

Interaction of Beef Growth Type×Production System for Carcass Traits of 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 differences in carcass traits. Growth types were animals with genetic potential for large mature weight-late maturing, intermediate mature weight-late maturing, intermediate mature weight-early maturing and small mature weight-early maturing. 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 slaughtered at approximately 20 and 14 months of age, respectively. Data collected were pre-slaughter shrunk body weight (SBW); hot carcass weight (HCW); dressing percentage (DRESS); fat thickness at the 12th and 13th rib interface (FAT); percentage kidney, pelvic, and heart fat (KPH); longissimus muscle area (LMA); marbling score (MARB); quality grade (QG); and yield grade (YG). Year and growth type were significant for all carcass traits. The growth type×production system interaction was an important source of variation in SBW, HCW, FAT, YG and MARB. The same interaction was non-significant for DRESS, KPH, LMA and QG. Carcass differences in measures of fatness were greater in the feedlot system than in the pasture system. These data could aid producers in matching beef growth type to the production system most suitable for efficient use of resources. (*Asian-Aust. J. Anim. Sci.* 2005, Vol 18, No. 2 : 259-266)

Key Words : Beef, Growth Types, Production System, Carcass Traits

INTRODUCTION

Traditionally, beef production in the United States has been based on production systems that involve grazing through the growth phase with subsequent feedlot finishing (Ensminger and Perry, 1997). The Southeastern United States has the potential to support production systems that allow slaughter of cattle developed on pasture (Taylor and Field, 1999). This is due to the region's intensive pasture production, which offers economic benefits that surpass those of finishing cattle on cereal grains. Forage traditionally is less expensive than feed grain per unit of energy and protein (Dixon and Stockdale, 1999) partly because no cheaper method of harvesting swards has been devised than is afforded by harvesting directly from grazing.

The U. S. beef cattle industry does a commendable job of developing technology to allow for an array of cattle growth types that perform well in the feedlot environment. Custom feedlot operators generally favor larger, later-maturing cattle due to their potential for greater feed intake and the extended time on-feed to achieve an acceptable

carcass endpoint. As a result, most selection criteria among beef cattle have focused largely on the offspring's performance in feedlot environments (Heitschmidt et al., 1996). Little data are available to determine how offspring of these same seedstock generally would perform in converting grazable forages into carcasses of similar endpoint. Bidner et al. (1981) reported that Angus-Hereford crossbred steers developed on all forage or high forage diets produced an acceptable carcass. In general these breeds are intermediate for mature size and rate of maturing (Johnson et al., 1990; Brown et al., 1991).

An overview of previous research suggests that production efficiency of cattle, regardless of production system, is influenced by beef cattle growth type (traits of mature weight and rate of maturing). These traits determine nutrient requirements of the animal and influence reproduction in the cowherd and also influence carcass size, leanness, and marbling at acceptable slaughter weights (Taylor and Fitzhugh, 1971; Brown et al., 1972ab; Butts et al., 1980). Thus, an important factor in producing carcass beef is to correctly match beef growth type to available inputs within a particular production system (Robinson et al., 2001a). In the past, differences in beef growth type were reflected in differences among breeds; however, the increased emphasis on selection for size over the last two decades has resulted in a broad array of growth types within most breeds. Given the differences in nutrient requirements among growth types and possible alternate feeding systems, more data are needed on the way that carcass and feed interact (Flora, 2001). Also more research needs to be done

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on all-forage diets (NRC, 1996). Therefore, this study was designed to evaluate carcass traits of four fundamentally different growth types of beef steers produced in pasture or feedlot production systems. Divergent growth types included in the study were chosen to increase the possibility of detecting differences in carcass traits among growth types and production systems.

MATERIALS AND METHODS

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 illness or injury. An additional 7 steers were removed because some of their carcass traits were outliers ($n=335$). Steers removed from the study were equally distributed across years and production regimes. 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 1950s. 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. With the exception of the Chianina cow herd, 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.

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 (*Secale cereale*, *Lolium multiflorum* and *Trifolium pratense*, 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 slaughtered at approximately 20 mo of age.

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 0.9 Mcal Ne_v/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. Throughout the study, husbandry was in accordance with guidelines recommended by the Consortium (1988).

