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# Effects of winter stocker growth rate and finishing system on: II. Ninth–eleventh-rib composition, muscle color, and palatability<sup>1</sup>

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**ABSTRACT:** Angus-cross steers (n = 198; 270 kg; 8 mo) were used in a 3-yr study to assess the effects of winter stocker growth rate and finishing system on 9–10–11th-rib composition, color, and palatability. During the winter months (December to April), steers were randomly allotted to 3 stocker growth rates: low (0.23 kg/d), medium (0.45 kg/d), or high (0.68 kg/d). At the completion of the stocking phase, steers were allotted randomly within each stocker growth rate to a high concentrate (CONC) or to a pasture (PAST) finishing system. All steers were finished to an equal time endpoint to minimize confounding due to animal age. At the end of the finishing phase, steers were transported to a commercial packing plant for slaughter and a primal rib (NAMP 107) was removed from 1 side of each carcass. The 9–10–11th-rib section was dissected into lean, fat, and bone, and LM samples were analyzed for palatability and collagen content. Hot carcass weight and 9–10–11th-rib section weight were greater ( $P = 0.01$ ) for high than low or medium. Winter stocker growth rate did not alter 9–10–11th rib composition. The percentage of fat-free lean, including the LM and other lean trim, was greater ( $P = 0.001$ ) for PAST than CONC. Total fat percentage of the 9–10–11th-rib section was 42% lower ( $P = 0.001$ ) for PAST than CONC

due to lower percentages of s.c., intermuscular, and i.m. fat. The percentage of total bone in the 9–10–11th-rib section was greater ( $P = 0.001$ ) for PAST than CONC. Finishing beef cattle on PAST increased ( $P = 0.001$ ) the percentage of lean and bone and reduced ( $P = 0.001$ ) the percentage of fat in the carcass based on published prediction equations from 9–10–11th rib dissection. Stocker growth rate did not influence the objective color scores of LM or s.c. fat. Longissimus muscle color of PAST was darker (lower  $L^*$ ;  $P = 0.0001$ ) and less red (lower  $a^*$ ;  $P = 0.002$ ) than CONC. Juiciness scores were greater ( $P = 0.02$ ) for CONC than PAST. Initial and overall tenderness scores as well as Warner-Bratzler shear force values did not differ ( $P \geq 0.28$ ) among finishing systems. Beef flavor intensity was lower ( $P = 0.0001$ ) and off-flavor intensity greater ( $P = 0.0001$ ) for PAST than CONC. Total collagen content was greater ( $P = 0.0005$ ) for PAST than CONC; however, there were no differences in percentage soluble or insoluble collagen. Growth rate during the winter stocker period did not influence rib composition, color, or beef palatability. Finishing steers on forage reduced fat percentages in the rib and LM without altering tenderness of beef steaks.

**Key words:** beef, forage, stocker, carcass composition, meat quality

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## INTRODUCTION

Consumer markets for natural, forage-finished beef products are expanding in the United States (Roosevelt, 2006). The Southeastern United States is well suited for production of forage-finished beef due to the climate,

abundance of forages, and year-round grazing season. Estimates are that over 24 million ha of perennial pastures exist in the Southeast, with about 75% of total pasture acreage in the humid eastern United States (Ball et al., 2002). In the upper Southeast (Virginia and West Virginia), stockpiled tall fescue provides high quality forage during late fall and early winter months, but quality declines in late winter after extended periods of low temperature, snow accumulation, or both (Bagley et al., 1983). During these time periods, animal growth performance may become limited. Research has shown that growth rate during stocking period can alter body composition (Carstens et al., 1991), subsequent

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feedlot performance (Drouillard et al., 1991), and maintenance energy requirements during finishing (Sainz et al., 1995; Hersom et al., 2004). Little information is available in regards to the effect of winter stocker growth rate on subsequent carcass composition and meat quality in forage-finishing systems.

