

## Effects of Size and Rate of Maturing on Carcass Composition of Pasture- or Feedlot- Developed Steers\*

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**ABSTRACT :** Steers (n = 335) of known genetic backgrounds from four fundamentally different growth types were subjected to two production systems to study the main effects and possible interactive effects on carcass composition. Growth types were animals with genetic potential for large mature weight (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 recorded were chilled carcass weight and percentages of forequarter, foreshank, chuck, rib, plate, brisket, hindquarter, round, rump, shortloin, sirloin, flank, lean, fat, bone, and retail cuts. The growth type×production system interaction was an important source of variation in chilled carcass weight (p = 0.0395) and percentage retail cuts (p = 0.001), lean (p = 0.001), fat (p = 0.001), rump (p = 0.0454), shortloin (p = 0.0487), and flank (p = 0.001). The ranking of the growth type x production system means for percentage lean was LL-pasture>IL-pasture = IE-pasture = SE-pasture>LL-feedlot, IL-feedlot>IE-feedlot = SE-feedlot. The growth type×production system interaction was non-significant (p>0.05) for forequarter, foreshank, chuck, rib, plate, brisket, hindquarter, round and bone. Growth types of IE and SE yielded greater (p<0.05) mean forequarter than did growth types of IL and LL (51.6±0.3 and 51.5±0.3 vs. 51.1±0.3 and 50.8±0.3%). Mean bone was highest (p<0.05) for the LL growth type and lowest (p<0.05) for the SE growth type (19.5±0.5 vs. 16.8±0.5%). Mean bone was greater (p<0.05) for the pastured steers than for the feedlot steers (21.8±0.8 vs. 14.5±0.6%). These data indicate that growth type responded differently in the two production systems and that these results should be helpful in the match of genetics to production resources. (*Asian-Aust. J. Anim. Sci.* 2006. Vol 19, No. 5 : 661-671)

**Key Words :** Beef, Growth Types, Production System, Carcass Composition

### INTRODUCTION

Consumers are demanding leaner, palatable beef (Savell et al., 1987), and the cattle industry should establish methods of targeting market end points with reduced carcass fat and maximum carcass value (May et al., 1992). Forage-fed beef carcasses have less fat than grain-finished carcasses (Robinson et al., 2001), thus forage-fed beef provide consumers with leaner meat than grain-finished beef. Pasture-based beef production systems offer economic benefits that surpass feedlot finishing because forage traditionally is less expensive than feed grain per unit of energy and protein (Dixon and Stockdale, 1999). More research is needed on all-forage development systems (NRC, 1976), as pasture-based systems are a viable alternative energy source for beef production (Allen et al., 1996).

Growth type has the potential to influence beef carcass composition (Priyanto et al., 1999) by altering the relative growth patterns of muscle, bone, and fat (Berg and Butterfield, 1968). Carcass composition varies among cattle growth types (Koch et al., 1976, 1979, 1982; Stiffler et al., 1985; Griffin et al., 1992) and it is important to understand how various cattle types can optimally produce lean, high-quality beef (May et al., 1992). For example, European breeds developed on a high plane of nutrition, typically have higher yields of lean edible product than English breeds (Koch and Dikeman, 1977; Koch et al., 1979, 1982). In the past, differences in beef growth types were reflected in differences among breeds; however, increased emphasis on selection for size over the last two decades has resulted in a broad array of growth types within most breeds (Brown et al., 2005).

As a result, it is often difficult to isolate the true effects of forage and grain feeding on carcass composition because the cattle involved are harvested at carcass weights which vary widely within and between studies (Muir et al., 1998). Therefore, feed-type differences have been confounded with plane-of-nutrition effects, such that cattle fed the higher energy feedlot diet have been heavier and fatter in comparison with those fed the forage-based diet (Williams et al., 1983; Bidner et al., 1986; Muir et al., 1998). Consequently, it is difficult to ascertain the extent to which

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the lighter weight and lower fat content has been due to lower growth rate or to forage rather than grain in the diet (Davies, 1977; Steen et al., 2003).

When divergent growth types are finished on high-energy diets to exploit lean tissue accretion, considerable variation in carcass fatness usually results (Brown et al., 2005). For comparisons of carcass composition, studies have used various standardization techniques. These standardization techniques have been reviewed and discussed by Muir et al. (1998). The correct match of nutrient requirement of growth type to feed resources in various production systems could provide for more acceptable lean to fat composition and eliminate the need for these adjustments.

Nutrient requirements among growth types and possible alternative feeding systems indicate more data are needed on how carcass composition and feed interact (Flora, 2001). Variation in carcass composition among growth types and production systems suggest a correct match of growth type and nutritional requirements to production system would aid in eliminating excess fatness and provide for lean tissue accretion. Indeed, Robinson et al. (2001) indicated an important factor in producing carcass beef is to correctly match beef growth type to available inputs within a production system. Therefore, the objective of this study was to determine the percentage yield of primal and subprimal cuts, carcass lean, fat and bone of four fundamentally different growth types of steers developed in either pasture or feedlot production systems. Divergent growth types included in the study were chosen to increase the possibility of determining differences in carcass composition among growth types and production systems.

## MATERIALS AND METHODS

### Animals

Three hundred thirty-five steers representing four genetically different beef growth types were developed on pasture or in a feedlot and harvested to study the interaction of growth type and production system on carcass 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 ( $n = 335$ ). It was by random chance that a few more steers of two of the four biological types were removed. The smallest growth type  $\times$  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 cow herd 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 cereale*, *Lolium multiflorum*, 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 1<sup>st</sup> of each year. Then, steers were allowed to graze pastures for 330 d and slaughtered 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% cotton seed hulls, 43% cracked corn, 9.5% crimped oats, 14.5% soybean meal and 2.2% 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 .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 Consortium (1998).

### 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 shrunk 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 (CCW) and ribbed between the 12<sup>th</sup> and 13<sup>th</sup> 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).

The left 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). The forequarter of the left side was fabricated into the rib, square cut chuck, arm section, wholesale plate, brisket and foreshank. Fat from the cod, pelvic and kidney regions, hanging tender and kidney were removed from the hindquarter. The flank was removed from the loin and separated into lean trim, fat, and flank. The round was separated into the knuckle, rump, hindshank, lean trim, fat, and bone. The wholesale loin was fabricated to yield the sirloin and shortloin, both of which were eventually fabricated into retail cuts. Each primal/subprimal cut was further processed into steaks, roasts, lean trim, and bone. Finally, 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. Right sides were quartered, then fabricated in the same manner as the left side.

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.

