderately abundant; 3 = slightly abundant; 4 = moderate; 5 = slight; 6 = traces; 7 = practically none; 8 = none). The scale used for beef flavor and off-flavor intensity was 1 = not detectable, 2 = slightly detectable, and 3 = strong.

During sessions, panelists were randomly seated in individual booths in a temperature- and light-controlled room. While being served, the panelists were under red-filtered lights, as suggested by the American Meat Science Association (1995). The 12 samples were served in a randomized order according to panelist. The panelists were provided distilled, deionized water and unsalted crackers to cleanse their palate.

Thiobarbituric Acid-Reactive Substances

After 7 d of retail display, steaks were removed from packaging and designated as post-TBARS steaks, vacuum-packaged, and frozen at −20°C for subsequent analysis. Lipid oxidation was evaluated by TBARS using the modified method of Buege and Aust (1978). A 10-g sample was placed in a blender (model 51BL31, Waring Products Inc., Torrington, CT) and homogenized with 30 mL of cold deionized water. The mixture was transferred to a disposable tube and centrifuged for 10 min at 1,850 × *g*. Two milliliters of supernatant was extracted from the tube and placed in a disposable glass tube with 4 mL of thiobarbituric acid/trichloroacetic acid and 100 μL of butylated hydroxyanisol. Tubes were vortexed and then incubated in a boiling water bath (100°C) for 15 min, followed by 10 min in a cold water bath (15–20°C). After cooling, samples were centrifuged for 10 min at 1,850 × *g*. The absorbance was read at 531 nm using a Beckman spectrophotometer (Model DU 7500, Beckman Instruments Inc., Brea, CA). A standard curve was generated for each day of analysis using 1,1,3,3-tetra-ethoxypropane. Lipid oxidation was measured in duplicate for each steak, and the average absorbance reading was used for each sample. Results were expressed as milligrams of malonaldehyde per kilogram of sample.

Statistical Analysis

Data were analyzed using the MIXED procedures of SAS (SAS Institute Inc., Cary, NC). The ANOVA model for carcass data, WBSF, lipid oxidation, and sensory traits included diet as the fixed effect and animal (sire) as the random effect. The ANOVA model for color attributes was analyzed using a repeated-measures model with time as the repeated measure, animal (sire) as the subject, and diet as the fixed effect. Data for initial, final, and change in color attributes were analyzed using the MIXED procedure of SAS. The model included diet as the fixed effect and animal (sire) as the random effect. Slaughter age was included in all models as a covariate. The least squares means were separated using a pairwise *t*-test when the model displayed a treatment effect ($\alpha \leq 0.05$).

RESULTS AND DISCUSSION

Results of carcass characteristics are presented in Table 2. Concentrate-fed heifers tended to produce heavier HCW ($P = 0.08$). Mandell et al. (1998) reported heavier HCW for grain-fed steers when slaughtered at a similar fat thickness compared with forage-fed steers ($P < 0.01$), and Realini et al. (2004) also found that carcasses from concentrate-finished steers were heavier than those from pasture-finished steers. Carcasses from

Table 2. Effects of the heifer finishing diet on carcass characteristics

	Concentrate		Forage		
Trait	**Mean**	**SE**	**Mean**	**SE**	***P*-value**
N	97		58		
HCW, kg	337.3	9.0	297.0	14.7	0.08
Fat thickness, cm	1.86	0.13	0.87	0.22	<0.01
LM area, cm^2	84.92	2.21	77.97	3.60	0.22
KPH, %	2.14	0.09	1.35	0.14	<0.01
USDA calculated YG	3.38	0.18	2.25	0.29	0.01
Marbling score[1]	60	3	28	4	<0.01

[1]10 = practically devoid; 20 = traces; 30 = slight; 40 = small; 50 = modest; 60 = moderate; 70 = slightly abundant; 80 = moderately abundant.