Production of forage-finished beef is not a new concept, and many publications exist comparing it with grain-finished beef for changes in carcass and meat quality (as reviewed in Cross and Smith, 1977, and Muir et al., 1998a). These studies have reported increased toughness in steaks from forage-finished beef. However, most of these earlier studies evaluated the effects of the forage-finishing system in cattle fed to equal weights (Bidner et al., 1986; Purchas and Davies et al., 1974) or compositional endpoints (Bowling et al., 1977; Crouse et al., 1984). In order to attain similar weights or compositional endpoints as grain-finished cattle, forage-finished cattle are older due to lower energy intake on forage (Fontenot et al., 1985). Animal age is positively associated with shear force and negatively associated with sensory tenderness scores (Smith et al., 1982), even in studies with a narrow age range (15 to 18 mo of age; Wulf et al., 1996).

Therefore, the objective of this research was to evaluate changes in beef 9–10–11th rib composition, color, and palatability from steers finished to a similar time endpoint on concentrate diet or forage diet after stocking at 3 growth rates during the winter period.

## MATERIALS AND METHODS

All procedures involving animals were approved by the respective institutional animal care and use committee.

Angus-cross steers ( $n = 198$ ) were used in a 3-yr study to assess changes in rib composition, color and palatability with different winter stocker growth rates and finishing systems. The steers were held during the winter months on a drylot from early December through mid April. In each year, steers were randomly allotted to 3 stocker growth rates: low (0.23 kg/d), medium (0.45 kg/d), or high (0.68 kg/d). Winter stocking diets consisted of timothy hay, soybean meal, soybean hull, and a 6:1 mineral supplement [6 Ca:1 P mineral mix (SSC-377808 Livestock, Mineral, Southern States Coop., Richmond, VA)]. Crude protein content was 10.5, 11.2, and 12.1% for low, medium, and high, respectively. At the completion of the winter phase, steers were randomly allotted within each stocker growth rate to a corn-silage concentrate (**CONC**) or pasture (**PAST**) finishing system. The composition of the supplements and finishing diet is available in Neel et al. (2007). No anabolic implants or ionophores were used in this experiment. Steers on PAST treatment grazed “naturalized” pasture, which consisted of a mix of bluegrass, orchardgrass, endophyte-free tall fescue, and white clover for majority of the time and hay meadow regrowth and triticale for short periods of time. All steers, regard-

less of finishing treatment, were finished to an equal time endpoint (yr 1 = 152 d; yr 2 = 174 d; yr 3 = 150 d) to minimize confounding due to animal age. Additional information on animal performance, carcass characteristics, and forage availability is available in Neel et al. (2007).

At the end of the finishing phase, steers were transported to a commercial packing plant for slaughter. At 24 h postmortem, carcasses were graded by trained personnel and the ribs (IMPS 107) from the left side of each carcass were identified, removed, vacuum-packed, and shipped via refrigerated semitruck to the University of Georgia Meat Science Technology Center. Upon arrival at meat laboratory, ribs were maintained at 4°C until 14 d of postmortem aging was complete. After 14 d of postmortem aging, the ribs were removed from vacuum-packaged bags and allowed to bloom for at least 30 min.

**Rib Composition.** The whole beef rib (NAMP 107; NAMP, 1988; 10.16-cm tail, untrimmed) was weighed, and the 9–10–11th-rib section removed and weighed. The external fat covering (s.c. fat) was removed the 9–10–11th-rib section and weighed. Then the LM was removed from the 9–10–11th-rib section and weighed. The remaining rib section was dissected into lean trim, fat, and bone, and each weighed. Samples of LM taken from the 11th rib were pulverized in liquid nitrogen for subsequent crude fat analysis and collagen content. Lean trim (not including LM) was ground individually and mixed thoroughly for subsequent crude fat determination. Crude fat content was determined in LM and lean trim samples in triplicate using a Soxhlet apparatus and petroleum ether (AOAC, 1980). Crude fat content was subtracted from LM and lean trim weights and added to intermuscular-i.m. weights for fat-free lean calculations. Results from the 9–10–11th-rib dissection were used to calculate carcass composition according to Lunt et al. (1985). Steaks (2.54-cm thick) were obtained from the LM (9–10–11th-rib section) for subsequent total fat content, Warner-Bratzler shear force measurement, trained sensory panel analyses, and collagen content.