### Statistical analysis

Data were analyzed according to methods of least squares analysis of variance with unequal subclass numbers. Sources of variation in CCW and composition traits 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 system, year×beef growth type×production 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. Composition trait data were not adjusted to a constant endpoint basis (i.e. 12<sup>th</sup> and 13<sup>th</sup> 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 ( $p < 0.001$ ) for all traits studied except 102-forequarter and 155-hindquarter (data not shown). Interactions involving year with growth type were significant ( $p < 0.05$ ) for all traits except 102-forequarter, 103-rib, 118-brisket, 155-hindquarter, and 173-shortloin. Interactions involving year with production system were significant for all traits except 102-forequarter. The year×growth type×production system interaction was non-significant ( $p > 0.05$ ) for all traits studied except 103-rib. 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, observation for CCW and carcass composition traits were adjusted to a mean year

**Table 1.** Least squares means and standard errors for the effects of beef growth type on carcass forequarter and hindquarter (%), primals and subprimals (%) and bone (%) in pasture- or feedlot-developed steers

Trait <sup>2</sup>	Growth types <sup>1</sup>			
	LL n = 79	IL n = 88	IE n = 87	SE n = 81
Forequarter	50.8±0.3 <sup>f</sup>	51.1±0.3 <sup>e</sup>	51.6±0.3 <sup>d</sup>	51.5±0.3 <sup>d</sup>
Foreshank	4.4±0.1 <sup>d</sup>	3.9±0.1 <sup>e</sup>	3.9±0.1 <sup>e</sup>	3.8±0.1 <sup>f</sup>
Chuck	26.9±0.3 <sup>d</sup>	26.3±0.3 <sup>e</sup>	26.1±0.3 <sup>f</sup>	26.1±0.3 <sup>f</sup>
Rib	7.5±0.1 <sup>d</sup>	7.5±0.1 <sup>d</sup>	7.4±0.1 <sup>d</sup>	7.3±0.1 <sup>e</sup>
Plate	7.1±0.2 <sup>f</sup>	7.8±0.2 <sup>e</sup>	8.3±0.2 <sup>d</sup>	8.4±0.2 <sup>d</sup>
Brisket	3.8±0.1 <sup>e</sup>	4.0±0.1 <sup>d</sup>	4.1±0.1 <sup>d</sup>	4.1±0.1 <sup>d</sup>
Hindquarter	48.5±0.3 <sup>d</sup>	48.1±0.3 <sup>e</sup>	47.7±0.3 <sup>f</sup>	47.5±0.3 <sup>f</sup>
Round	20.3±0.4 <sup>d</sup>	18.2±0.4 <sup>e</sup>	17.9±0.4 <sup>f</sup>	17.5±0.4 <sup>f</sup>
Bone	19.5±0.5 <sup>d</sup>	18.5±0.5 <sup>e</sup>	17.8±0.5 <sup>f</sup>	16.8±0.5 <sup>g</sup>

<sup>1</sup> LL = large mature weight late maturing; IL = intermediate mature weight late maturing; IE = intermediate mature weight early maturing; SE = small mature weight early maturing.

<sup>2</sup> Percentage of chilled carcass right side weight.

<sup>d, e, f, g</sup> Means in the same row with different superscripts differ ( $p < 0.05$ ).

effect. Therefore, main effects means of year and interactions effect means involving years are not presented.

Within production system steer age at harvest accounted for substantial variation in all traits ( $p < 0.001$ ) except 103-rib, 173-shortloin, and 113-chuck ( $p > 0.05$ ). Across production system, pastured developed steers were 6 mo older at harvest than the feedlot finished steers. Steers developed on pasture required additional time and inputs to approach a more suitable harvest weight and composition compared to the feedlot 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 not significant ( $p > 0.05$ ) for 102-forequarter, 117-foreshank, 113-chuck, 103-rib, 121-plate, 118-brisket, 155-hindquarter, 164-round, and bone. Therefore, the main effect means for beef growth type and for production system are presented for these traits.

Least squares means and standard errors for the effects of beef growth type on percentages of carcass fore- and hindquarters, percentages of primals and subprimals, and percentage of bone in pasture- or feedlot developed steers are presented in Table 1. Growth types of IE and SE yielded greater ( $p < 0.05$ ) mean percentage of 102-forequarter than did growth types of IL and LL (51.6±0.3 and 51.5±0.3 vs.

51.1±0.3 and 50.8±0.3). The LL growth type had less ( $p < 0.05$ ) mean percentage of 102-forequarter than did the IL growth type (50.8±0.3 vs. 51.1±0.3). These results are not in agreement with those of other scientists (May et al., 1992; Arthur et al., 1995; Miller et al., 1996) who reported no difference in 102-forequarter among different biological types of cattle.

The LL growth type had greater ( $p < 0.05$ ) mean 117-foreshank than the other three growth types (4.4±0.1 vs. 3.9±0.1, 3.9±0.1 and 3.8±0.1%) while the SE growth type had less ( $p < 0.05$ ) mean 117-foreshank than the other three growth types. The mean percentage of 117-foreshank of the IL and IE growth types were similar ( $p > 0.05$ ) and intermediate to the LL and SE growth types. These results are supported by data of Miller et al. (1996) and Arthur et al. (1995) who reported greater 117-foreshank in the large-late maturing Brown Swiss and Charolais breeds respectively, when these breeds were compared to breeds of medium size. Results of this study are not in agreement with those of other studies (Belk et al., 1991; May et al., 1992; Priyanto et al., 1999). May et al. (1992) found no difference in mean percentage of 117-foreshank among large, medium and small steers of three muscle thicknesses (thick, average, and thin). Additionally, Priyanto et al. (1999) found no difference in mean 117-foreshank among Hereford, Brahman, and Hereford × Brahman steers at 100 and 165 kg of carcass side weight. Conversely, Belk et al. (1991) reported that small-framed steers produced the highest-yielding 117-foreshank when compared to other frame sizes.

Mean 113-chuck differed ( $p < 0.05$ ) between the LL and IL growth types (26.9±0.3 vs. 26.3±0.3%) and these growth types had greater ( $p < 0.05$ ) yield of mean percentage of 113-chuck than IE and SE growth types (26.1±0.3). There was no difference ( $p > 0.05$ ) in mean 113-chuck of the IE and SE growth types (26.1±0.3 and 26.1±0.3%). Our results are in

agreement with those of Priyanto et al. (1999) who found that 113-chuck differed among breed types with Hereford steers having less 113-chuck at 100 kg side weight than Brahman and Brahman×Hereford steers. At 165 kg side weight Brahman×Hereford steers had more 113-chuck than did Brahman steers. The results in this study are not in agreement with those reported by May et al. (1992) and Miller et al. (1996). May et al. (1992) found similar mean percentage 113-chuck among large, medium and small steers with each size having three muscle thickness levels and 0.75 mm at 12<sup>th</sup> rib fat thickness. Miller et al. (1996) reported no difference in mean percentage 113-chuck among Brown Swiss, Okie #1, Mexican #1, and Mexican #2 steers.

There was no difference ( $p>0.05$ ) in mean percentage of 103-rib among the LL, IL, and IE growth types ( $7.5\pm 0.1$ ,  $7.5\pm 0.1$ ,  $7.4\pm 0.1$ , respectively), while the SE growth type had less ( $p<0.05$ ) mean 103-rib ( $7.3\pm 0.1\%$ ) than the other three growth types. These results are not in agreement with those of May et al. (1992) who found that small-framed steers had greater mean percentage of 103-rib than medium- or large-framed steers. However, Priyanto et al. (1999) found less 103-rib in Hereford and Hereford×Brahman steers compared to Brahman steers. Miller et al. (1996) also found that Brown Swiss and Okie steers yielded more 103-rib than Mexican #2 steers and that the higher yields of rib was likely due to less muscling in the Mexican steers.