heifers finished on concentrate in the current study had greater ($P < 0.01$) adjusted fat thickness, greater ($P < 0.01$) percentage of KPH, greater ($P = 0.011$) USDA calculated YG, and greater ($P < 0.01$) visual marbling scores than forage-finished heifers. Longissimus muscle area was similar ($P > 0.05$) between finishing diets. All carcasses from grain-fed heifers had grade A skeletal maturity; however, 6 carcasses from the grass-fed heifers had sufficient ossification for grade B maturity, 5 were grade C maturity, and 1 carcass had grade D skeletal maturity (data not shown). The older skeletal maturity scores can be explained by the advanced chronological age of the grass-finished heifers, which were approximately 12 mo older than their concentrate-finished contemporaries at slaughter. The absence of a significant difference for LMA agrees with a past study (Mandell et al., 1998) in which forage finishing did not decrease LMA in relation to concentrate finishing when time on feed differed between diets; however, Realini et al. (2004) reported larger LMA in carcasses of concentrate-finished steers compared with pasture-finished steers. The reduced fat thickness of the forage-finished carcasses in the present study is in alignment with the results of previous studies (Schroeder et al., 1980; Realini et al., 2004). The reduced YG of forage-finished heifers aligns with the increase in cutability of forage-fed animals reported by Schroeder et al. (1980). Schroeder et al. (1980) also reported greater marbling scores for carcasses from grain-fed cattle, which supports the results from the current study.

Results of WBSF and sensory traits can be found in Table 3. Longissimus muscle steaks from concentrate-finished heifers had lesser ($P < 0.01$) WBSF values and greater ($P < 0.01$) sensory tenderness ratings for initial and overall tenderness and for connective tissue than steaks from forage-finished heifers. Similar results for tenderness were produced in a previous study (Schroeder et al., 1980). Possible explanations may involve increased fat deposition and the prevention of cold-shortening or perhaps the younger age of concentrate-fed cattle. It is well documented that increased fat thickness can significantly improve beef tenderness by reducing cold-shortening during the postmortem chilling period (Lochner et al., 1980; Marsh et al., 1981; Dolezal et al., 1982). However, Faucitano et al. (2008) found no differences in WBSF values attributable to diet and showed that grain feeding resulted in decreased sensory panel tenderness scores compared with grass feeding, which contradicts the current findings. French et al. (2001) also reported no difference between concentrate and grass diets for WBSF or any sensory traits.

There was no difference ($P > 0.05$) between diets for initial or sustained juiciness. Steaks from concentrate-finished heifers had greater cooked beef flavor intensity ($P < 0.01$), lesser grassy/cowy flavor intensity ($P < 0.01$), and greater painty/fishy flavor intensity ($P = 0.01$) than steaks from forage-finished heifers. There was no difference ($P > 0.05$) between diets for livery/metallic flavor intensity. The inferior cooked beef flavor of forage-fed beef agrees with the lesser flavor scores found by Schroeder et al. (1980). Also supporting the current study, Mandell et al. (1998) reported slightly more cooked beef flavor and less off-flavor in grain-fed versus forage-fed beef. The increased cooked beef flavor intensity of concentrate-fed beef may be related to the elevated marbling levels of concentrate-fed heifers.

Results of lipid oxidation are displayed in Table 3. Initial TBARS were greater ($P = 0.05$) in steaks obtained from concentrate-finished heifers when compared with grass-finished heifers; however, TBARS were not statistically different ($P > 0.05$) between diets after 7 d in retail display. The susceptibility of a fatty acid to oxidize is related primarily to the degree of unsaturation; however, the fatty acid composition of the lipid, the presence and activity of pro- and antioxidants, the oxygen level, and storage conditions (temperature, light intensity/exposure, moisture content, etc.) will all affect the rate of autoxidation of meat products (Belitz et al., 2004). Although fatty acid composition was not reported in the current study, increasing the PUFA content caused by forage feeding can increase the susceptibility to lipid oxidation; however, the vitamin E antioxidant found in forage-based diets can offset the pro-oxidative properties of PUFA (Faustman et al., 1998), thus reducing lipid oxidation. O'Sullivan et al. (2003) demonstrated that lipid oxidation was greater in concentrate-fed animals compared with animals with various levels of forage inclusion in their diet. This difference was observed initially and throughout retail display. Similarly, Realini et al. (2004) reported steaks from pasture-fed animals had lesser initial TBARS values than steaks from concentrate-

fed animals, with this advantage being maintained throughout retail display. These results contradict the findings of Yang et al. (2002), who found that pasture feeding increased lipid oxidation of aged beef compared with grain-fed beef supplemented with vitamin E.

