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Effect of Beef Growth Type on Cooking Loss, Tenderness, and Chemical Composition of Pasture- or Feedlot-developed Steers

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ABSTRACT : Steers (n = 335) of known genetic background from four fundamentally different growth types were subjected to two production systems to study differences in cooking loss (CL), tenderness, and chemical composition. Growth types were animals with genetic potential for large mature weight-late maturing (LL), intermediate mature weight-late maturing (IL), intermediate mature weight -early maturing (IE), and small mature weight-early maturing (SE). Each year, in a nine-year study, calves of each growth type were weaned and five steers of each growth type were developed on pasture or feedlot and harvested at approximately 20 and 14 mo of age, respectively. Data collected were CL and Warner-Bratzler shear force (WBS) for the *Longissimus dorsi* (LM), *Psoas major* (PS), and *Quadriceps femoris* (QF) muscles. Chemical composition was also determined from the right fore– and hindquarter. Data were analyzed using least squares analysis of variance for unequal subclass numbers. The beef growth type×production system interaction was significant for CL and WBS of the LM and ash in the lean trim of the forequarter. Growth types of LL and IL had greater ($p<0.05$) mean percentage CL in the PS and QF muscles than did IE and SE steers. Growth type LL had the highest ($p<0.05$) mean for both moisture and protein in the fore- and hindquarters; while SE had the lowest numerical mean value for moisture and protein in the fore- and hindquarters. Shear force of the PS did not differ ($p>0.05$) among steers of the four growth types. Increasing challenges to the cattle feeding industry may dictate that pasture development play a larger role in future production regimes. Producers should strive to match genetic growth type with available resources in order to remain viable and continue producing a quality product. (**Key Words :** Feeding Regimen, Growth Type, Tenderness, Chemical Composition)

INTRODUCTION

Feed grains have been used for years to finish cattle for slaughter. There are some challenges however that possibly could impact the cattle feeding industry. Some of these include: competition and possible rising cost of feed grains (USDA-ERS, 2004), concerns about environmental impacts of confined animal feeding (USDA-ERS, 2002), health concerns and consumers demand for leaner beef (University of California, 2002), and use of feed grains for human nutrition in underdeveloped countries (International Vegetarian Union, 2003). This has led to an interest in alternative feeding regimes for cattle. Due to the relative cost inputs, alternative feeding systems will likely involve large quantities of forages. These systems may range from finishing cattle on grass with limited amounts of concentrates, growing cattle on grass then finishing them in dry lot for a relatively short period of time, or feeding a high roughage diet in dry lot (Schaake et al., 1993). French et al. (2001) stated that feed costs are a major proportion of total variable cost in beef systems and grazed grass is generally the cheapest feedstuff available. Achieving high annual intakes of grazed grass can therefore reduce beef production cost (French et al., 2001).

There has been much concern over the variability of quality traits such as tenderness of grass fattened beef. It was reported by Mitchell et al. (1991) and by Xiong et al. (1996) that grain-fed beef had better tenderness and had a better flavor than that of grass-fed beef. However, it has been reported by Bruce et al. (2004) and by Varela et al. (2004) that there was no difference or that pasture-fed beef was superior in flavor and tenderness to that of grain-fed beef.

Another concern of grass-fed beef is the cooking loss. Mandell et al. (1998) found that grass-fed beef had a higher cooking loss than that of grain-fed beef. However, in a

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study done by Bruce et al. (2004), it was found that grain-fed beef had a higher cooking loss than grass-fed beef. In an effort to better understand the variability of beef carcasses involving different feeding regimens, the objectives of this study are to evaluate cooking loss, Warner-Bratzler shear force, and chemical composition of four fundamentally different growth types of steers developed on either forage or grain diets.

MATERIALS AND METHODS

Animals

Steers (n = 335) representing four genetically different beef growth types were developed on pasture or in feedlot and harvested to study the interaction of growth type and production system on cooking loss, tenderness, and chemical composition traits. Five calves from each beef growth type were assigned to each production system (pasture vs. feedlot) in each year of a nine-year study. Eighteen steers were removed from the study because of chronic bovine respiratory disease or injury. An additional 7 steers were removed because some of their carcass traits were outliers. It was by random chance that a few more steers of two of the four biological types were removed. The smallest growth type×production system subclass contained 39 steers; therefore, removal of the steers should not have been an important source of bias in these data.