Growth types of IE and SE had greater ( $p<0.05$ ) mean 121-plate than did growth types of LL and IL ( $8.3\pm 0.2$  and  $8.4\pm 0.2$  vs.  $7.1\pm 0.2$  and  $7.8\pm 0.2\%$ , respectively). The IL growth type had greater ( $p<0.05$ ) yield of mean 121-plate when compared to the LL growth type ( $7.8\pm 0.2$  vs.  $7.1\pm 0.2\%$ ). These results are not in agreement with those of Belk et al. (1991) who reported that large framed steers had the highest-yielding plate when compared to other frame sizes and the work of Miller et al. (1996) who reported that Brown Swiss and Okie steers yielded more 121-plate than Mexican #2 steers. However, May et al. (1992) found similar numerical mean percentages of 121-plate among large-, medium-, and small-framed steers with 1.5 cm fat thickness and thick, average, or thin muscling.

There was no difference ( $p>0.05$ ) in mean percentage of 118-brisket among the IL, IE, and SE growth types ( $4.0\pm 0.1$ ,  $4.1\pm 0.1$  and  $4.1\pm 0.1$ , respectively). The LL growth type had less ( $p<0.05$ ) mean 118-brisket ( $3.8\pm 0.1\%$ ) when compared to the other three growth types. These results are not in agreement with those of May et al. (1992), Belk et al. (1991) and Miller et al. (1996) who reported no difference in mean percentage 118-brisket among different biological types of cattle. May et al. (1992) reported similar mean percentages of 118-brisket among steers of three frame sizes (large, medium and small) and three fat thickness

levels (.75 cm, 1.5 cm and 2.25 cm). Also, Belk et al. (1991) found similar values for mean percentage 118-brisket among large, medium, and small framed steers with three levels of muscle thickness (No. 1, No. 2, No. 3). Miller et al. (1996) found similar mean percentage of 118-brisket among Brown Swiss, Okie #1, and Mexican #1 and #2 steers.

The LL growth type yielded greater ( $p<0.05$ ) mean percentage of 115-hindquarter when compared to the other three growth types. Growth types of IE and SE were similar ( $p>0.05$ ) for yield of mean percentage of 115-hindquarter. The IL growth type had less ( $p<0.05$ ) mean 115-hindquarter than did the LL growth type ( $48.1\pm 0.3$  vs.  $48.5\pm 0.3\%$ ). These results are in agreement with those of Price (1976) who reported a 1.5% greater ( $p<0.05$ ) mean 115-hindquarter for Charolais×Hereford compared to Hereford steers. These results are not in agreement with those of Garcia-de-Siles et al. (1977) who reported similar percentage of hindquarter for Holstein and Hereford steers.

The mean yield of 164-round was greater ( $p<0.05$ ) for the LL growth type when compared to the other three growth types ( $20.3\pm 0.4$  vs.  $18.2\pm 0.4$ ,  $17.9\pm 0.4$ , and  $17.5\pm 0.4\%$ ). There was no difference ( $p>0.05$ ) in mean percentage of 164-round between the IE and SE growth types. The IL growth type was intermediate to the LL and IE growth types for mean percentage of 164-round. The results of this study are supported by those of Miller et al. (1996), Belk et al. (1991) and May et al. (1992). Miller et al. (1996) found significant difference in mean percentage yield of 164-round among four biological types of steers. Mean percentage yield of 164-round for the four biological types of steers in this study was less than mean percentage of yield of 164-round found by Miller et al. (1996) for Brown Swiss (23.50), Okie #1 (23.44), Mexican #1 (23.81), and Mexican #2 (25.08) steers. The dairy×Brahman crossbred Mexican #2 steers had about 1.6% more wholesale round than Brown Swiss or Okie steers (Miller et al., 1996). In addition, Reiling et al. (1992) and Williams et al. (1989) reported that 164-round yields differed ( $p<0.05$ ) between large- and small-framed steers. May et al. (1992) stated that regardless of frame size, and fat thickness the percentage yield of round tended to decrease as muscle score changed from thick to thin. The results of this study are not in agreement with those of Price (1976) who found a nonsignificant 0.3% difference in mean percentage round among Charolais x Hereford and Hereford steers.

Mean percentage of bone was highest ( $p<0.05$ ) for the LL growth type and lowest ( $p<0.05$ ) for the SE growth type ( $19.5\pm 0.5$  vs.  $16.8\pm 0.5$ , respectively). There was only a 2.7 kg difference ( $p<0.05$ ) in mean bone weight between the two extreme growth types LL vs. SE (data not shown). The IL and IE growth types were intermediate to the LL and SE growth types and differed ( $p<0.05$ ) for mean bone

**Table 2.** Least squares means and standard errors for the effects of production system on carcass forequarter and hindquarter (%), primals and subprimals (%), and bone (%) in pasture- or feedlot-developed steers

Trait <sup>1</sup>	Production system	
	Pasture n = 168	Feedlot n = 167
Forequarter	49.8±0.5 <sup>d</sup>	52.7±0.4 <sup>c</sup>
Foreshank	4.7±0.2 <sup>c</sup>	3.4±0.1 <sup>d</sup>
Chuck	26.5±0.5	26.2±0.4
Rib	7.4±0.2	7.4±0.1
Plate	6.8±0.3 <sup>d</sup>	9.0±0.2 <sup>c</sup>
Brisket	3.6±0.2 <sup>d</sup>	4.4±0.1 <sup>c</sup>
Hindquarter	48.6±0.5 <sup>c</sup>	47.3±0.4 <sup>d</sup>
Round	21.0±0.6 <sup>c</sup>	16.0±0.5 <sup>d</sup>
Bone	21.8±0.8 <sup>c</sup>	14.5±0.6 <sup>d</sup>

<sup>1</sup> Percentage of chilled right side weight.

<sup>c,d</sup> Means in the same row with different superscripts differ ( $p < 0.05$ ).

(18.5±0.5 vs. 17.8±0.5%). Mean percentage of bone for the four biological types of steers in this study, generally were higher than those reported by Miller et al. (1992) who reported 16.55, 14.46, 15.22, and 16.06 for Brown Swiss, Okie #1, Mexican #1, and Mexican #2 steers, respectively, but similar to those reported by Taylor (1982) who found percentage of bone for moderate growth rate Friesian (18.99±0.24) and Hereford (14.5±0.46) and for high growth rate Friesian (15.87±0.32) and Hereford (13.25±0.38). In the study by Priyanto et al. (1999), at 100 kg of side weight, Hereford steers had less ( $p < 0.05$ ) mean bone than Brahman and Brahman×Hereford steers. Additionally, Arthur et al. (1995) reported that mean percentage bone was 21.5 and 19.5 for yearling domestic and heavy export steers, respectively. These results are supported by those of Koch et al. (1979) and Koch et al. (1976). Koch et al. (1979) showed a small but significant and economically important difference in bone percentage between large- and medium-framed steers. They also found that large-framed Chianina crosses had the highest bone percentage and medium framed Angus crosses had the lowest bone percentage of all biological types studied. Koch et al. (1976) stated that large-framed Simmental and Charolais crosses had more bone than medium-framed Hereford, Angus, Limousin, and South Devon crosses. However, Koch et al. (1976) acknowledged that the differences in percentage bone were small on a weight-constant basis. However, Gregory et al. (1994) stated that total bone percentage for larger-framed steers (Charolais and Limousin) was lower than that of medium-framed steers (Angus, Red Poll and Hereford) when compared on an age-constant basis.