### *Instrumental Color*

Instrumental color measurements were recorded for  $L^*$  (measures darkness to lightness; lower  $L^*$  indicates a darker color),  $a^*$  (measures redness; higher  $a^*$  value indicates a redder color), and  $b^*$  (measures yellowness; higher  $b^*$  value indicates a more yellow color) using a Minolta chromameter (CR-310, Minolta Inc., Osaka, Japan) with a 50-mm-diam. measurement area using a D65 illuminant, which was calibrated using the ceramic disk provided by the manufacturer. Color readings were determined at 14 d postmortem on the exposed LM at the posterior (12th rib) of the rib and s.c. fat covering the posterior rib. Values were recorded from 3 locations of exposed lean and s.c. fat to obtain a representative reading.

### Warner-Bratzler Shear Force

Two steaks (2.5 cm thick) were removed from the LM (10th rib) and vacuum-packaged after dissection. One steak was immediately frozen at  $-20^{\circ}\text{C}$  (14 d aging), and the other steak was aged at  $4^{\circ}\text{C}$  for an additional 14 d and frozen at  $-20^{\circ}\text{C}$  (28 d of aging). Steaks were frozen for approximately 30 d before shear force analyses. Steaks (2.5 cm thick) were thawed for 24 h at  $4^{\circ}\text{C}$  and broiled on Farberware (Bronx, NY) electric grills to an internal temperature of  $71^{\circ}\text{C}$  (AMSA, 1995). Steaks were allowed to cool to room temperature before six 1.27-cm-diam. cores were removed from each steak parallel to the longitudinal orientation of the muscle fibers. All cores were sheared perpendicular to the long axis of the core using a Warner-Bratzler shear machine (G-R Manufacturing, Manhattan, KS).

### Sensory Panel Evaluation

Steaks (2.54-cm thick) for sensory panel evaluation were obtained from the LM (9th rib), aged at  $4^{\circ}\text{C}$  for a total of 14 d postmortem, and frozen at  $-20^{\circ}\text{C}$ . Steaks were frozen for approximately 42 d before sensory analyses. Steaks were thawed for 24 h at  $4^{\circ}\text{C}$  and broiled on Farberware electric grills to an internal temperature of  $71^{\circ}\text{C}$  (AMSA, 1995). Steaks were immediately cut into  $2.54 \times 1.27 \times 1.27$ -cm cubes and served warm to an 8-member sensory panel (AMSA, 1995). Panelists were recruited verbally and selected based on willingness to serve at scheduled times and interest in evaluation of beef steaks. Potential panelists were screened on several steak samples and chosen to serve based on abilities to discriminate known differences in tenderness, juiciness, and flavor. The sensory panel trained for several weeks on the sensory attributes and scoring system, and performance was evaluated for continued inclusion in the sensory analyses. Each panelist evaluated 2 cubes from each sample for juiciness, initial tenderness, overall tenderness, and beef flavor intensity using an 8-point scale (1 = extremely dry, tough and bland to 8 = extremely juicy, tender, and intense). Off-flavor scores were also recorded on a 9-point scale (0 = none, 1 = extremely slight off-flavor to 8 = extremely intense off-flavor).

### Collagen Content

Frozen powdered samples (5 g) were heated for 63 min. at  $77^{\circ}\text{C}$  in 1/4-strength Ringer's solution and separated into supernatant and residue fractions following the procedure of Hill (1966). Each fraction was individually hydrolyzed in 6 N HCl for 6 h at 1 atm and  $102^{\circ}\text{C}$ . Hydroxyproline levels were determined according to Bergman and Loxley (1963). Collagen content (mg/g) was calculated from the hydroxyproline levels and hydroxyproline conversion values of 7.25 and 7.52 for insoluble and soluble collagen, respectively (Cross et al., 1973).