Beef growth types were determined by growth curve parameters of mature weight and rate-of-maturing of the cattle herds represented. Growth types included genetic potential for large mature weight-late maturing (LL, n = 79), intermediate mature weight-late maturing (IL, n = 88), intermediate mature weight-early maturing (IE, n = 87), and small mature weight-early maturing (SE, n = 81). The LL steers were Chianina, Charolais, or crosses between these breeds. The IL steers were either Red Poll or Hereford, the IE steers were current-pedigree Angus, and the SE steers represented a sample of small Angus cattle that were like those popular in the U.S. in the 1950's. The beef growth types were selected due to their broad variation in available growth curves and maturity patterns and their combined impact on carcass traits. Growth types were established using the three-parameter growth curve model described by Brody (1945). With the exception of the Chianina cowherd, composite growth curves of these herds were presented and discussed by Johnson et al. (1990). Mean estimated mature weight and maturing rate in the Chianina cowherd were 636 kg and 0.041%/mo, respectively, (unpublished data). Brown et al. (1991) also characterized size and maturing rate differences between these beef growth types.

Production system

Steers used in this study were born in the spring, received no creep feed, and were weaned at approximately 7 mo of age. Each year, after weaning, one half of the steers of each beef growth type (5 of each growth type) were allocated to a pasture production system. Pasture-developed steers grazed in the cool seasons on tall fescue (*Festuca arundinacea Schreb.*) that was overseeded with rye, ryegrass, and red clover (*Secole cereal, Lolium multiforum,* and *Trifolium pretense*, respectively). Warm season grazing consisted of tall fescue and bermudagrass (*Cynodon dactylon*) overseeded with sudan (*Sorghum vulgare*) in addition to some millet (*Pennisetum glaucum*). Forage availability was appraised weekly by experienced personnel and was found to be adequate for steer growth above maintenance (unpublished data) except in the second year where steers received supplemental prairie hay due to drought conditions. Steers in the pasture production system grazed unimproved pasture until overseeded pasture was available about December 1st of each year. Then, steers were allowed to graze pastures for 330 d and harvested at approximately 20 mo of age.

Upon weaning, the other half of the steers of each beef growth type (5 of each growth type) were allocated to a feedlot production system and fed a ration that contained 33.0% cotton seed hulls, 43.0% cracked corn, 9.0% crimped oats, 14.0% soybean meal, and 1.0% calcium carbonate. Also 2,200 IU of vitamin A were added per kilogram of feed. As formulated (NRC, 1976), the diet contained 1.6 Mcal Ne_m and 0.9 Mcal Ne_g/kg DM and 12% CP (Brown et al., 1991). Feedlot steers were given *ad libitum* access to feed for 210 d and slaughtered at 14 mo of age.

In both production systems, steers had free access to fresh water and a commercial mineral mixture that contained 12.5 to 15% calcium and 12% phosphorus. A detailed description of the management of steers in each production system in this study is given by Camfield et al. (1999). All steers within a given production system were harvested at a similar age and all beef growth types had similar opportunity for development. Throughout the study, husbandry was in accordance with guidelines recommended by the FASS (1999).

Slaughter and fabrication

Body weights were recorded for both pasture- and feedlot-developed steers at the University of Arkansas, Savoy Unit, before shipping study animals 21 km to the University of Arkansas Red Meat Abattoir in Fayetteville, AR, where feed and water were withheld overnight. Pre-slaughter body weights were taken prior to stunning. After dressing, splitting, determining hot carcass weight, and dressing percentage, carcasses were chilled and stored in a cooler for 96 h at 2°C. Upon completion of chilling, carcasses were weighed and ribbed between 12th and 13th ribs and carcass measurements taken by trained personnel.

Carcass measurements were obtained 96 h post-mortem in order to more efficiently utilize labor and processing facilities. Main effect means for carcass traits of steers in the study, as influenced by beef growth type within pasture- or feedlot production systems, have been summarized by Camfield et al. (1999). The interaction effect means for beef growth type x production system for carcass traits of these steers have been reported by Brown et al. (2005).