Least squares means and standard errors for the effects of production system on percentage of carcass fore- and hindquarters, percentage of primals and subprimals, and percentage bone in pasture- or feedlot-developed steers are

presented in Table 2. Feedlot-developed steers yielded higher ( $p < 0.05$ ) mean 102-forequarter than did pasture-developed steers (52.7±0.4 vs. 49.8±0.5%). These results concur with those of Norton (1993) who also found a higher ( $p < 0.05$ ) mean percentage of forequarter in feedlot-developed steers compared to pasture-developed steers (51.9±0.1 vs. 51.6±0.1). These results are not in agreement with those of Murray et al. (1974) who compared carcass composition of steers in three production systems, two of which involved high growth (0.8 kg/d) and low growth (0.4 kg/d). The low growth steers yielded higher arithmetic mean percentage of forequarter than did the high growth rate steers (49.0 vs. 48.6).

Mean 117-foreshank was greatest ( $p < 0.05$ ) for pasture-developed steers when compared to feedlot-developed steers (4.7±0.2 vs. 3.4±0.1%). These results are in agreement with those of Norton (1993) who found a greater mean percentage of foreshank for pasture-developed steers than for feedlot-developed steers (4.3±0.03 vs. 3.9±0.03).

There was no difference ( $p > 0.05$ ) in mean 113-chuck among the pasture- or feedlot-developed steers (26.5±0.5 and 26.2±0.4%). This result is not in agreement with that of Norton (1993) who found a greater mean percentage of 113-chuck for pasture-developed steers when compared to mean percentage of 113-rib for feedlot-developed steers (27.1±0.1 vs. 26.2±0.1, respectively). Likewise there was no difference ( $p > 0.05$ ) in mean percentage of 103-rib between the pasture- or feedlot-developed steers. This result is not in agreement with that of Norton (1993) who reported a higher mean percentage of 103-rib for pasture-developed steers compared to feedlot-developed steers (7.5±0.03 vs. 7.3±0.03).

Feedlot steers had greater ( $p < 0.05$ ) mean percentage of 121-plate than did pasture-developed steers (9.0±0.2 vs. 6.8±0.3). Norton (1993) also reported that feedlot-developed steers yielded a greater mean percentage of 121-plate when compared to mean percentage of 121-plate for pasture-developed steers 8.6±0.1 vs. 7.5±0.1, respectively).

Mean 118-brisket was higher ( $p < 0.05$ ) for feedlot-developed steers when compared to mean 118-brisket of pasture-developed steers (4.4±0.1 vs. 3.6±0.2%). This result is in agreement with that of Norton (1993) who reported a 0.1% difference in mean percentage of 118-brisket among feedlot- and pasture-developed steers.

Mean percentage of 115-hindquarter was greater ( $p < 0.05$ ) for pasture-developed than for feedlot-developed steers (48.6±0.5 vs. 47.3±0.4). These results are similar to those reported by Norton (1993) who reported 48.3±0.1 and 48.1±0.1% for pasture- and feedlot-developed steers, respectively. These results are not in agreement with those reported by Murray et al. (1974) who found a similar arithmetic mean percentage of hindquarter (51.0) for steers

in low growth rate and high growth rate production system. Mean 164-round was greater for pasture-developed than for feedlot-developed steers (21.0±0.6 vs. 16.0±0.5%). Norton (1993) also reported a greater mean percentage of 164-round for pasture-developed steers. In the Norton (1993) study, mean percentage of 164-round was 19.9±0.1 and 17.7±0.1 for pasture- and feedlot-developed steers, respectively.

The mean percentage of bone was greater ( $p < 0.05$ ) for the pastured steers than for the feedlot steers (21.8±0.8 vs. 14.5±0.6). This 7.3% difference in mean bone percentage among pasture or feedlot developed steers equated to only 1.6 kg difference in mean bone weight among the two production systems (data not shown). These results support those of Schaake et al. (1993), Sapp et al. (1996), and Sully and Morgan (1982) who found a higher mean percentage of bone for cattle in production systems where pasture was all or part of the developmental diet compared to cattle in production systems involving finishing on grain diets. Mean percentages of bone found by Schaake et al. (1993) by production system were: 21.2 off of fescue-clover pasture in the spring; 21.1 off of millet, bermudagrass, or sudan grass in summer; 20.7 off summer pasture and 75 d in feedlot; and 18.3 (SE = 0.41) after weaning, conditioning, and 170 d in feedlot. Sapp et al. (1996) found no difference in mean percentage bone for steers developed on pasture and steers developed on pasture plus approximately 180 d in feedlot (17.66 vs. 17.76) but mean percentage of bone in both

production systems differed from mean percentage bone in feedlot-finished steers (16.67). In addition, mean bone for pasture (21.8±0.8%) and feedlot (14.6±0.6%) steers in this study was smaller than the 23.1 and 20.6% for pasture and feedlot steers reported by Sully and Morgan (1982). Murry et al. (1974) suggested that pasture steers have higher mean percentage of bone because they are older at harvest. The results in this study are not in agreement with those of Priyanto et al. (1999) and those of Murry et al. (1974). In the study by Priyanto et al. (1999) there was no difference in mean bone between pasture- and pen-fed steers. Murry et al. (1974) found that there was no difference in mean bone percentage among steers managed for three rates of daily gain.

The beef growth type×production system interaction was an important source of variation in CCW ( $p = 0.0395$ ), retail cuts ( $p = 0.001$ ), lean ( $p = 0.001$ ), fat ( $p = 0.0101$ ), rump ( $p = 0.0454$ ), shortloin ( $p = 0.0482$ ), and flank ( $p = 0.001$ ) (mean squares shown). Although many studies (Bowling et al., 1978; Harrison et al., 1978; Williams et al., 1989; Sapp et al., 1996; Steen et al., 2003) have been conducted using different biological types (animal types) and production systems (management groups) no test of interaction of these effects were conducted except in the study by Smith et al. (1977) who found no significant animal type×management group interaction for any of the traits in the current study.

**Table 3.** Least squares means and standard errors for the beef growth type×production system interaction effect on chilled carcass weight (kg), primals and subprimals (%), lean and fat trim (%) and retail cuts (%) in pasture- or feedlot-developed steers