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 (SBW) were taken prior to stunning. After dressing, splitting, determining hot carcass weight (HCW), and dressing percentage (DRESS), carcasses were chilled and stored in a cooler for 96 h at 2°C. Upon completion of chilling, the carcass were ribbed between the 12th and 13th ribs and trained personnel obtained the following measurements: fat depth over the *longissimus thoracis* muscle (FAT; adjusted for abnormal subcutaneous fat distribution according to USDA, 1989 standards); percentage kidney, pelvic, and heart fat (KPH); longissimus muscle area (LMA); marbling score (MARB) (AMSA, 1990); USDA (1989) quality grade (QG) and USDA (1989) yield grade (YG). Carcass measurements were obtained 96 h post-mortem in order to more efficiently utilize labor and processing facilities. All steers within a given production system were harvested at a similar age and all beef growth types had similar opportunity for

Table 1. Least squares means and standard errors for dressing percentage, kidney, pelvic and heart fat, longissimus muscle area and quality grade of beef steers by production system

Trait	Production system	
	Pasture	Feedlot
	n=168	n=167
Dressing percentage (%)	57.3±0.9 ^b	61.9±0.7 ^a
Kidney, pelvic and heart fat (%)	2.3±0.38 ^b	4.8±0.29 ^a
Longissimus muscle area (cm ²)	52.1±2.99 ^b	68.3±2.3 ^a
Quality grade ^c	15.2±0.6 ^b	21.3±0.5 ^a

^{a,b} Row means with common superscripts do not differ ($p < 0.05$).

^c Quality grade (15=high standard, 16=low select, 17=average select, 18=high select, 19=low choice, 20=average choice, 21=high choice).

development. A detailed description of the management of steers in each production system in this study is given by Camfield et al. (1999).

Data were analyzed according to methods of least squares, analysis of variance with unequal subclass numbers. Main effect means for carcass traits as influenced by beef growth type within pasture- or feedlot-production systems have been summarized by Camfield et al. (1999). However, the impact of growth type × production system interaction on carcass traits has not been previously reported, and is, therefore, summarized in this study. The interactions of these main effects on carcass traits were partitioned with 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 slaughter 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 slaughter weight and composition compared to that of the feedlot-developed steers. Carcass trait data were not adjusted to a constant endpoint basis (i.e. 12th and 13th 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). Least squares means were generated and then separated using repeated t-tests in the LSMEANS option of the GLM procedure of SAS.

RESULTS AND DISCUSSION

Year was an important source of variation ($p < 0.001$) for SBW, HCW, DRESS, KPH, FAT, LMA, MARB, QG and YG (data not shown). Interactions involving year with growth type and with production system were significant ($p < 0.05$) for all traits in this study except LMA and MARB.

The year×beef growth type×production system interaction was non-significant for all traits. 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 SBW and carcass traits were adjusted to a mean year effect. Therefore, main effect means of year and interaction effect means involving year are not presented.

Within production system, steer age at slaughter accounted for substantial variation in SBW, HCW, FAT, QG, MARB, YG, KPH (all, $p < 0.001$) and LMA ($p = 0.028$). Steer age within production system was not significant ($p = 0.102$) for DRESS.

The beef growth type × production system interaction was not significant ($p = 0.102$) for DRESS, KPH, LMA and QG. Therefore, the main effect means for production system and beef growth type are presented for these traits.

Least squares means and standard errors for DRESS, KPH, LMA, and QG of beef steers by production system are presented in Table 1. Mean DRESS was greater ($p < 0.05$) for steers in the feedlot-production system when compared to DRESS of steers in the pasture-production system (61.9±0.7 vs. 57.3±0.9%, respectively). This 4.6% difference was likely due to higher carcass yields because of greater fat deposition and muscling of steers in the feedlot production system. These results are consistent with those reported by Luitingh (1963), Preston et al. (1963), Breidenstain et al. (1965) and Oltjen et al. (1971) who reported that as energy concentration of the diet increased, DRESS also increased. These results are also in agreement with those of Bidner et al. (1986) who found a 1.7% higher DRESS ($p < 0.05$) for grain fed cattle when compared to pastured cattle. Our results are not in agreement with those of Bidner et al. (1981) who reported no difference in DRESS of cattle in four treatments involving all pasture, pasture plus grain, and pasture plus feedlot for 70 days or feedlot for 74 days. In the current study, mean DRESS of both pasture- and feedlot-developed steers was higher than mean DRESS (56.3%) reported across six treatment groups of steers: four grazing treatments of which two received maize silage and two feedlot treatments that received maize silage plus concentrate supplementation (Wales et al., 1998). In the Wales et al. (1998) study, groups of steers were harvested when their mean shrunk live weight was 450 kg and there was no difference in mean DRESS of the six groups. Hunter et al. (2001) reported mean DRESS of 57.0±0.5% and 54.1±0.6% for feedlot- finished and pasture-developed steers, respectively, which were controls for a growth implant study involving three market channels for Australian beef. Likewise, carcasses from the feedlot-finished system had larger ($p < 0.05$) LMA than carcasses