Carcass sides were then fabricated into primal/subprimal and retail cuts, lean trim, fat and bone following procedures outlined by the Institutional Meat Purchase Specifications for Fresh Beef (IMPS; USDA, 1988). All subcutaneous and accessible intermuscular fat was removed to produce cuts free of trimmable fat. Weights for each cut were recorded at each stage of fabrication. Percentage of total lean was calculated by combining the weights of the lean from the right fore- and hindquarter and dividing by the chilled weight of the right side. Percentage of total fat was calculated as the sum of kidney, pelvic, heart and subcutaneous, and accessible intermuscular fat from all retail cuts from the right side divided by the chilled carcass weight of the right side. The combined weight of bone removed from the right forequarter and hindquarter was divided by the chilled weight of the right side to calculate the percentage of total bone. Total retail cut yield was the total weight of retail cuts from both sides expressed as a percentage of the chilled carcass weight. Brown et al. (2006) reported the effects of size and rate of maturing on composition of these steers.

Individual muscle samples removed from the left side of the carcass included : *Longissimus dorsi* muscle (LM) taken from the 11th and 12th rib, *Psoas major* (PS) taken from the 3rd and 4th lumbar vertebrae and *Quadriceps femoris* (QF) taken from the anterior portion of the round tip. All muscle samples were vacuum packed using a Multivac vacuum packer (Model 2794, Multivac, Inc., Kansas City, MO, USA). Muscle samples were stored at -18°C until cooking loss and shear force could be determined. Samples were thawed to an internal temperature of -2°C and trimmed of external and seam fat before cooking. From each muscle, two steaks (3.2 cm thick, non-frozen) were cooked in a cooking bag in a 70°C water bath for 1 h on non-consecutive days. Steaks were allowed to cool to room temperature before analysis. Tenderness was then determined by the Warner-Bratzler method using four 1.3 cm^3 cores per steak obtained from random sites within each steak. Cores used in shear force determinations were obtained by the Kastner and Henrickson method (1969).

To obtain the amount of muscle, fat and bone, both the fore- and hindquarters of the right side of each animal were separated into the three components; however, the components of both quarters were not mixed. Quarters were kept separate to obtain ground lean samples from both the fore- and hindquarters for moisture, protein, fat and, ash determinations. After separation, lean was ground using a 1.0 cm plate and placed in a freezer at -18°C for 30 min to improve grinding. The chilled lean was then hand mixed and ground again using a 0.3 cm plate. For each quarter, approximately 0.2 kg of sample lean was removed for every 2.3 kg of lean in the quarter during the second grinding. Samples were placed in the freezer for an additional 15 min. Samples were hand mixed and ground again using a 0.3 cm plate to ensure uniformity. The total sample size was then reduced to approximately 3.6 kg. Each 3.6 kg sample from both quarters of the right side of each animal was individually vacuum packed and stored at -18°C until all analyses were performed.

Before moisture determination, ground lean samples were thawed to an internal temperature of -2°C. A 3.2 cm thick subsample was cut 5.1 cm from one end of each sample using a band saw. Approximately 0.6 cm was removed from the outside of the subsample. For each quarter, three subsamples weighing 50-70 g were placed in a 100 ml beaker and freeze-dried using a Labconco freeze dryer (Model 4.5, Labconco Corp., Kansas City, MO, USA) until total weight of the beaker and sample did not decrease by more than 0.1 g in a period of 12 h. Moisture percentage was calculated by loss in weight due to freeze-drying.

After moisture determination, all three replications from each quarter were mixed and powderized together using a Waring commercial blender (Model 51BL30, Waring Products, Inc., New York, NY, USA). Samples were placed in jars and sealed to prevent samples from regaining moisture. Samples were then freeze-dried for an additional 12 h before percent protein, fat, and ash determination.