### Statistical Analyses

Data were analyzed as a completely randomized design using the GLM procedure (SAS Inst. Inc., Cary, NC), with stocker growth rate, finishing system, and 2-way interaction as fixed effects and year as a random effect. For sensory data, panelist was included in the model as a random effect in addition to the above model. The experimental unit was animal for all comparisons. Least squares means were generated and separated using the PDIFF option of SAS. Pearson product moment correlations among color, lipid, shear force, and sensory measures were calculated using the CORR procedure of SAS.

## RESULTS AND DISCUSSION

Composition of the 9–10–11th-rib section as influenced by stocker growth rate and finishing system is presented in Table 1. Hot carcass weight and 9–10–11th-rib section weight were greater ( $P = 0.01$ ) for high than low or medium. Hersom et al. (2004) also observed heavier HCW with steers on higher rates of gain during the winter grazing period, but these differences were minimized when all steers were finished on concentrates to a common endpoint of backfat thickness. Carcasses from steers finished on CONC were 78 kg heavier ( $P = 0.001$ ) than PAST at slaughter. The 9–10–11th-rib section weight was heavier ( $P = 0.001$ ) for CONC than PAST. Crouse et al. (1984) and Bennett et al. (1995) reported lighter carcass weights of forage-finished steers compared with concentrate-fed when finished to similar time endpoints.

Winter stocker growth rate did not alter ( $P \geq 0.34$ ) the percentage of lean, fat, or bone in the 9–10–11th-rib. Sainz et al. (1995) also found similar carcass fat concentration for animals finished on high concentrate diets, ad libitum, after low or high concentrate feeding during the growing phase. These results indicate that restricting growth rate to 0.23 kg/d during the winter feeding period did not alter the percentage lean, fat, or bone in the carcass of steers finishing on pasture or concentrates for over 150 d. The percentage of fat-free lean, including the LM and other lean trim was greater ( $P = 0.001$ ) for PAST than CONC. Total fat percentage of the 9–10–11th-rib section was 42% lower ( $P = 0.001$ ) for PAST than CONC due to lower percentages of s.c., intermuscular, and i.m. fat. The percentage of total bone in the 9–10–11th-rib section was greater ( $P = 0.001$ ) for PAST than CONC. Predicted carcass composition from the 9–10–11th-rib dissection data according to Lunt et al. (1985) is shown in Figure 1. Finishing beef cattle on PAST resulted in higher ( $P = 0.001$ ) percentage of lean and bone, and lower ( $P = 0.001$ ) percentage of fat in the carcass.

Our results on carcass composition prediction agree with Lunt et al. (1985) and others (Crouse and Dikeman, 1976; Shackelford et al., 1995; and Dikeman et al., 1998). Byers (1982) reported that lipid deposition

**Table 1.** Effect of winter stocker growth rate, and finishing system on HCW, 9–10–11th-rib section weight, and 9–10–11th-rib composition

Item	Stocker growth rate <sup>1</sup> (S)			Finishing system <sup>2</sup> (F)			P-value		
	Low	Medium	High	CONC	PAST	SE	S	F	S × F
No. of observations	67	66	65	103	95				
Final liveweight, kg	495 <sup>b</sup>	504 <sup>b</sup>	523 <sup>a</sup>	541	475	19	0.020	<0.001	0.97
HCW, kg	276.4 <sup>b</sup>	287.3 <sup>b</sup>	299.8 <sup>a</sup>	326.8	248.9	26.95	0.004	<0.001	0.97
9–10–11th-rib section wt, kg	3.86 <sup>b</sup>	3.94 <sup>b</sup>	4.15 <sup>a</sup>	4.63	3.34	0.82	0.05	<0.001	0.56
9–10–11th-rib section composition									
Fat-free lean, %	49.91	49.75	48.68	45.19	53.51	3.80	0.37	<0.001	0.22
Fat-free LM, %	26.2	26.1	25.85	24.57	27.53	2.90	0.72	<0.001	0.12
Fat-free other lean, %	23.41	23.66	22.83	20.62	25.98	2.82	0.38	<0.001	0.50
Total fat, %	25.47	24.90	25.24	31.86	18.54	4.81	0.88	<0.001	0.42
s.c. fat, %	10.61	10.25	10.29	13.08	7.69	2.70	0.62	<0.001	0.39
Intermuscular and i.m. fat, %	14.85	14.64	14.95	18.77	10.86	3.55	0.95	<0.001	0.61
Total bone, %	24.92	25.35	26.07	22.95	27.94	2.99	0.34	<0.001	0.40