Table 2. Least squares means and standard errors for dressing percentage, kidney, pelvic, and heart fat, longissimus muscle area, and quality grade of beef steers by beef growth type

Trait	Growth type ^a			
	LL	IL	IE	SE
	n=79	n=88	n=87	n=81
Dressing percentage (%)	60.3±0.6 ^b	59.0±0.6 ^d	59.6±0.6 ^c	59.5±0.6 ^c
Kidney, pelvic, and heart fat (%)	2.8±0.2 ^c	3.9±0.3 ^b	3.7±0.2 ^b	3.8±0.2 ^b
Longissimus muscle area (cm ²)	68.2±2 ^b	58.8±2 ^c	58.4±2 ^c	55.5±2 ^d
Quality grade ^e	16.5±0.4 ^d	18.2±0.4 ^c	19.1±0.4 ^b	19.1±0.4 ^b

^a LL: large-mature weight late maturing; IL: intermediate-mature weight late maturing;

IE: intermediate-mature weight early maturing; SE: small-mature weight early maturing.

^{b, c, d} Row means with common superscripts do not differ ($p < 0.05$).

^e Quality grade (15=high standard, 16=low select, 17=average select, 18=high select 19=low choice, 20=average choice, 21=high choice).

from the pasture-developed system. Perhaps the feedlot steers in the Hunters et al. (2001) study had more opportunity to express their true growth and fattening potential when compared to the pasture steers. Our results, pertaining to LMA, are not in agreement with those of Wales et al. (1998) who reported no difference in LMA of six groups of steers, four of which were developed on pasture and two of which were developed in feedlot.

As expected in present study, mean QG was greater ($p < 0.05$) for carcasses from feedlot steers when compared to mean QG of carcasses from pasture steers (21.3±0.5 vs. 15.2±0.6). This difference in QG resulted from MARB advantages for carcasses from the feedlot-production system (739.9±32 vs. 355.3±41.5 for the feedlot- and pasture-production systems, respectively). Wales et al. (1998) also reported that feedlot-developed steers had higher MARB than pasture-developed steers. Robinson et al. (2001b) found that the primary differences in carcasses between feedlot-finished and pasture-developed steers were the fat and marbling content. In this study, the disadvantage in mean MARB for carcasses of pasture-developed steers likely resulted from two factors. First, across growth types (independent of size and rate of maturing), the more rapid growth rate of the feedlot steers likely predisposed them to increased fatness (Keele et al., 1992). Secondly, at similar growth rates, steers consuming a high-energy diet deposit fat at a higher rate than do steers grazing pasture or consuming a low-energy diet (Tudor, 1992; Sainz et al., 1995).

Presented in Table 2 are the least squares means and standard errors for DRESS, KPH, LMA and QG by beef growth type. The IL steers had the lowest ($p < 0.05$) mean DRESS and the LL steers had the greatest ($p < 0.05$) mean DRESS; however, there were no differences ($p > 0.05$) between IE and SE steers in mean DRESS. Even though there were significant differences in mean DRESS among beef growth types (means ranging from 59.0% to 60.3%), they were small and consistent with those reported in the literature. In addition to the 1.3% difference in mean DRESS yielding a higher proportion of body weight as carcasses for the LL steers, these steers also yielded a

higher proportion of carcasses as salable red meat due to larger ($p < 0.05$) longissimus muscle area, less ($p < 0.05$) external fat thickness (data not shown) and, ultimately, a superior ($p < 0.05$) yield grade than other growth types studied. Harrison et al. (1978) reported that differences existed in DRESS for cattle of different frame sizes and maturing rates.

In this study, mean carcass KPH was lowest ($p < 0.05$) for LL steers. There was no difference ($p > 0.05$) in mean carcass KPH for IL, IE and SE steers. McKeith et al. (1985) also found that large-framed steers yielded carcasses with less KPH than did medium-framed steers when fed for 224 d.