Generally, diet did not have an effect on instrumental or subjective lean color over the entire length of retail display (Table 4). However, steaks from concentrate-fed heifers had greater L* values initially (0 h) and throughout the length of retail display ($P < 0.05$). Although the final (156 h) L* values were also greater ($P < 0.05$) from the concentrate diet, the amount of change from 0 to 156 h did not differ between diets ($P = 0.08$). Finishing diet did not have an effect on initial, final, overall, or change in a* or b* values ($P > 0.05$). Measures of subjective lean color were not different ($P > 0.05$) between diets over the entire length of retail display. However, panelists initially (0 h) rated steaks from concentrate-fed heifers as brighter red ($P < 0.01$), with a more desirable overall appearance ($P < 0.01$) than steaks from forage-fed heifers. Although initial scores differed according to panelists, muscle color and overall appearance were not different ($P > 0.05$) at the conclusion (156 h) of retail display. Even so, the amount of change from 0 to 156 h was less ($P \leq 0.02$) for steaks from forage-fed heifers compared with those from concentrate-fed heifers for both subjective muscle color and overall appearance.

Schroeder et al. (1980) reported that grain-fed beef was initially brighter and resisted discoloration longer than forage-fed beef, which partially supports the results of the current study. Concentrate-fed steaks were initially rated brighter than forage-fed steaks; however, there were no differences in the amount of or change in surface discoloration of steaks from the different finishing diets. The results of the current study also contradict the findings of Yang et al. (2002), who reported lesser a* values in meat from pasture-fed cattle compared with grain-fed beef with or without vitamin E supplementation. However, O'Sullivan et al. (2003) did not find significant differences in color caused by diet, which supports the current findings, with the exception of L* values.

Table 3. Effects of the heifer finishing diet on Warner-Bratzler shear force (WBSF), lipid oxidation, and sensory traits

	Concentrate		Forage		
Trait	Mean	SE	Mean	SE	*P*-value
N	97		58		
WBSF, kg	3.67	0.18	5.05	0.29	<0.01
TBARS[1]					
d 0[2]	0.14	0.01	0.10	0.01	0.05
d 7[2]	0.12	0.01	0.13	0.02	0.68
Sensory					
Initial juiciness[3]	5.74	0.12	5.50	0.20	0.43
Sustained juiciness[3]	5.12	0.11	5.00	0.18	0.68
Initial tenderness[4]	6.28	0.16	4.29	0.26	<0.01
Overall tenderness[4]	6.12	0.17	3.95	0.28	<0.01
Connective tissue[5]	5.95	0.17	3.76	0.28	<0.01
Beef flavor[6]	2.46	0.07	1.86	0.11	<0.05
Grassy/cowy flavor[6]	1.13	0.07	2.06	0.11	<0.01
Painty/fishy flavor[6]	1.32	0.05	0.99	0.08	0.01
Livery/metallic flavor[6]	1.05	0.03	1.12	0.05	0.39

[1]Thiobarbituric acid-reactive substances (TBARS); expressed as milligrams of malonaldehyde per kilogram of sample.

[2]Expressed as days in a simulated retail display.

[3]1 = extremely dry; 2 = very dry; 3 = moderately dry; 4 = slightly dry; 5 = slightly juicy; 6 = moderately juicy; 7 = very juicy; 8 = extremely juicy.

[4]1 = extremely tough; 2 = very tough; 3 = moderately tough; 4 = slightly tough; 5 = slightly tender; 6 = moderately tender; 7 = very tender; 8 = extremely tender.

[5]1 = abundant; 2 = moderately abundant; 3 = slightly abundant; 4 = moderate; 5 = slight; 6 = traces; 7 = practically none; 8 = none.