Trait	Production system	Growth type <sup>12</sup>			
		LL n = 79	IL n = 88	IE n = 87	SE n = 81
Chilled carcass weight	Pasture	217.2±11.3 <sup>i</sup>	186.3±12.3 <sup>i</sup>	174.8±11.5 <sup>k</sup>	157.6±11.9 <sup>l</sup>
	Feedlot	317.3±9.7 <sup>f</sup>	283.9±8.7 <sup>g</sup>	290.3±9.4 <sup>g</sup>	263.1±9.1 <sup>h</sup>
Rump <sup>3</sup>	Pasture	6.8±0.3 <sup>d</sup>	5.9±0.3 <sup>e</sup>	5.7±0.3 <sup>e</sup>	5.8±0.3 <sup>e</sup>
	Feedlot	5.5±0.2 <sup>e</sup>	4.6±0.2 <sup>f</sup>	4.2±0.2 <sup>g</sup>	4.1±0.2 <sup>g</sup>
Shortloin <sup>3</sup>	Pasture	5.6±0.2 <sup>f</sup>	5.5±0.2 <sup>fg</sup>	5.6±0.2 <sup>g</sup>	5.5±0.2 <sup>g</sup>
	Feedlot	6.0±0.2 <sup>d</sup>	5.7±0.1 <sup>e</sup>	5.6±0.2 <sup>def</sup>	5.6±0.1 <sup>f</sup>
Sirloin <sup>3</sup>	Pasture	7.9±0.2 <sup>d</sup>	7.8±0.2 <sup>de</sup>	7.6±0.2 <sup>ef</sup>	7.5±0.2 <sup>f</sup>
	Feedlot	6.2±0.2 <sup>g</sup>	5.8±0.2 <sup>h</sup>	5.5±0.2 <sup>i</sup>	5.5±0.2 <sup>i</sup>
Flank <sup>3</sup>	Pasture	3.4±0.2 <sup>h</sup>	4.5±0.3 <sup>g</sup>	4.6±0.2 <sup>g</sup>	4.7±0.3 <sup>g</sup>
	Feedlot	5.9±0.2 <sup>f</sup>	7.4±0.3 <sup>e</sup>	7.9±0.2 <sup>d</sup>	7.9±0.2 <sup>d</sup>
Lean <sup>3</sup>	Pasture	70.5±1.4 <sup>f</sup>	65.5±1.5 <sup>g</sup>	65.1±1.4 <sup>g</sup>	65.0±1.5 <sup>g</sup>
	Feedlot	62.0±1.2 <sup>g</sup>	55.1±1.1 <sup>h</sup>	53.6±1.2 <sup>i</sup>	53.5±1.2 <sup>i</sup>
Fat <sup>3</sup>	Pasture	5.8±1.8 <sup>k</sup>	11.5±1.9 <sup>j</sup>	12.3±1.8 <sup>ij</sup>	13.6±1.9 <sup>i</sup>
	Feedlot	22.1±1.5 <sup>h</sup>	29.8±1.4 <sup>g</sup>	32.1±1.5 <sup>f</sup>	32.7±1.4 <sup>f</sup>
Retail cuts <sup>4</sup>	Pasture	77.7±1.4 <sup>f</sup>	72.8±1.5 <sup>g</sup>	72.5±1.4 <sup>g</sup>	71.9±1.4 <sup>g</sup>
	Feedlot	69.1±1.2 <sup>g</sup>	62.5±1.1 <sup>h</sup>	60.9±1.2 <sup>i</sup>	60.5±1.1 <sup>i</sup>

<sup>1</sup> LL = large mature weight late maturing; IL = intermediate mature weight late maturing;

IE = intermediate mature weight early maturing; SE = small mature weight early maturing.

<sup>2</sup> 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.

<sup>3</sup> Percentage of chilled carcass right side weight.

<sup>4</sup> Percentage of chilled carcass weight.

<sup>f, g, h, i, j, k, l</sup> Trait means with different superscripts differ ( $p < 0.05$ ).

The beef growth type $\times$ production system interaction for CCW resulted in a change in ranking of mean CCW among the growth types in the two production systems (rank order interaction) (Table 3). The ranking of the beef growth type $\times$ production combination means for CCW was LL-feedlot>IL-feedlot = IE-feedlot>SE-feedlot>LL-pasture>IL-pasture>IE-pasture>SE-pasture. There was no difference ( $p>0.05$ ) between the IE and IL steers for mean CCW in the feedlot-production system, whereas the IL steers had greater ( $p<0.05$ ) mean CCW than the IE steers in the pasture production system. Given ample pasture resources for cattle development, IL steers will produce heavier CCW than IE steers. In contrast, should a feedlot-production system be chosen, the IL and IE steers should produce similar CCW. The LL steers had greater ( $p<0.05$ ) mean CCW in both production systems, but the difference between mean CCW of the LL-feedlot combinations was greater than the difference between mean CCW of the LL-pasture and the IL-pasture combinations (33.4 vs. 30.9 kg, respectively). The difference between IL-pasture and IE-pasture combinations for mean CCW was 11.5 kg while the difference between the IL-feedlot and IE-feedlot combination for mean CCW was 6.4 kg, illustrating the difference in performance among these growth types in the two production systems. The SE steers had lesser ( $p<0.05$ ) mean CCW when compared to the other beef growth types in both production systems, but there was greater ( $p<0.05$ ) no difference between the IE-feedlot and SE-feedlot combinations for mean CCW (27.2 kg) than those was between the IE-pasture and SE-pasture combinations for mean CCW (17.2 kg). Chilled carcass weight was lower ( $p<0.05$ ) for all pastured steers compared to the feedlot-developed steers, even after an additional 6-mo age advantage for the pasture-developed steers. Therefore, it would seem likely that the pasture production system did not meet nutrient requirements for maximizing growth and tissue accretion.

The interaction of beef growth type $\times$ production system for rump resulted from differences between mean percentages of rump of the beef growth types across the two production systems (an interaction of magnitude). The ranking of the beef growth type $\times$ production system combination means for percentage rump was LL-pasture>IL-pasture = IE-pasture = SE-pasture = LL-feedlot>IL-feedlot>IE-feedlot = SE-feedlot. The combinations of IL-pasture, IE-pasture, and SE-pasture were similar ( $p>0.05$ ) for mean rump (5.9 $\pm$ 0.3, 5.7 $\pm$ 0.3 and 5.8 $\pm$ 0.3%, respectively) and were different ( $p<0.05$ ) from the LL-pasture combination for mean percentage of rump (6.8 $\pm$ 0.3), whereas the IE-feedlot and SE-feedlot combinations were similar ( $p>0.05$ ) for yield of mean rump (4.2 $\pm$ 0.2 and 4.1 $\pm$ 0.2%) and differed ( $p<0.05$ ) from the yield of mean rump of

the IL-feedlot combination (4.6 $\pm$ 0.2%). The LL-feedlot combination yielded greater ( $p<0.05$ ) mean rump than did the IL-feedlot combination (5.5 $\pm$ 0.2 vs. 4.6 $\pm$ 0.2%). Previous research has shown that large-framed steers produce higher-yielding rump than either medium-or small-framed steers (May et al., 1992; Reiling et al., 1992).

The interaction of beef growth type $\times$ production system for mean percentages of shortloin resulted from a change in ranking of the IL and IE growth types between the pasture and feedlot systems (5.5 $\pm$ 0.2 and 5.6 $\pm$ 0.2 vs. 5.7 $\pm$ 0.1 and 5.6 $\pm$ 0.2%, respectively). The LL-pasture and IL-pasture combinations were similar ( $p>0.05$ ) for yield of mean shortloin (5.6 $\pm$ 0.2 and 5.5 $\pm$ 0.2%). When compared, the IE-pasture and SE-pasture combinations were similar ( $p>0.05$ ) for yield of mean shortloin (5.6 $\pm$ 0.2 and 5.5 $\pm$ 0.2%). The LL-feedlot combination yielded greater ( $p<0.05$ ) mean shortloin than the IL-feedlot combination (6.0 $\pm$ 0.2 vs. 5.7 $\pm$ 0.1%) but did not differ ( $p>0.05$ ) from the yield of the IE-feedlot combination (6.0 $\pm$ 0.2 vs. 5.6 $\pm$ 0.2%). The IE- and SE-feedlot combinations were similar ( $p>0.05$ ) for yield of mean shortloin (5.6 $\pm$ 0.2 and 5.6 $\pm$ 0.1%).