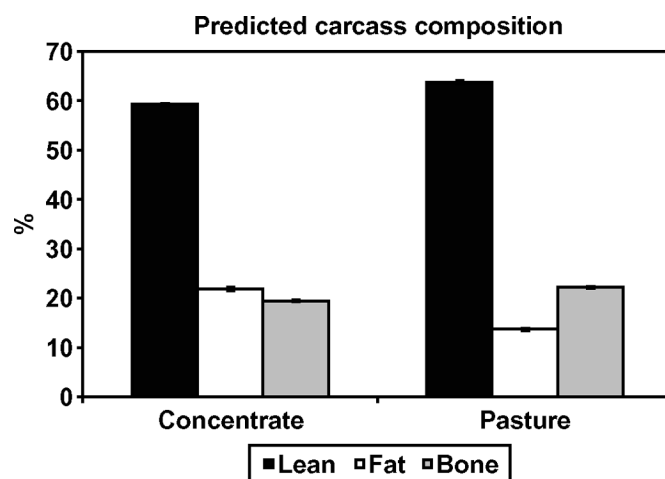
<sup>a,b</sup>Means with uncommon superscripts in the same row differ ( $P < 0.05$ ).

<sup>1</sup>Stocker growth rate: low = 0.23 kg/d, medium = 0.45 kg/d, and high = 0.68 kg/d.

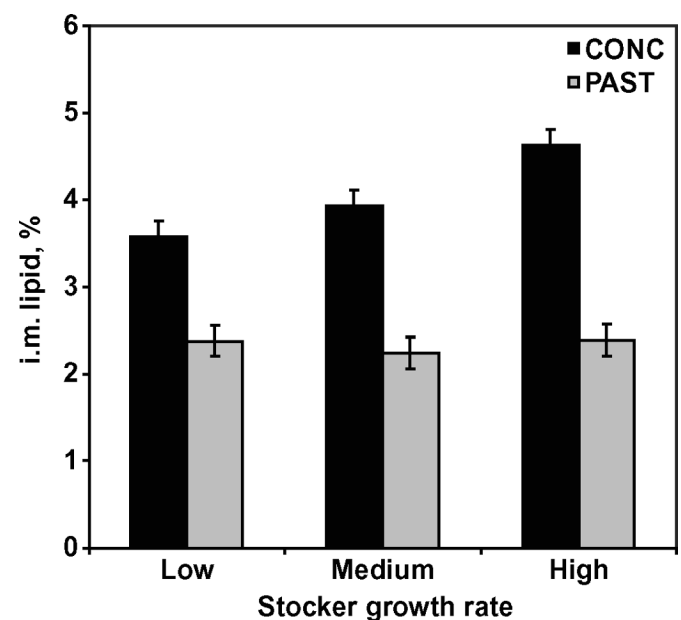
<sup>2</sup>Finishing system: CONC = high concentrate diet and PAST = pasture only.

and accumulation of fat is directly related to energy intake by the animal. In contrast, Lunt et al. (1985) did not observe a difference in actual carcass percent separable fat between grain- and forage-fed cattle slaughtered at the same weight endpoint. There was an interaction between stocker growth rate and finishing system ( $P = 0.05$ ) for total lipid content of LM (Figure 2). For CONC finished, higher gains during the stocker growth period resulted in greater total lipid content of LM after finishing. In contrast, stocker growth rate did not alter total lipid content of LM in PAST finished. From the figure, it appears that i.m. fat deposition increased linearly with increasing growth rate during the winter period for steers finished on high concentrate diets. The lack of an effect in pasture finished cattle is likely due to limited IMF deposition in these cattle (all Select grade). Fluharty et al. (2000) showed that early

weaned calves fed high-concentrate diets accelerated growth rate and resulted in greater fat deposition earlier in the feeding period. Sainz et al. (1995) reported that feeding low concentrate-high forage diets instead of high concentrate diets during the growing phase can hinder feedlot performance and carcass quality when animals were finished at restricted intakes (70% of ad libitum) on a high concentrate diet. In contrast, Coleman et al. (1995) found that steers fed silage growing diets instead of limit-fed grain had lower marbling scores at entry into the feedlot, but lipid deposition