[6]1 = not detectable; 2 = slightly detectable; 3 = strong.

IMPLICATIONS

Finishing diet type has a significant effect on carcass characteristics, especially those related to fat deposition. Diet did not affect lean color over the entire length of retail display, with the exception of L* values. However, there was less change in the muscle color and overall appearance of steaks from forage-fed heifers, which was partially due to the darker initial scores of steaks from the forage diet. Forage-finished cattle are often older than their concentrate-finished counterparts, which can partially explain differences observed in palatability traits in this study. Even after accounting for slaughter age, concentrate-fed steaks were rated as more tender by panelists and required less force to shear than forage-fed steaks. Moreover, concentrate-fed steaks were rated as having stronger beef flavor intensity and less detectable grassy/cowy flavor than forage-fed steaks. Because consumers in the United States have grown so accustomed to the flavor of grain-fed beef, the flavor profile obtained from grass-fed product is not always appreciated by consumers. Although incorporating forages into beef finishing diets can be nutritionally beneficial to humans, this study points to several differences in beef palatability attributable to finishing diet composition.

Table 4. Effects of heifer finishing diets on initial, final, overall, and change in instrumental and subjective lean color[1]

	Concentrate		Forage		
Trait	**Mean**	**SE**	**Mean**	**SE**	***P*-value**
N	97		58		
Instrumental color					
L*[2] (0 to 156 h)	38.36	0.58	32.25	0.88	<0.01
L* (0 h)	39.39	0.65	32.58	1.05	<0.01
L* (156 h)	37.05	0.68	31.46	1.10	<0.01
Δ L*	2.50	0.38	0.78	0.62	0.08
a*[3] (0 to 156 h)	19.52	0.77	22.15	1.17	0.17
a* (0 h)	24.19	0.45	23.19	0.73	0.38
a*(156 h)	10.60	1.19	12.45	1.93	0.54
Δ a*	13.60	1.22	10.74	1.98	0.36
b*[4] (0 to 156 h)	18.70	0.41	18.34	0.62	0.72
b* (0 h)	19.64	0.41	18.54	0.67	0.30
b* (156 h)	14.83	0.55	13.75	0.89	0.43
Δ b*	4.80	0.58	4.91	0.94	0.94
Subjective color					
Muscle color[5] (0 to 156 h)	4.11	0.15	3.91	0.24	0.59
Muscle color (0 h)	5.92	0.12	4.46	0.20	<0.01
Muscle color (156 h)	1.82	0.24	2.67	0.38	0.16
Δ Muscle color	4.09	0.24	1.79	0.39	<0.01
Surface discoloration[6] (0 to 156 h)	2.66	0.20	2.31	0.33	0.50
Surface discoloration (0 h)	1.02	0.05	1.13	0.08	0.37
Surface discoloration (156 h)	5.90	0.43	4.96	0.69	0.39
Δ Surface discoloration	4.88	0.42	3.83	0.68	0.33
Overall appearance[7] (0 to 156 h)	4.23	0.17	4.19	0.27	0.94
Overall appearance (0 h)	6.52	0.11	5.50	0.18	<0.01
Overall appearance (156 h)	1.41	0.23	1.79	0.37	0.52
Δ Overall appearance	5.10	0.24	3.71	0.39	0.02

[1]Change (Δ) in instrumental and subjective lean color was calculated by subtracting spectrophotometer readings/panelist scores at 156 h from readings/scores at 0 h.

[2]L* (brightness; 0 = black, 100 = white).

[3]a* (redness/greenness; positive values = red, negative values = green).

[4]b* (yellowness/blueness; positive values = yellow, negative values = blue).

[5]Muscle color (1 = extremely dark red, 8 = extremely bright cherry red).

[6]Surface discoloration (1 = no discoloration, 7 = total discoloration).

[7]Overall appearance (1 = extremely undesirable, 8 = extremely desirable).