Fat percentages were determined by ether extract using the method previously described by Camfield et al. (1997). (Goldfisch apparatus (Labconco Corp., Kansas City, MO, USA)). Protein percentages were determined by using a Tecator Kjeltec Auto 1030 Analyzer (Tecator Kjeltec Auto Analyzer, Tecatur^{TM}, Herndon, VA, USA) and ash percentages were determined by using a Lindberg muffle furnace (Model FA1730, Lindberg Muffle Furnace, Thermolyne Corp., Dubuque, Iowa, USA) heated to 600°C for 6 h (AOAC, 1990). Fat, protein, and ash percentage determinations were replicated three times.

Statistical analysis

Data were analyzed according to methods of least squares analysis of variance with unequal subclass numbers. Sources of variation in cooking loss, tenderness, and chemical composition were partitioned in a mathematical model that included terms for an overall mean, year, beef growth type, production system, year×beef growth type, year×production system, beef growth type×production

Table 1. Least squares means and standard errors for the beef growth type×production system interaction effect for cooking loss (%) and shear force (kg) in the *Longissimus dorsi* muscle and ash (%) in the lean trim of the forequarter of pasture- or feedlot-developed steers

Trait	Production system	Beef growth type[1, 2]			
		LL n = 79	IL n = 88	IE n = 87	SE n = 81
Cooking loss	Pasture	28.6±1.1[ab]	29.3±1.2[a]	29.0±1.2[ab]	28.0±1.2[ab]
	Feedlot	27.7±1.0[ab]	27.1±0.87[bc]	26.1±0.93[bc]	25.7±0.91[c]
Shear Force	Pasture	3.1±0.3[a]	3.2±0.3[a]	3.2±0.3[a]	2.7±0.3[b]
	Feedlot	1.7±0.3[c]	1.5±0.2[cd]	1.3±0.2[d]	1.2±0.2[d]
Ash	Pasture	1.1±0.03[a]	1.0±0.03[ab]	0.97±0.03[bc]	0.99±0.03[ab]
	Feedlot	0.96±0.03[bc]	0.92±0.2[d]	0.94±0.03[cd]	0.92±0.03[d]

[1] LL = Large mature weight, late maturing; IL = Intermediate mature weight, late maturing.
IE = Intermediate mature weight, early maturing; SE = Small mature weight, early maturing.
[2] LL-pasture, n = 39; LL-feedlot, n = 40; IL-pasture, n = 43; IL-feedlot, n = 45.
IE-pasture, n = 44; IE-feedlot, n = 43; SE-pasture, n = 42; SE-feedlot, n = 39.
[a, b, c, d] Trait means with different superscripts differ (p<0.05).

system, age within production system, and residual error. The 6-mo difference in mean harvest age of steers between production systems was considered to be part of the variance partitioned by the production-system effect. These data were analyzed as such because pasture-developed steers require additional time and input to approach a more suitable harvest weight and composition compared to that of the feedlot-developed steers. Cooking loss, tenderness, and chemical composition data were not adjusted to a constant endpoint basis (i.e. 12^{th} and 13^{th} rib fat thickness) because variation of interest in the stated objective would be reduced or eliminated by this adjustment. All analyses were performed using the general linear models (GLM) procedure of SAS (SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

Year was an important source of variation (p<0.01) for all traits studied. Interactions involving year with growth type were significant (p<0.001) for shear force of the *Longissimus dorsi*. Interactions involving year with production system were significant (p<0.01) for cooking loss of the *Longissimus dorsi* and *Psoas major* muscles, shear force of the *Longissimus dorsi* muscle, and moisture and fat of the lean trim of both the forequarter and hindquarter. The year×growth type x production system interaction was non significant (p>0.05) for all traits studied. Significant interactions involving year were expected and likely resulted from temporary environmental effects on pasture that made it impossible to exactly duplicate pastures from year to year (Vallentine, 1990). Also, as year was included in the statistical model, observations for traits studied were adjusted to a mean year effect. Therefore, main effect means of year and interaction effect means involving years are not presented.