The beef growth type $\times$ production system interaction resulted from differences in mean 181-sirloin among the four beef growth types between the two production systems (an interaction of magnitude). Differences in mean of yield of 181-sirloin between the LL and IL and between IL and IE growth types developed in the feedlot was greater ( $p<0.05$ ) than differences among similar growth types for pastured steers (0.4 and 0.3 vs. 0.1 and 0.2%, respectively). The combinations of LL-pasture and IL-pasture were similar ( $p>0.05$ ) for mean 181-sirloin (7.9 $\pm$ 0.2 and 7.8 $\pm$ 0.2%). The combination of IL-pasture and IE-pasture were similar ( $p>0.05$ ) for mean 181-sirloin (7.8 $\pm$ 0.2 and 7.6 $\pm$ 0.2%). There was no difference ( $p>0.05$ ) in the IE-pasture and SE-pasture combinations for mean 181-sirloin (7.6 $\pm$ 0.2 and 7.5 $\pm$ 0.2%). The LL-feedlot combination had greater ( $p<0.05$ ) mean percentage of 181-sirloin than the IL-, IE- and SE-feedlot combinations (6.2 $\pm$ 0.2 vs. 5.8 $\pm$ 0.2, 5.5 $\pm$ 0.2, and 5.5 $\pm$ 0.2%). The IL-feedlot combination yielded greater ( $p<0.05$ ) mean 181-sirloin than did the IE- and SE-feedlot combinations. The IE- and SE-feedlot combinations were similar ( $p>0.05$ ) in mean percentage of 181-sirloin (5.5 $\pm$ 0.2). Across all beef growth types, pasture steers yielded greater ( $p<0.05$ ) mean percentage of 181-sirloin than did feedlot-developed steers. Previous research has shown that large-framed steers produce higher-yielding loins than either medium-or small-framed steers (May et al., 1992; Reiling et al., 1992).

The beef growth type $\times$ production system interaction for flank resulted from differences in mean percentage flank between the IE and SE growth types in the two production



systems. The IE-feedlot and SE-feedlot combination means were similar ( $p>0.05$ ) and different ( $p<0.05$ ) from the IL-feedlot and LL-feedlot combination means for flank ( $7.9\pm 0.2$  vs.  $7.4\pm 0.3$  and  $5.9\pm 0.2\%$ , respectively). The SE-pasture and IE-pasture combinations were similar ( $p>0.05$ ) for mean flank ( $4.7\pm 0.3$  vs.  $4.6\pm 0.2\%$ ). The IL-pasture combination for mean percentage flank was greater ( $p<0.05$ ) than mean percentage flank of the LL-pasture combination. The LL-pasture combination had the lowest mean percentage flank of all combinations. The ranking of the beef growth type  $\times$  production system interaction means for percentage flank was SE-feedlot = IE-feedlot > IL-feedlot > LL-feedlot > SE-pasture = IE-pasture > IL-pasture > LL-pasture. Previous research has shown that large-framed steers produce lower-yielding flank than either medium- or small-framed steers (May et al., 1992; Reiling et al., 1992).

The beef growth type  $\times$  production system interaction for mean lean resulted from differences in the ranking of the IL, IE and SE growth types in the two production systems. The LL-pasture combination yielded greater ( $p<0.05$ ) mean percentage lean than did the combinations of IL-pasture, IE-pasture, and SE-pasture ( $70.5\pm 1.4$  vs.  $65.5\pm 1.5$ ,  $65.1\pm 1.4$ , and  $65.0\pm 1.5\%$ ). Likewise, the LL-feedlot combination was greater ( $p<0.05$ ) for mean percentage of lean than the combinations of IL-feedlot, IE-feedlot, and SE feedlot ( $62.0\pm 1.2$  vs.  $55.1\pm 1.1$ ,  $53.6\pm 1.2$ , and  $53.5\pm 1.2$ ). There was no difference in mean percentage lean among the IL-pasture, IE-pasture, and SE-pasture combinations ( $65.5\pm 1.5$ ,  $65.1\pm 1.4$ , and  $65.0\pm 1.5\%$ ). Conversely, the IL-feedlot combination was greater ( $p<0.05$ ) for mean percentage lean than the IE-feedlot and SE-feedlot combinations ( $55.1\pm 1.1$  vs.  $53.6\pm 1.2$  and  $53.5\pm 1.2\%$ ). The ranking of the beef growth type  $\times$  production system interaction means for percentage lean was LL-pasture > IL-pasture = IE-pasture = SE-pasture > LL-feedlot > IL-feedlot > IE-feedlot = SE-feedlot. These data agree with Koch et al. (1976, 1979, 1982) and Dolezal et al. (1993), who found that larger-framed cattle produce leaner carcasses than small-framed cattle when compared on a weight constant or a constant time-on-feed basis. Tatum et al. (1986) reported that larger-framed cattle are leaner than small-framed cattle when compared at similar slaughter weights, because larger-framed cattle tend to fatten at relatively heavy weights.

In general, the ranking of beef growth type  $\times$  production system interaction means for percentage fat was inversely proportional to the mean percentage of lean. This interaction resulted from differences ( $p<0.05$ ) in the IL- and IE-feedlot combinations and the similarity ( $p>0.05$ ) of the IL- and IE-pasture combinations. The combinations of IE-feedlot and SE-feedlot were similar ( $p>0.05$ ) for mean percentage fat ( $32.1\pm 1.5$  and  $32.7\pm 1.4$ ). The IL-feedlot and the LL-feedlot combinations were different ( $p<0.05$ ) for

mean fat ( $29.8\pm 1.4$  vs.  $27.1\pm 1.5\%$ ) and both combinations were different ( $p<0.05$ ) from the IE-feedlot and SE-feedlot combinations. The IE- and SE-pasture combinations were similar ( $p>0.05$ ) for mean fat ( $12.3\pm 1.8$  and  $13.6\pm 1.9\%$ ). When compared, IL-pasture and IE-pasture combinations were similar ( $p>0.05$ ) for mean percentage fat ( $11.5\pm 1.9$  and  $12.3\pm 1.8$ ). The LL-pasture combination had less mean fat than the IL-pasture, IE-pasture, and SE-pasture combinations ( $5.8\pm 1.8$  vs.  $11.5\pm 1.9$ ,  $12.3\pm 1.8$ , and  $13.6\pm 1.9\%$  respectively). The ranking of the beef growth type  $\times$  production system interaction means for fat was SE-feedlot = IE-feedlot > IL-feedlot > LL-feedlot > SE-pasture = IE-pasture = IL-pasture > LL-pasture. Numerous reports have indicated that cattle developed on a forage diet have a smaller proportion of fat than comparable animals finished on grain diets (Wanderstock and Miller, 1948; Dinius et al., 1975; Bidner et al., 1986). Stonaker et al. (1952), Koch et al. (1976, 1979, 1982), and Butts et al. (1980a, 1980b) reported that differences between large- and small-framed carcasses tended to be reduced when compared at similar levels of fatness, but larger cattle tend to be older and heavier because of their slower maturity rates and tendency to fatten at heavier weights.

