BULL-STEER COMPARISONS FOR GROWTH AND CARCASS TRAITS

by

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Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Animal Science
(Breeding and Genetics)

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May, 1979

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ACKNOWLEDGMENTS

The author would like to express appreciation to the following people:

, major professor, for his guidance, collection of field data, and valuable suggestions on preparation of this manuscript.

for his guidance in the statistical and biological interpretations and for serving on the graduate committee.

and for their personal encouragement and willingness to serve on the graduate committee.

for his support in this endeavor.

and for their guidance in the statistical analyses for the author's investigation.

for typing a large part of this manuscript.

My wise, for helping every time and in every way.

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INTRODUCTION

The practice of castration of domestic animals is quite possibly as old as the domestication of animals itself and may have originated due to easier manageability of castrates and especially the greater ease of management of castrated animals in the presence of mature females (Turton, 1962). Castration not only modifies the body form but also the composition of the body. Castrated males are generally fatter, not only in terms of subcutaneous fat but also in terms of intramuscular and peritoneal fat deposition. In the uncastrated male there is a relatively greater development of the forequarter muscles and a greater longissimus muscle area on a per unit weight basis (Turton, 1962 and Hedrick, 1968).

Hedrick (1972), in a historical review of beef cattle type and body composition, pointed out that changes in desired type and body composition over the past 150 years are largely due to shifts in market demands. In earlier days, animal byproducts (e.g., tallow and hides) accounted for as much as 75% of the value of the live animal; whereas, animal byproducts now account for less than 10% of the live animal worth, with the dressed carcass comprising the remaining 90%. Certainly, in past years, castration of beef cattle has been compatible with market demands for beef tallow, but in light of current demands for leaner more efficient beef carcasses, a re-evaluation of the practice of castration is needed. The opening of the "Bullock" grade and the incorporation of the "yield grade" in the U.S.D.A. grading system in 1976 should be sufficient stimuli for the beef producer to take a serious look at beef produced by intact male beef cattle.

The study reported here is a multi-trait inquiry into the comparison of bulls and steers. The range of characteristics explored encompasses the total growth and carcass contrast between the intact and castrated male cattle. Throughout the remainder of this report intact and castrated males will at times be referred to as bulls and steers, respectively, and are considered to be two separate "sexes".

The objective of this study was to ascertain any existing differences, or lack of differences, between intact and castrated male beef cattle. This was evaluated over a period extending from preweaning through slaughter.

LITERATURE REVIEW

Much effort has been directed toward the evaluation of existing differences, or lack of differences, between bulls and steers. The academic interest in this topic spans a time period from the late 1940's to the present.

Age of Castration

In considering the comparison of or contrast between bulls and steers, it is necessary to examine if indeed the castrated males can be grouped into one sex classification. In that the age of castration can and does vary, one must examine any resulting differences. Klosterman et al. (1954) explored the differences between calves castrated at one month of age and those castrated at weaning. He found that the two steer groups did not differ significantly in rate or economy of gain in the feedlot, dressing percentage or carcass quality. The observation was made that the bull calves at weaning did exhibit a weight advantage; however, this advantage was diminished following castration and both steer groups were similar in gain before being started on feed. The point is made that it may be advantageous to breeders to wait until weaning time to select breeding stock due to greater accuracy of selection. Unfortunately, castration at heavier weights is more difficult and likely to be hazardous to the animal. In a similar study conducted by Wierbicki et al. (1955), involving calves castrated at one month of age and at weaning, nearly identical results were obtained in steer group differences for average daily gain, dressing percentage and carcass quality, with the differences being small and nonsignificant. Also, no significant differences were noted between the early and late castrates for live slaughter or carcass weights.

Glimp et al. (1971) examined calves castrated at birth and calves castrated at approximately 200 days of age (weaning) for a wide range of growth and carcass variables. Traits studied were carcass weight, ribeye area, backfat thickness, marbling score, Warner-Bratzler shear test, carcass grade, preweaning average daily gain, postweaning average daily gain, 14-months weight, dressing percentage, estimated cutability, and taste panel parameters. Differences for the majority of these traits were small and nonsignificant. Postweaning average daily gain differences between the two steer groups were significant, although quite small (.02 kg per day) with the advantage being with the later castrated individuals. However, the steer groups differed less than 1 kg at the end of the trial (weights being adjusted to a common age of approximately 14 months).

Carroll et al. (1963) conducted a study involving two pairs of Shorthorn male twins and two pairs of Friesian male twins. Within a pair, one twin was castrated at birth and the remaining twin was castrated at seven months of age. Weights were obtained for all animals at 4, 8, 28, 52, and 76 weeks of age with amount of weight gained for all possible periods of time being calculated. These researchers found that the early castrated animals were significantly lighter than later castrated animals at 28 weeks of age and that the later castrated animals had significantly greater weight gains for both the 4 to 28 week period and the 8 to 28 week period. However, following castration the weight advantage of the late castrates was dissipated, and the early castrates exhibited a significantly greater weight gain for the period of 28 to 52 weeks of age. By 76 weeks of age there did not exist any significant weight differences between the two castrate groups, and no significant differences were noted in weight gain for the 4 to 76 weeks period. Carroll et al. (1963) concluded that castration of calves at either one or seven months of age has little effect on the lifetime performance of animals slaughtered at approximately 18 months of age. They also determined that no significant difference existed between early and late castrates for either feed intake or feed efficiency. This result is in agreement with work by Champagne et al. (1964), where small and nonsignificant differences were noted for the amount of hay and concentrate consumed per pound of gain.