LITERATURE CITED

American Meat Science Association. 1991. Guidelines for Meat Color Evaluation. Proc. Recip. Meat Conf. Vol. 44. Natl. Live Stock and Meat Board, Chicago, IL.

American Meat Science Association. 1995. Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat. Natl. Live Stock and Meat Board, Chicago, IL.

Belitz, H. D., W. Grosch, and P. Schieberle. 2004. Food Chemistry. 3rd rev. ed. Springer-Verlag, Berlin, Germany.

Berry, B. W., J. A. Maga, C. R. Calkins, L. H. Wells, Z. L. Carpenter, and H. R. Cross. 1980. Flavor profile analyses of cooked beef loin steaks. J. Food Sci. 45:1113.

Bohnenkamp, J. S., and B. W. Berry. 1987. Effect of sample numbers on the sensory acuity of a trained ground beef texture panel. J. Sens. Stud. 2:23.

Buege, J. A., and S. D. Aust. 1978. Microsomal lipid peroxidation. p. 302 in Methods in Enzymology. P. Fleischer and L. Packer, ed. Academic Press, New York, NY.

Commission Internationale de l'Éclairage. 1976. Recommendations on uniform color spaces-color difference equations, psychometric color terms. Suppl. No. 2 to CIE Publ. No. 15 (E-1.3.1) 1971. Commission Internationale de l'Éclairage, Paris, France.

Cross, H. R., R. Moen, and M. S. Stanfield. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. 32:48.

Dolezal, H. G., G. C. Smith, J. W. Savell, and Z. L. Carpenter. 1982. Comparison of subcutaneous fat thickness, marbling, and quality grade for predicting palatability of beef. J. Food Sci. 47:397.

Faucitano, L., P. Y. Chouinard, J. Fortin, I. B. Mandell, C. Lafrenière, C. L. Girard, and R. Berthiaume. 2008. Comparison of alternative beef production systems based on forage finishing or grain-forage diets with or without growth promotants: 2. Meat quality, fatty acid composition, and overall palatability. J. Anim. Sci. 86:1678.

Faustman, C., W. K. M. Chan, D. M. Schaefer, and A. Havens. 1998. Beef color update: The role for vitamin E. J. Anim. Sci. 76:1019.

Fernandez-Gines, J. M., J. Fernandez-Lopez, E. Sayas-Barbera, and J. A. Perez-Alvarez. 2005. Meat products as functional foods: A review. J. Food Sci. 70:37.

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.

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.

Johnson, P. B., and G. V. Civille. 1986. A standardized lexicon of meat WOF descriptors. J. Sens. Stud. (Roma) 1:99.

Lochner, J. V., R. G. Kauffman, and B. B. Marsh. 1980. Early-postmortem cooling rate and beef tenderness. Meat Sci. 4:227.

Mandell, I. B., J. G. Buchanan-Smith, and C. P. Campbell. 1998. Effects of forage vs grain feeding on carcass characteristics, fatty acid composition, and beef quality in Limousin-cross steers when time on feed is controlled. J. Anim. Sci. 76:2619.

Marsh, B. B., J. V. Lochner, G. Takahashi, and D. D. Kragness. 1981. Effects of early post-mortem pH and temperature on beef tenderness. Meat Sci. 5:479.

O'Sullivan, A., K. Galvin, A. P. Moloney, D. J. Troy, K. O'Sullivan, and J. P. Kerry. 2003. Effect of pre-slaughter rations of forage and/or concentrates on the composition and quality of retail packaged beef. Meat Sci. 63:279.

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 character-

istics, fatty acid composition, and quality of Uruguayan beef. Meat Sci. 66:567.

Schroeder, J. W., D. A. Cramer, R. A. Bowling, and C. W. Cook. 1980. Palatability, shelf life, and chemical differences between forage- and grain-finished beef. J. Anim. Sci. 50:852.

USDA. 1996. Institutional Meat Purchasing Specifications for Fresh Beef. Agric. Mark. Serv., USDA, Washington, DC.

Yang, A., M. C. Lanari, M. Brewster, and R. K. Tume. 2002. Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. Meat Sci. 60:41.