The beef growth type  $\times$  production system interaction for retail cuts resulted from differences in mean percentage retail cuts for some of the growth types in the two production systems (an interaction of magnitude). There was a 4.9% difference ( $p<0.05$ ) between the LL-pasture and IL-pasture steers for mean retail cuts. Whereas, the difference ( $p<0.05$ ) in mean retail cuts between the LL-feedlot and the IL-feedlot was 6.6%. The LL-growth type yielded greater ( $p<0.05$ ) mean percentage of retail cuts in both production systems. There were no differences ( $p>0.05$ ) in mean percentage retail cuts between the IE and SE growth types in both production systems, but the pasture system yielded greater ( $p<0.05$ ) mean percentage retail cuts than the feedlot system ( $72.5\pm 1.4$  and  $71.9\pm 1.4$  vs.  $60.9\pm 1.2$  and  $60.5\pm 1.1$ , respectively). The ranking of the beef growth types  $\times$  production system means for retail cuts was LL-pasture > IL-pasture = IE-pasture = SE-pasture > LL-feedlot > IL-feedlot > IE-feedlot = SE-feedlot. Gregory et al. (1994) showed differences in retail product between two trim levels (8 mm and 0 mm of fat trim). These differences tended to be less in breeds that are larger-framed with lower fat content than in smaller-framed breeds with more fat content. Koch et al. (1979) reported that larger-framed Chianina crosses had more retail product than either medium-framed Angus or Red Poll crosses when compared at a constant carcass weight. Koch et al. (1976) stated that large-framed Charolais, Limousin, and Simmental crosses had higher ( $p<0.05$ ) percentages of retail product than either medium framed Hereford-Angus, Jersey, or South Devon crosses.

## IMPLICATIONS

Differences in mean CCW between IL- and IE-pasture combinations and IL- and IE-feedlot combinations illustrate performance differences among beef growth types in two production systems. Given ample pasture resources, IL steers will produce heavier CCW than IE steers. In contrast, IL and IE steers should produce similar CCW under a feedlot production system. Pasture system yielded greater mean percentage retail cuts and bone than the feedlot system. The CCW was lower for all pastured steers compared to feedlot-developed steers indicating the pasture system did not meet nutrient requirements for maximum growth and tissue accretion. Beef growth type x production system interaction for mean percentage fat was inversely proportional to mean percentage lean and further indicated that cattle developed on forage have less fat than comparable animals finished on grain. While genetic potential may be more effectively exploited in a feedlot situation, a need exists within the cattle industry to correctly match nutrient requirement of animal growth type to resources regardless of production system.

## REFERENCES

- Allen, V. G., J. P. Fontenot, R. F. Kelly and D. R. Notter. 1996. Forage Systems for Beef Production from Conception to Slaughter: III. Finishing Systems. *J. Anim. Sci.* 74:625-638.
- Arthur, P. F., H. Hearnshaw, D. Johnson and P. D. Stephenson. 1995. Evaluation of Angus, Charolais, and Hereford as terminal sire breeds on Hereford and first-cross cows. II. Carcass characteristics and retail yield of progeny. *Aust. J. Agric. Res.* 46:1245-1258.
- Belk, K. E., J. D. Tatum and F. L. Williams, Jr. 1991. Deposition and distribution of carcass fat for steers differing in frame size and muscle thickness. *J. Anim. Sci.* 69:609-616.
- Berg, R. T. and R. M. Butterfield. 1968. Growth patterns of bovine muscle, fat and bone. *J. Anim. Sci.* 17:611-619.
- Bidner, T. P., A. R. Schupp, A. B. Mohamad, N. C. Ramore, R. E. Montgomery, C. P. Bagley and K. W. McMillin. 1986. Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high-energy diet. *J. Anim. Sci.* 62:381-387.
- Bowling, R. A., J. K. Riggs, G. C. Smith, Z. L. Carpenter, R. L. Reddish and O. D. Butler. 1978. Production, carcass, and palatability characteristics of steers produced by different management systems. *J. Anim. Sci.* 46:333-340.
- Brown, A. H., Jr., J. J. Chewning, Z. B. Johnson, W. C. Lowe and C. J. Brown. 1991. Effects of 84-, 112- and 140-day postweaning feedlot performance tests for beef bulls. *J. Anim. Sci.* 69:451-461.
- Brody, S. 1945. *Bioenergetics and Growth*. 1<sup>st</sup> ed. Page 529. Reinhold Publishing Inc., New York.
- Brown, A. H., Jr., P. K. Camfield, Z. P. Johnson, L. Y. Rakes, F. W. Pohlman, C. J. Brown, B. A. Sandelin and R. T. Baublits. 2005. Interaction of Beef Growth Type x Production System for Carcass Traits of Steers. *Asian-Aust. J. Anim. Sci.* 18:259-266.
- Butts, W. T., Jr., W. R. Backus, E. R. Lidvall, J. A. Corrick and R. F. Montgomery. 1980a. Relationships among definable characteristics of feeder-calves, subsequent performance and carcass traits. I. Objective measures. *J. Anim. Sci.* 51:1297-1305.
- Butts, W. T. Jr., E. R. Lievall, W. R. Backus and J. A. Corrick. 1980b. Relationships among definable characteristics of feeder-calves, subsequent performance and carcass traits. II. Subjective scores. *J. Anim. Sci.* 51:1306-1313.
- Camfield, P. K., A. H. Brown, Jr., Z. B. Johnson, C. J. Brown, P. K. Lewis and L. Y. Rakes. 1999. Effects of growth type on carcass traits of pasture-or feedlot-developed steers. *J. Anim. Sci.* 77:2437-2443.
- Consortium. 1998. Guide for care and use of agricultural animals in agricultural research and teaching. Consortium for Developing a Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, Champaign, IL.
- Davies, H. L. 1977. Continued studies on the effect of grain or pasture on the carcass composition and meat quality of Friesian steers. *Aust. J. Agri. Res.* 28:775-761.
- Dinius, D. A., R. R. Oltjen and T. S. Rumsey. 1975. Pelleted forage diets plus supplemental energy and feed additives for finishing beef cattle. *J. Anim. Sci.* 41:868-875.
- Dixon, R. M. and C. R. Stockdale. 1999. Associative effects between forages and grains: consequences for feed utilization. *Aust. J. Agric. Res.* 50:757-773.
- Dolezal, H. G., J. D. Tatum and F. L. Williams, Jr. 1993. Effects of feeder cattle frame size, muscle thickness, and age class on days fed, weight, and carcass composition. *J. Anim. Sci.* 71:2975-2985.
- Flora, C. B. 2001. Midwestern beef and the environment. The ecosystem strengths of better integrated value chains. Paper presented at Midwest Region Commodities and the Environment Conference. Chicago, IL.
- Garcia-de-Siles, J. L., J. H. Ziegler, L. L. Wilson and J. D. Sink. 1977. Growth, carcass, and muscle characters of Hereford and Holstein steers. *J. Anim. Sci.* 44:973-984.
- Gregory, K. E., L. V. Cundiff, R. M. Koch, M. E. Dikeman and M. Koohmaraie. 1994. Breed effects and retained heterosis for growth, carcass and meat traits in advanced generations of composite population of beef cattle. *J. Anim. Sci.* 72:933-850.
- Griffin, D. B., J. W. Savell, J. B. Morgan, R. P. Garret and H. R. Cross. 1992. Estimates of subprimal yields from beef carcasses as affected by USDA grades, subcutaneous fat trim level, and carcass sex class and type. *J. Anim. Sci.* 70:2411-2430.
- Harrison, A. R., M. E. Smith, D. M. Allen, M. C. Hunt, C. L. Lastner and D. H. Kropf. 1978. Nutritional regime effects on quality and yield characteristics of beef. *J. Anim. Sci.* 47:383-388.
- Johnson, Z. B., C. J. Brown and A. H. Brown, Jr. 1990. Evaluation of growth patterns of beef cows. *Ark. Agric. Exp. Sta. Bul.* 923.
- Koch, R. M., M. E. Dikeman, D. M. Allen, M. May, J. A. Crouse and D. R. Champion. 1976. Characterization of biological types of cattle. III. Carcass composition, quality, and palatability. *J. Anim. Sci.* 43: 48-62.
- Koch, R. M. and M. E. Dikeman. 1977. Characterization of