**Figure 1.** Effect of finishing system on predicted carcass composition based on 9–10–11th-rib composition (Lunt et al., 1985).



**Figure 2.** Effect of winter stocker growth rate and finishing system on i.m. lipid percentage. Low = 0.23 kg/d; medium = 0.45 kg/d; and high = 0.68 kg/d. The interaction between stocker growth rate and finishing system was significant ( $P = 0.05$ ).

**Table 2.** Effect of winter stocker growth rate and finishing system on objective color measures of LM and s.c. fat color, and LM pH (yr 3 only)

Item	Stocker growth rate <sup>1</sup> (S)			Finishing system <sup>2</sup> (F)			P-value		
	Low	Medium	High	CONC	PAST	SE	S	F	S × F
Longissimus muscle color									
No. of observations	67	66	65	103	95				
L*	40.66	40.21	40.62	42.06	38.93	2.44	0.32	<0.001	0.72
a*	24.14	24.01	24.03	24.96	23.17	2.34	0.29	0.002	0.27
b*	11.19	11.05	11.13	11.76	10.49	1.40	0.88	<0.001	0.36
Longissimus muscle pH (yr 3 only)									
No. of observations	24	21	22	34	33				
pH	5.67	5.65	5.71	5.57	5.79	0.23	0.65	0.04	0.50
Subcutaneous fat color									
No. of observations	67	66	65	103	95				
L*	75.78	75.58	76.45	76.97	74.91	2.38	0.25	<0.001	0.69
b*	15.76	15.82	15.29	13.83	17.41	1.66	0.16	<0.001	0.90

<sup>1</sup>Stocker growth rate: low = 0.23 kg/d, medium = 0.45 kg/d, and high = 0.68 kg/d.

<sup>2</sup>Finishing system: CONC = high concentrate diet or PAST = pasture only.

was accelerated on the finishing diet such that similar marbling scores were attained after 45 d on feed. These results indicate that growth rate during the winter period can impact total lipid content of the LM at slaughter and therefore alter marbling scores and quality grades of carcasses from steers finished on high concentrate diets.

Stocker growth rate did not influence ( $P \geq 0.16$ ) the objective color scores of longissimus muscle or s.c. fat (Table 2). Restricted growth rates (0.23 kg/d) during the winter feeding period had no effect on LM or s.c. fat color in steers finished on concentrates or pasture for an additional 150 d. In order to influence meat color, myoglobin concentration or glycogen concentration at slaughter would have to be altered. No references are available to demonstrate changes in myoglobin or glycogen concentrations with different growth rates during the stocking phase. It is logical to assume that any changes during the winter stocking period would be minimized after finishing on concentrates or pasture for 150 d. Longissimus muscle color of PAST was darker (lower L\*;  $P = 0.0001$ ) and less red (lower a\*;  $P = 0.002$ ) than CONC. Others (Crouse et al., 1984; Bidner et al., 1986; Bennett et al., 1995) have reported darker lean color scores for forage-finished vs. grain-finished beef in the United States. Realini et al. (2004) and Dunne et al. (2006) also reported a lower L\* values in LM from steers finished on forages vs. concentrates in Uruguay and Ireland, respectively. Muscle color is influenced by pigment concentration and light scatter at the cut surface, which is highly dependent upon muscle pH (Cornforth, 1994). High muscle pH increases mitochondrial oxygen consumption and increased water-holding capacity, which result in a thinner oxymyoglobin layer and less scatter of incident light (Cornforth, 1994). Bidner et al. (1986) and Dunne et al. (2006) found higher myoglobin or heme pigments, respectively, in the LM of forage-finished steers when finished to an equal weight endpoint. Due to the changes observed in

LM color during yr 1 and 2, we included pH measurements of the LM in yr 3 to determine if the observed color changes were also associated with changes in muscle pH. Longissimus muscle pH was higher ( $P = 0.001$ ) for PAST than CONC. The higher muscle pH and darker lean color in forage-finished beef may be a result of lower level of gluconeogenic substrates available compared with a high-grain diet and, thus, lower muscle glycogen levels.