Carcasses from the LL steers had the largest ($p < 0.05$) LMA of any growth type. These results agree with those of Koch et al. (1976, 1982) who found that large-framed cattle tend to produce carcasses with larger LMA than do small- or medium-framed cattle when compared on a weight-constant or a time-on-feed constant basis. Likewise, McCarty et al. (1985) reported that carcasses from small-framed cattle have smaller ($p < 0.05$) LMA than do those from large-framed cattle when slaughtered at a time-on-feed-constant basis. In our study, part of the difference in muscle area among growth types may have been due to breed effects. Continental European breeds (Chianina and Charolais) represented in the LL steers have been reported to have larger muscle area than the British breeds (Red Poll, Hereford, Angus) represented in the IL, IE, and SE steers (Gregory et al., 1994). The reason may derive from their evolution. Breeds originating in western and central Europe were originally draft animals and early selection led to musculature specific to the function of work (Preston and Willis, 1979).

Most likely due to their superior leanness, carcasses from the LL steers had lower ($p < 0.05$) mean QG (low select) when compared to the QG of carcasses of all other beef growth types studied. Carcass QG of IE and SE steers were different ($p < 0.05$) from QG of carcasses of IL steers, which resulted from a range in mean MARB from 602.3±27 to 538±27. Mean QG for IE and SE steers were above the industry standard of low Choice. Koch et al. (1976) and

Table 3. Least squares means and standard errors for beef growth type×production system interaction for shrunk body weight, hot carcass weight, carcass external fat thickness, marbling score and yield grade

Trait	Production System	Growth type ^{ab}			
		LL n=79	IL n=88	IE n=87	SE n=81
Shrunk body weight (kg) (SBW)	Pasture	381.3±18.4 ^g	334.2±20.0 ^h	311.6±18.7 ⁱ	280.6±19.3 ^j
	Feedlot	521.9±15.8 ^d	475.6±14.1 ^e	479.3±15.4 ^e	433.7±14.9 ^f
Hot carcass weight (kg) (HCW)	Pasture	222.2±11.5 ^g	189.4±12.5 ^h	177.9±11.7 ⁱ	159.1±12.1 ^j
	Feedlot	325.3±9.9 ^d	290.8±8.9 ^e	297.1±9.6 ^e	268.9±9.3 ^f
External fat thickness (cm) (FAT)	Pasture	0.11±0.13 ^h	0.34±0.14 ^g	0.42±0.13 ^g	0.43±0.14 ^g
	Feedlot	0.92±0.1 ^f	1.29±0.1 ^e	1.63±0.1 ^d	1.59±0.1 ^d
Marbling Score ^c (MARB)	Pasture	271.8±41.3 ^j	336.5±44.8 ^h	401.2±41.9 ^g	411.9±43.3 ^g
	Feedlot	614.7±35.5 ^f	739.5±31.8 ^e	812.7±34.4 ^d	792.9±33.3 ^d
Yield grade (YG)	Pasture	1.8±0.2 ^h	2.4±0.3 ^g	2.4±0.2 ^g	2.4±0.2 ^g
	Feedlot	3.2±0.2 ^f	4.0±0.2 ^e	4.2±0.2 ^d	4.2±0.2 ^d

^a LL: large mature weight late maturing, IL: intermediate mature weight late maturing, IE: intermediate mature weight early maturing, SE: small mature weight early maturing.

^b 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.

^c Marbling score: 200=trace, 300=slight, 400=small, 500=modest, 600=moderate, 700=slightly abundant, 800=moderately abundant.

^{d, e, f, g, h, i, j} Trait means with different superscripts differ ($p < 0.05$).

McKeith et al. (1985) found that carcasses of large-framed cattle (i.e., Charolais, Simmental, Brahman, and Limousin) had lower MARB and inferior QG than carcasses of medium- and small-framed cattle (i.e., Angus, Hereford, Red Poll and Jersey).

The beef growth type × production system interaction was an important source of variation in SBW ($p=0.047$), HCW ($p=0.042$), FAT ($p=0.001$), YG ($p=0.001$) and MARB ($p=0.003$) (Table 3). The beef growth type×production system interaction resulted from differences in mean SBW among the four beef growth types between the two production systems (an interaction of magnitude). The ranking of the beef growth type×production-system combination means for SBW was LL feedlot>IL feedlot=IE feedlot>SE feedlot>LL pasture>IL pasture>IE pasture>SE pasture. There was no difference between the IE and the IL steers for mean SBW in the feedlot-production system, whereas the IL steers had a greater mean SBW than the IE steers in the pasture-production system. The LL steers had greater ($p < 0.05$) mean SBW in both production systems, but the difference between mean SBW of the LL-pasture and IL-pasture combinations was greater than the difference between mean SBW of the LL-feedlot and IL-feedlot combinations (47.1 vs. 42.6 kg, respectively). The difference between the IL-pasture and IE-pasture combinations for mean SBW was 22.6 kg while the difference between the IL-feedlot and IE-feedlot combinations for mean SBW was 3.7 kg, illustrating the difference in performance among these growth types in the two production systems. The SE steers had lesser ($p < 0.05$) mean SBW when compared to the other beef growth types in both production systems, but the difference between the IE-feedlot and SE-feedlot combinations for mean SBW (41.9 kg) and the IE-pasture and SE-pasture combinations