- biological types of cattle. V. Carcass wholesale cut composition. *J. Anim. Sci.* 45:30-42.
- Koch, R. M., M. E. Dikeman, R. J. Lipsey, D. M. Allen and J. D. Crouse. 1979. Characterization of biological types of cattle-cycle II: III. Carcass composition, quality, and palatability. *J. Anim. Sci.* 49:448-460.
- Koch, R. M., M. E. Dikeman and J. D. Crouse. 1982. Characterization of biological types of cattle (cycle III). III. Carcass composition, quality, and palatability. *J. Anim. Sci.* 54:35-45.
- May, S. C., W. L. Miles, J. W. Edwards, F. L. Williams, J. W. Wise, J. B. Morgan, J. W. Savell and H. R. Cross. 1992. Beef carcass composition of slaughter cattle differing in frame size, muscle score and external fatness. *J. Anim. Sci.* 70:2431-2445.
- Miller, M. R., C.B. Ramsey, S. W. Claborn and C. K. Wu. 1996. Subprimal cutability and carcass value as effected by cattle type. *J. Muscle Foods.* 7:17-27.
- Muir, P. D., J. M. Deaker and M. D. Brown. 1998. Effects of forage- and grain-based feeding systems on beef quality: A Review. *New Zealand J. Agric. Res.* 41:623-635.
- Murray, D. M., N. M. Tulloh and W. H. Winter. 1974. Effects of three different growth rates on empty body weight, carcass weight, and dissected carcass composition of cattle. *J. Agric. Sci.* 82:535-547.
- Norton, M. C. 1993. Effects of maturation rate and frame size on the yield and composition of beef carcasses finished on either pasture or grain. MS Thesis, University of Arkansas, Fayetteville.
- NRC. 1976. Nutrient Requirements of Beef Cattle. 7<sup>th</sup> ed. National Academy Press. Washington, DC.
- Price, M. A. 1976. Changes in body composition associated with weight loss in early- and later-maturing types steers. *Aust. J. Agri. Res.* 27:729-738.
- Priyanto, R., E. R. Johnson and D. G. Taylor. 1999. The economic importance of genotype in steers fed pasture or leucerne hay and prepared for the Australian and Japanese beef markets. *New Zealand J. Agric. Res.* 42:393-404.
- Reiling, B. A., G. H. Rouse and D. A. Duello. 1992. Predicting percentage of retail yield from carcass measurements, the yield equation and closely trimmed boxed beef weights. *J. Anim. Sci.* 70:2151-2158.
- Robinson, D. L., D. M. Ferguson, V. H. Oddy, D. Perry and J. Thompson. 2001. Genetic and environmental influences on beef tenderness. *Aust. J. Agric. Res.* 41:997-1003.
- Sainz, R. D., F. Dela Torre and W. G. Oltjen. 1995. Compensatory growth and carcass quality in growth-restricted and refed beef steers. *J. Anim. Sci.* 73:2971-2979.
- Sapp, P. H., M. A. McCann and S. E. Williams. 1996. Evaluation of performance and carcass characteristic of pasture and/or grain-fed steers. In *Animal and Dairy Science Department 1996 Annual Report*, (Ed. Scott A. Martin). College of Agricultural and Environmental Sciences, The University of Georgia. pp. 47-53.
- Savell, J. W., R. E. Branson, H. R. Cross, D. M. Stiffler, D. B. Griffin and G. C. Smith. 1987. National consumer retail beef study: Palatability evaluation of beef loin steaks that differ in marbling. *J. Food Sci.* 52:517-519.
- Schaake, S. L., G. C. Skelley, E. Halpin, L. W. Grimes, R. B. Brown, D. L. Cross and C. E. Thompson. 1993. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage or for different periods in drylot. *J. Anim. Sci.* 71:3199-3205.
- Smith, G. M., J. D. Crouse, B. W. Mandigo and K. L. Neer. 1977. Influence of feeding regime and biological type on growth, composition, and palatability of steers. *J. Anim. Sci.* 45:236-253.
- Steen, R. W. J., N. P. Lavery, D. J. Kilpatrick and M. G. Porter. 2003. Effects of pasture and high-concentrate diets on the performance of beef cattle, carcass composition at equal growth rates, and the fatty acid composition of beef. *New Zealand J. Agric. Res.* 46:69-81.
- Stiffler, D. M., C. M. Griffin, C. E. Murphy, G. C. Smith and J. W. Savell. 1985. Characterization of cutability and palatability attributes among different slaughter groups of beef cattle. *Meat Sci.* 13:167-182.
- Stonaker, H. H., M. H. Hazaleus and S. S. Wheeler. 1952. Feedlot and carcass characteristics of individually fed compressed and conventional type Hereford steers. *J. Anim. Sci.* 11:17-25.
- Sully, R. J. and J. H. L. Morgan. 1982. The influence of feeding level and type of feed on the carcasses of steers. *Aust. J. Agric. Res.* 33:721-729.
- Tatum, J. D., H. G. Dolezal, F. L. Williams, Jr., R. A. Bowling and R. E. Taylor. 1986. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. II. Absolute growth and associated changes in carcass composition. *J. Anim. Sci.* 62:121-131.
- Taylor, D. G. 1982. A comparative study of Hereford and Friesian steers. II. Carcass characteristics and meat quality. *Aust. J. Agric. Res.* 33:157-163.
- Tudor, G. D. 1992. Effects of diet on fat deposition in cattle. *Proceedings of the Australian Society of Animal Production* 19:89.
- USDA. 1988. Institutional Meat Purchase specifications for Fresh Beef. *Agric. Marketing Serv., USDA, Washington, DC.*
- Vallentine, J. F. 1990. *Grazing Management*. Academic Press, Inc. New York.
- Wanderstock, J. J. and J. I. Miller. 1948. Quality and palatability of beef as affected by method of feeding and carcass grade. *Food Res.* 13:291-303.
- Williams, J. E., D. G. Wagner, L. E. Walters, G. W. Horn, G. R. Waller, P. L. Sims and J. J. Guenther. 1983. Effect of production systems on performance, body composition and lipid and mineral profiles of soft tissue in cattle. *J. Anim. Sci.* 57:1020-1027.
- Williams, S. E., J. D. Tatum and T. L. Stanton. 1989. The effects of muscle thickness and time on feed on hot fat trim yield, carcass characteristics, and boneless subprimal yields. *J. Anim. Sci.* 67:2669-2676.