Longissimus b\* values were lower ( $P < 0.01$ ) for PAST than CONC. There was a positive correlation ( $r = 0.39$ ;  $P < 0.01$ ) in this study among LM b\* value and total lipid content indicating that carcasses with greater lipid will have a high b\* color value regardless of finishing system. Simonne et al. (1996) and Yang et al. (2002a) have both reported greater beta-carotene content in LM of steers finished on forage; however, values were relatively low in LM ( $\leq 0.16 \mu\text{g/g}$ ) compared with s.c. fat ( $0.99 \mu\text{g/g}$ ). Subcutaneous fat color, both lightness (L\*) and yellowness (b\*), did not differ among the 3 stocker growth rates. Subcutaneous fat color was darker (lower L\*;  $P = 0.0001$ ) and yellower (higher b\*;  $P = 0.0001$ ) for PAST than CONC. Similarly, others (Crouse et al., 1984; Bennett et al., 1995; Yang et al., 2002b) have reported a yellower fat color in carcasses from forage- vs. concentrate-finished.

Winter stocker growth rate did not alter any of the trained sensory panel scores for juiciness, tenderness, flavor, or off-flavors (Table 3). Warner-Bratzler shear force values did not differ ( $P \geq 0.56$ ) among stocker growth rates after 14 or 28 d of postmortem aging. These results indicate that restricting growth rate (0.23 kg/d) during the winter feeding period before finishing on concentrates or pasture does not reduce beef palatability. Juiciness scores were higher ( $P = 0.02$ ) in steaks from CONC than PAST. Tatum et al. (1982) reported a low, positive relationship between marbling amount and palatability traits in beef. Savell et al. (1986) evaluated total fat content and palatability to determine the

**Table 3.** Effect of winter stocker growth rate and finishing system on trained sensory panel scores of juiciness, tenderness and flavor

Item	Stocker growth rate <sup>1</sup> (S)			Finishing system <sup>2</sup> (F)			P-value		
	Low	Medium	High	CONC	PAST	SE	S	F	S × F
No. of observations	67	66	65	103	95				
Trained sensory panel score									
Juiciness <sup>3</sup>	4.92	4.88	4.90	4.97	4.82	1.33	0.89	0.02	0.42
Initial tenderness <sup>3</sup>	5.23	5.33	5.22	5.28	5.24	1.32	0.35	0.53	0.30
Overall tenderness <sup>3</sup>	5.14	5.25	5.10	5.19	5.14	1.35	0.17	0.49	0.10
Beef flavor intensity <sup>3</sup>	4.56	4.58	4.67	4.85	4.36	1.21	0.41	<0.001	0.24
Off-flavor intensity <sup>4</sup>	1.22	1.34	1.30	0.89	1.69	1.37	0.53	<0.001	0.05
Warner-Bratzler shear force, kg									
d 14 postmortem	2.73	2.64	2.56	2.71	2.56	0.79	0.56	0.34	0.51
d 28 postmortem	2.40	2.44	2.35	2.34	2.46	0.49	0.80	0.28	0.77

<sup>1</sup>Stocker growth rate: low = 0.23 kg/d, medium = 0.45 kg/d, and high = 0.68 kg/d.

<sup>2</sup>Finishing system: CONC = high concentrate diet or PAST = pasture only.

<sup>3</sup>8-point scale: 1 = extremely dry, tough, and bland to 8 = extremely juicy, tender, and intense.