Within production system steer age at harvest was an important source of variation (p<0.05) in shear force of the *Longissimus dorsi* muscle, fat in the lean trim of the forequarter, and protein in the lean trim of the hindquarter. Across production system, pasture-developed steers were 6 mo older at harvest than the feedlot finished steers. Consequently, feed type differences are confounded with age of steer. This likely resulted because of the difficulties in achieving sustained high rates of gain in the pastured steers as the pasture in this study, even though of excellent quality, contained less energy than the feedlot diet. In addition, even at similar growth rates, steers consuming a feedlot diet deposit fat at a higher rate than pasture-fed steers (Tudor, 1992; Sainz et al., 1995). These results are in agreement with those of previous studies (Schaake et al., 1993; Camfield et al., 1999; Brown et al., 2005) where forage-fed steers were older at harvest than grain-finished steers when each group was fed to a set harvest weight endpoint or harvest composition endpoint.

The beef growth type×production system interaction was significant (p<0.05) for cooking loss and shear force of the *Longissimus dorsi* muscle and ash in the lean trim of the forequarter. The beef growth type×production system interaction was not significant (p>0.05) for cooking loss and shear force of the *Psoas major* and *Quadriceps femoris* muscles, moisture, fat, and protein in the lean trim of the forequarter and moisture, fat, ash, and protein in the lean trim of the hindquarter. Growth type was a significant source of variation for cooking loss and shear force of the *Psoas major* and *Quadriceps femoris* muscles. Growth type was significant (p<0.001) for moisture, fat, and protein in the lean trim of the forequarter and moisture, fat, ash, and protein of the lean trim of the hindquarter. Main effect means for these traits are presented, because the interaction of growth type×production system was non-significant.

Least square means and standard errors for the beef growth type×production system interaction effect for cooking loss and shear force in the *Longissimus dorsi* of pasture- or feedlot-developed steers are presented in Table 1.

Table 2. Least squares means and standard errors for cooking loss and shear force of the *Psoas major* and *Quadriceps femoris* muscles by beef growth types in pasture- and feedlot-developed steers

Trait	Muscle type	Growth type[1]			
		LL n = 79	IL n = 88	IE n = 87	SE n = 81
Cooking loss (%)	*Psoas major*	26.2±0.6[a]	26.5±0.6[a]	25.1±0.6[b]	25.0±0.6[b]
	Quadriceps femoris	32.9±0.5[a]	32.9±0.5[a]	32.0±0.5[b]	32.0±0.5[b]
Shear force (kg)	*Psoas major*	1.9±0.1[a]	1.8±0.1[a]	1.9±0.1[a]	1.8±0.1[a]
	Quadriceps femoris	2.3±0.2[a]	2.0±0.2[ab]	1.9±0.1[bc]	1.7±0.1[c]

[1] LL = Large mature weight, late maturing; IL = Intermediate mature weight, late maturing.
IE = Intermediate mature weight, early maturing; SE = Small mature weight, early maturing.
[a, b, c] Means within muscle type with different superscripts differ (p<0.05).

This interaction resulted from differences in magnitude of cooking loss among the growth types in the pasture and feedlot production systems. The LL-pasture, IL-pasture, IE-pasture, SE-pasture and LL-feedlot combinations did not differ (p>0.05) in mean percentage cooking loss, likewise the LL-feedlot, IL-feedlot and IE-feedlot combinations did not differ (p>0.05) in mean percentage cooking loss. Mean percentage cooking loss was similar (p>0.05) among LL-pasture, IE-pasture, SE-pasture, LL-feedlot, IL-feedlot and IE-feedlot combinations. The combinations of IL-feedlot, IE-feedlot, and SE-feedlot did not differ (p>0.05) in mean percentage cooking loss. The IL-pasture steers had the highest numerical value for mean percentage cooking loss in the *Longissimus dorsi* of the eight combinations, while the SE-feedlot steers had the lowest numerical value for mean percentage cooking loss in the *Longissimus dorsi* muscle. The IL-pasture and SE-feedlot combinations differed (p<0.05) in mean percentage-cooking loss. The pasture or forage fed beef having a higher cooking loss than grain fed beef is in contrast with several authors having pasture fed beef with lower cooking losses (Bruce et al., 2004) or having no difference (French et al., 2001; Varela et al., 2004). However, Mandell et al. (1998), found forage fed cattle to have higher cooking losses than the grain fed cattle.