for mean SBW (31 kg) was 10.9 kg indicating that feedlot development was more effective than pasture development in exploiting the genetic potential for mature size and rate of maturing of the steers. Shrunk body 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×production system influenced HCW in a similar manner as with SBW, with differences in performance between beef growth types changing across production systems. This would be expected because of the high correlation ($r=0.83$; Preston and Willis, 1979) between live weight and carcass weight. Therefore, given ample pasture resources for cattle development, IL steers will produce heavier HCW than IE steers. In contrast, should a feedlot-production system be chosen, the IL and IE steers should produce carcasses of similar weight.

This interaction for FAT resulted from differences between mean FAT of the beef growth types across the two production systems. The numerical ranking of beef growth type by production-system subclasses for mean FAT was LL pasture<IL pasture=IE pasture=SE pasture<LL feedlot<IL feedlot<IE feedlot=SE feedlot. This interaction for FAT resulted from the change in relative difference in mean FAT of the IL growth type compared to the mean FAT of the IE and SE growth types between the two production systems. The IL-pasture steers were similar ($p > 0.05$) in mean FAT (0.34 cm) to the IE-pasture (0.42 cm) and the SE-pasture (0.43 cm) steers but the IL-feedlot steers had less ($p < 0.05$) mean FAT (1.29 cm) than the IE-feedlot (1.59 cm) steers

and the SE-feedlot steers (1.63 cm). Mean FAT of the IE-feedlot and the SE-feedlot combinations was similar ($p>0.05$) and mean FAT of the LE-pasture and SE-pasture combinations was similar ($p>0.05$).

Although SE steers should reach maturity first and have greater FAT, no differences ($p>0.05$) in mean FAT were observed between the IE-pasture steers and SE-pasture steers nor between steers in the IE-feedlot and SE-feedlot subclasses. Although at slaughter the feedlot steers were younger than pastured steers, the abundance of available nutrients allowed for fat deposition at an earlier chronological age. It has long been known that beef carcass fat deposition is directly related to the energy density of the diet (Berg and Butterfield, 1976; Berg and Walters, 1983). In our data, beef carcass fatness from the two production systems was directly related to the nutrients available for fattening among the beef growth types. There were no differences in mean FAT among the IL-pasture, IE-pasture, and SE-pasture subclasses although there were genetic differences with the potential to influence mature size and degree of maturity at harvest. This likely resulted from the inability of the pasture production system to provide the necessary nutrients to exploit differences for adipose deposition in these beef growth types.

The interaction of beef growth type \times production system in our study is consistent with the breed \times diet-energy density interaction reported by Gregory et al. (1994). Gregory et al. (1994) reported that when fed a higher energy diet, Angus, Hereford, Red Poll and MARC III (composite) breed groups had consistently more subcutaneous fat thickness compared to Charolais, Simmental, Braunvich, Gelbveih, Limousin and MARC I (composite) breed groups. In the study by Gregory et al. (1994), the Angus, Hereford, Red Poll and MARC III (composite) cattle were earlier maturing than were the Charolais, Simmental, Braunvich, Gelbveih, Limousin and MARC I (composite) cattle. The interaction means from the Gregory et al. (1994) study are not published, so no direct comparison can be made for FAT between the ranking of the growth types in our study and the ranking of the breed groups fed the two dietary energy levels in the 1994 study.

The LL steers in both production systems were less mature and, therefore, leaner (less fat) when compared to the other three growth types. However, it would be expected that with adequate time and nutrition, these steers would achieve similar external fat thickness only at larger body weights and with greater total energy inputs. Our findings are in agreement with the conclusions of Koch et al. (1976), Koch et al. (1982) and Koch et al. (1979) in that when cattle of diverse mature sizes (large vs. small) are compared at similar harvest weights, larger genotypes tend to be younger (because of faster growth rates), less mature (because of slower maturing rates and younger ages) and leaner

(because of tendency to fatten at relatively heavier weights).