<sup>4</sup>9-point scale: 0 = none, 1 = extremely slight off-flavor to 8 = extremely intense off-flavor

minimum fat percentage required for acceptable palatability of broiling cuts. These authors concluded that the window of acceptability was from 3 to 7.3% fat in LM for an acceptable eating experience. Total lipid content of the LM averaged 2.3% for PAST and 4.0% for CONC in this study, which would put the PAST steaks below the threshold in the window of acceptability. However, initial and overall tenderness scores did not differ ( $P \geq 0.49$ ) among finishing systems. Warner-Bratzler shear force values also did not differ ( $P \geq 0.28$ ) among finishing treatments. These data suggest that beef tenderness is not altered when steers are slaughtered at similar time endpoints, regardless of final weight or composition. Similarly, others have reported no changes in beef tenderness of forage- vs. concentrate-finished beef when finished to an equal time point (Mandell et al., 1998; Realini et al., 2005), similar fat thickness end point (Crouse et al., 1984; Muir et al., 1998b), or similar weight end point (Bidner et al., 1981, 1986). In contrast, others (Bowling et al., 1977; Hedrick et al., 1983; Bennett et al., 1995) have reported increased shear force and lower sensory tenderness ratings for forage-finished beef. Beef flavor intensity was lower ( $P = 0.0001$ ) and off-flavor intensity higher ( $P = 0.0001$ ) for PAST than CONC. However, scores for off-flavor intensity were relatively low (1.69; extremely slight off-

flavor intensity). Mandell et al. (1998) also observed lower beef flavor scores and greater off-flavor scores in forage-finished compared with concentrate-finished beef. In this study, 65 and 21% of steaks from CONC and PAST, respectively, had average off-flavor scores of <1 (no off-flavors detected). Correlations among LM lipid content and beef flavor intensity were positive ( $r = 0.34$ ;  $P < 0.0001$ ) but negative ( $r = -0.39$ ;  $P < 0.0001$ ) for off-flavor intensity, indicating that the amount of i.m. lipid influenced sensory perceptions of beef and off flavors in this study.

Total collagen content was greater ( $P = 0.0005$ ) for PAST than CONC (Table 4). However, there were no differences in percentage soluble or insoluble collagen among finishing systems. Winter stocker growth did not alter total collagen or percentage of soluble and insoluble collagen. Crouse et al. (1984) reported higher total collagen and percent soluble collagen in LM from steers finished on a high energy compared with a low energy diet. These authors also found that total collagen level was not highly associated with subjective or objective measures of meat textural properties. Others also reported nonsignificant relationships between tenderness and total collagen content (Carpenter et al., 1963; Field, 1971) or collagen solubility (Smith and Carpenter, 1970) of LM. Parrish et al. (1962) concluded that

**Table 4.** Effect of winter stocker growth rate and finishing system on collagen content and solubility of the longissimus muscle

Item	Stocker growth rate <sup>1</sup> (S)			Finishing system <sup>2</sup> (F)			P-value		
	Low	Medium	High	CONC	PAST	SE	S	F	S × F
No. of observations	67	66	65	103	95				
Total collagen, mg/g	5.63	5.61	6.00	5.34	6.15	0.86	0.12	<0.001	0.85
Soluble collagen, %	10.77	10.67	10.89	10.92	10.64	3.41	0.94	0.62	0.92
Insoluble collagen, %	89.23	89.33	89.12	89.08	89.36	3.41	0.95	0.62	0.92

<sup>1</sup>Stocker growth rate: low = 0.23 kg/d, medium = 0.45 kg/d, and high = 0.68 kg/d.

<sup>2</sup>Finishing system: CONC = high concentrate diet or PAST = pasture only.

total collagen content was a useful predictor of tenderness only in less tender cuts where connective tissue content was high.

In conclusion, growth rate during the winter stocker period did not alter end-product composition or quality regardless of finishing system. Finishing beef cattle on forages reduced carcass weight and fat percentages; however, similar tenderness to concentrate-finished beef was observed. Differences in beef flavor and off-flavor intensity were noted by trained sensory panelists for forage-finished compared with concentrate-finished beef.

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