Shear force of the *Longissimus dorsi* was similar (p>0.05) for the combinations of IL-feedlot, IE-feedlot, and SE-feedlot and the shear force for these combinations were less (p<0.05) than the shear force of the *Longissimus dorsi* of the four growth type x pasture combinations. This interaction is a result of magnitude rather than ranking between the IE and SE growth types between the two production systems. Shear force was greatest (p<0.05) for the *Longissimus dorsi* of the LL-pasture, IL-pasture, and IE-pasture combinations when compared to that required for the five other combinations. The ranking of the growth type ×production system combinations for shear force (low to high) of the *Longissimus dorsi* was SE-feedlot, IE-feedlot, IL-feedlot, LL-feedlot, SE-pasture, LL-pasture, IE-pasture and the IL-pasture. The feedlot developed steers having a lower shear force value than the pasture developed steers is in agreement with Varela et al. (2004) and Mitchell et al. (1991). However Bruce et al. (2004) and French et al. (2001) found there to be no difference. Regardless of development scheme, the steaks would be considered tender (Morgan et al., 1991).

Least squares means and standard errors for the beef growth type x production system interaction effects for ash in the lean trim of the forequarter of pasture- and feedlot-developed steers are presented in Table 1. This interaction resulted from differences in magnitude of mean percentage ash in the lean trim of the forequarter among the growth types in the two production systems. The LL-pasture, IL-pasture, and SE-pasture combinations were similar (p> 0.05) for mean percentage ash in the lean trim of the forequarter. When compared in a range, means for percentage ash in the lean trim of the forequarter were similar (p>0.05) for the IL-pasture, IE- pasture, SE-pasture, and LL-feedlot combinations. Likewise there was no difference (p>0.05) in mean percentage ash in the lean trim of the forequarter among the IL-feedlot, IE-feedlot, and the SE-feedlot combinations. The numerical ranking of the combinations for mean percentage ash in the lean trim of the forequarter was LL-pasture, IL-pasture, SE-pasture, IE-pasture, LL-feedlot, IE-feedlot, IL-feedlot and SE-feedlot. Steen et al. (2003) also found pasture developed calves to have higher ash concentrations than that of feedlot cattle or cattle fed higher concentrate diets. There was no difference in mean percentage ash in the lean trim of the forequarter of the IE-pasture, LL-feedlot, and IE-feedlot steers.

Presented in Table 2 are the least squares means and standard errors for cooking loss and shear force of the *Psoas major* and *Quadriceps femoris* muscles by beef growth type in pasture and feedlot developed steers. The IE and SE growth types had lower (p<0.05) mean percentage cooking loss in both the *Psoas major* and *Quadriceps femoris* than did the IL and LL growth types. Shear force of the *Psoas major* did not differ (p>0.05) among the four growth types. When means for shear force of the *Quadriceps femoris* are compared in a range, there was no difference (p>0.05) in the LL and IL growth types, no differences (p>0.05) in the IL and IE growth types, and no difference in the IE and SE growth types. However, the LL

Table 3. Least squares means and standard errors for moisture, fat, protein in the lean trim of the forequarter and moisture, fat, ash, and protein in the lean trim of the hindquarter of pasture- and feedlot-developed steers

Trait	Growth type[1]			
	LL n = 79	IL n = 88	IE n = 87	SE n = 81
Forequarter				
Moisture (%)	69.4±0.6[a]	67.2±0.6[b]	66.4±0.6[bc]	66.1±0.6[c]
Fat (%)	9.7±0.7[a]	12.7±0.7[b]	13.9±0.7[c]	14.2±0.7[c]
Protein (%)	20.1±0.3[a]	19.3±0.3[b]	19.0±0.3[c]	18.9±0.3[c]
Hindquarter				
Moisture (%)	71.3±0.5[a]	69.6±0.5[b]	69.1±0.5[bc]	68.7±0.5[c]
Fat (%)	6.5±0.5[a]	8.7±0.5[b]	9.5±0.5[c]	10.1±0.5[d]
Protein (%)	21.4±0.2[a]	20.7±0.2[b]	20.4±0.2[c]	20.3±0.2[c]
Ash (%)	1.1±0.02[a]	1.0±0.02[b]	1.0±0.02[b]	1.0±0.02[b]