The beef growth type \times production system interaction for MARB resulted in differences in intramuscular fat among the beef growth types between the two production systems. The ranking of the beef growth type \times production system combinations for mean MARB was IE feedlot=SE feedlot>IL feedlot>SE pasture=IE pasture>IL pasture>LL pasture. The IE-feedlot combination had the highest numerical value for mean MARB (812.7), however, there was no difference ($p>0.05$) in mean MARB of the IE-feedlot and SE-feedlot combinations. Koch et al. (1976) and McKeith et al. (1985) found that MARB from carcasses of large-framed cattle (i.e. Charolais, Simmental, Brahman and Limousin) were lower than those from carcasses harvested from medium-framed or small-framed cattle (i.e., Angus, Hereford, Red Poll and Jersey). Therefore, regardless of production system, IE and SE steers would be expected to produce carcasses with higher MARB than LL or IL steers. There was no difference ($p>0.05$) between the SE-pasture and IE-pasture combinations for mean MARB (10.6). Likewise there was no difference ($p>0.05$) between the SE-feedlot and IE-feedlot combinations for mean MARB (19.8). The IE-pasture and IL-pasture combinations differed in mean MARB (64.7) and the SE-feedlot and IE-feedlot combinations differed ($p<0.05$) in mean MARB by 53.4 points. The IL-pasture and LL-pasture combinations differed ($p<0.05$) in mean MARB (64.7), but the IL-feedlot and the LL-feedlot combinations differed ($p<0.05$) in mean MARB by a much larger amount (124.8). The LL-pasture combination had less ($p<0.05$) mean MARB than all other growth type \times production system subclasses. The pastured steers developed less MARB, although 180 days older in chronological age at harvest, than did the feedlot steers. Consequently, should a pasture-production system be chosen, carcasses for IE and SE steers would likely yield higher degrees of marbling than carcasses from LL or IL steers.

This interaction also resulted from differences in performance among beef growth types between the two production systems in mean YG. The ranking of the beef growth type \times production system interaction combinations for mean YG was LL pasture<IL pasture=IE pasture=SE pasture<LL feedlot=IL feedlot<IE feedlot<SE feedlot. The LL-pasture combination had the lowest ($p<0.05$) numerical value for YG when compared to all other growth type \times production system combinations. Although the pasture-developed steers were chronologically older than the feedlot-developed steers, the lower plane of nutrition for the pastured steers precluded both FAT and muscle development when compared to the higher plane of the feedlot steers. This agrees with previously published reports that conclude cutability is less (higher YG) for grain-fed versus forage-fed animals (Young and Kauffman, 1978;

Schroeder et al., 1980; Bidner et al., 1981). There was no difference ($p>0.05$) in the performance of steers in the IE-feedlot and SE-feedlot subclasses for YG. Longissimus muscle area (LMA) was not confounded by a growth type×production system interaction. However, the IE steers had slightly larger LMA (data not shown); this difference with regard to YG was negated by greater FAT. There was no difference ($p>0.05$) in the YG of the steers in the IL-pasture, IE-pasture and SE-pasture combinations, while the YG of steers in the IL-feedlot combination was less ($p<0.05$) than the YG of steers in the IE-feedlot and SE-feedlot combinations (4.0 vs. 4.2).

Obvious differences existed in the ability of the two production systems to supply nutrient resources for steer growth and development. This was shown in almost all of the interactions explained above. Adequate nutrients must be available to the animal for optimal growth and development. Obviously, if essential nutrients are limited, then growth and development will be limited. The extent of growth and development limitation generally varies in direct proportion to the degree that the nutrient is limited. Finally, differences in skeletal size, weight and composition between and within the beef growth types represented appear to be directly related to nutrient availability to express muscle and adipose tissue accretion.

IMPLICATIONS

Differences in mean SBW and HCW between IL- and IE-pasture combinations and IL- and IE-feedlot combinations illustrate the difference in performance among beef growth types in two development programs. Carcass fatness was directly related to available nutrients. Under a pasture production system, carcasses for IE and SE steers would likely yield higher degrees of marbling, although overall marbling advantages for feedlot-produced carcasses resulted in higher quality grades for feedlot vs. pasture steers. Growth type×pasture combinations had lower yield grades than the growth type×feedlot combinations reflecting the lower plane of nutrition for the pastured steers. Overall, feedlot development was more effective than pasture development in exploiting genetic potential for mature size and rate of maturing of steers. However, a need exists to synchronize production systems with germplasm resources regardless of development program.

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