[1] LL = Large mature weight, late maturing; IL = Intermediate mature weight, late maturing.
IE = Intermediate mature weight, early maturing; SE = Small mature weight, early maturing.
[a, b, c, d] Trait means with different superscripts differ (p<0.05).

growth type differed (p<0.05) from the IE and SE growth types and the SE growth type differed from LL and IL growth types. This variation in shear force for the differing growth types is most likely due to genetic differences among the breeds. Although the analysis was not done on the *Quadriceps femoris,* Wheeler et al. (2005) found that there are differences (p<0.05) between Charolais and Angus breeds in regards to shear force for *Longissimus dorsi* muscle. With regards to the *Psoas major,* lack of variation can be found among breeds. Shackelford et al. (1995) found *Bos indicus* cattle to have higher shear force values than that of *Bos taurus* cattle for the *Longissimus dorsi*. However, they found no differences between the two breed types in the *Psoas major* muscles which is in agreement with this study.

Least square means and standard errors for moisture, fat, and protein in the lean trim of the forequarter and moisture, fat, protein and ash in the lean trim of the hindquarter of the pasture- and feedlot-developed steers are presented in Table 3. In the forequarter, the LL steers had greater (p<0.05) mean percentage moisture in the lean trim when compared to the other growth types. There was no difference in mean percentage moisture in the lean trim of the IL and IE growth types. Of the four growth types, lean trim of the forequarter of the SE steers had the lowest numerical value for mean percentage moisture; however, there was no difference in mean percentage moisture in the lean trim of the IE and SE growth types.

The LL growth type had the lowest (p<0.05) mean percentage fat in the lean trim of the forequarter when compared to fat content of the IL, IE, and SE growth types. As expected, the lean trim of the forequarter of IE and SE steers had similar (p>0.05) and greatest (p<0.05) mean percentage fat.

Mean percentage protein in the lean trim of the forequarter was greater for the LL steers when compared to steers of the other three growth types. The IL steers had greater mean percentage protein in the lean trim of the forequarter than did the IE and SE steers. The numerical ranking of the growth types for mean percentage protein was LL>IL>IE>SE. The IE and SE growth types were similar (p>0.05) for mean percentage protein in the lean trim of the forequarter of pasture and feedlot-developed steers.

In the lean trim of the hindquarter of pasture- and feedlot-developed steers, mean percentage moisture was greatest (p<0.05) for the LL growth type. Conversely, the SE growth type had the greatest (p<0.05) mean percentage fat in the lean trim of the hindquarter. The ranking of the growth types for mean percentage fat in the lean trim of the hindquarter was LL<IL<IE<SE (p<0.05).

Lean trim of the hindquarter of LL steers had the greatest (p<0.05) mean percentage protein than the other three growth types. Mean percentage protein in the lean trim of the hindquarter of IE and SE growth types did not differ (p>0.05). The IL growth type had the second highest (p<0.05) mean percentage protein. Coleman et al. (1993) found Charolais calves to have a higher percent moisture, higher percent protein and lower percent fat than that of Angus calves.

The mean percentage ash in the lean trim of the hindquarter was greatest (p<0.05) for the LL growth type. There was no difference (p>0.05) in the mean percentage ash in the lean trim of the IL, IE and SE growth types. Although not significant, Ozluturk et al. (2004) found Charolais calves to have higher percent ash in the hindquarter than that of both Simmental and Eastern Anatolian Red calves.

CONCLUSION

Differences in mean cooking loss, Warner-Bratzler shear force, and chemical composition of genetically different steers illustrate differences in performance among beef growth types in two production systems (pasture vs. feedlot). The beef growth type×production system interaction was significant for cooking loss and shear force of the *Longissimus dorsi*. Feedlot-developed steers had both lower cooking loss, ash content and shear force value than steers developed on pasture. Growth type was a significant source of variation for moisture, fat and protein in lean trim of the fore- and hindquarter. These results show that feedlot development more effectively exploits genetic potential these traits. However, increasing challenges to the cattle feeding industry may dictate that pasture development play a larger role in future beef production regimes. Producers should strive to accurately match genetic growth type with ranch resources in order to remain viable and continue producing a quality product.

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