Most studies comparing age of castration deal with animals castrated at either one or seven months of age. Champagne et al. (1969) looked at four different ages of castration: at birth, two months, seven months, and nine months of age. The characteristics investigated were yearling weight, average daily gain (weaning to yearling), ribeye area, backfat thickness, marbling score, Warner-Bratzler shear test value, carcass grade score, estimated and actual cutability, feed efficiency and dressing percentage. Carcasses of the animals castrated at nine months of age had significantly less marbling than the carcasses of animals castrated at two and seven months of age but not less than those animals castrated at birth. As might be expected, the carcasses of two and seven month castrates graded higher than did the carcasses of individuals castrated at birth and at nine months of age. There existed a trend in this study for the ribeye area to increase as the age at castration increased; however, when the ribeye area was expressed on a per 100 kg body weight basis, these differences disappeared. The remainder of the differences in carcass characteristics and feedlot performance attributable to age at castration were small and nonsignificant.

The literature cited overwhelmingly indicates that differences in age at castration result in small and for the most part nonsignificant differences in growth, feedlot performance and carcass characteristics. When comparing "early castration" to "late castration", the effects of endogenous hormones in the intact males may account for a decided advantage in rate and economy of gain over the early castrates; however, this advantage is nullified by the setback to growth caused by the castration operation (Turton, 1962). Due to these considerations the remainder of this endeavor will ignore differing ages of castration when comparing steers with bulls, with the exception of descriptive purposes for some studies.

Growth Characteristics and Feed Efficiency

The percentage advantage or disadvantage of bulls compared to steers for weaning weight, yearling weight and postweaning average daily gain (ADG) is presented in table 1. The references have been numbered for convenience of discussion. Percentage advantage or disadvantage has been determined by the dividing of trait values

TABLE 1. PERCENT ADVANTAGE (+) OR DISADVANTAGE (-) FOR SELECTED GROWTH TRAITS OF BULLS (B) COMPARED TO STEERS (S)[a]

	Reference	No. of animals B	No. of animals S	Weaning weight (%)	Yearling weight (%)	Post-weaning ADG (%)	Pertinent remarks
1	Anderson, D. C. (1976)			2.17		14.30	
2	Arthaud et al. (1977)	16	16		- .32	3.10	- high energy ration
		16	16		3.85	5.99	- moderate energy ration
3	Bailey and Hironaka (1969)	18	18	4.0			- severe growth restrictions
4	Bailey et al. (1966)	39	38	1.10			
		19	19			12.26	- feedlot situation
		20	19			16.98	- feedlot situation
		20	19			20.31	- growing ration
5	Brinks et al. (1961)	1327	1032	12.92			
6	Carroll et al. (1975)	32	32	5.95			
7	Champagne et al. (1969)	20	10		8.58	18.27	- castrated at birth; gain period was from weaning to yearling
			10		7.47	17.14	- castrated at 2 mo
			10		11.62	21.78	- castrated at 7 mo
			10		12.55	25.51	- castrated at 9 mo
8	Cobic, T. (1968)	10	10	- .48	5.74	16.41	- received 1 kg conc/100 kg live wt; gain period of weaning to 15 mo
		10	10	4.25	8.10	2.18	- received 1 kg conc/day
9	Cundiff et al. (1966)	4665	2368	10.95			
10	Glimp et al. (1971)	20	20		1.31	6.25	- castrated at birth
			20		1.51	1.71	- castrated at weaning
11	Gortsema et al. (1974)	13	13	9.59			
12	Hedrick et al. (1969)	12	12		17.14		- bulls were sig. older by 14 days
		14	14		22.29		- random half of both sexes were implanted with 24 mg DES, bulls were sig. older by 14 days
13	Jacobs et al. (1975)[a]	29	36			18.75	

[a]In some instances the data from some references has been converted to a standardized tabular form.

-Continued-

TABLE 1 (continued). PERCENT ADVANTAGE (+) OR DISADVANTAGE (-) FOR SELECTED GROWTH TRAITS OF BULLS (B) COMPARED TO STEERS (S)[a]

Reference	No. of animals B	No. of animals S	Weaning weight (%)	Yearling weight (%)	Post-weaning ADG (%)	Pertinent remarks
14 Jacobs et al. (1975)[b]	40	39	.61	6.32	11.83	- weaning to yearling (gain periods)
	40	39			20.48	- yearling to slgt. (gain periods)
15 Jacobs et al. (1976)	20	20			18.69	
16 Jones et al. (1964)	10	10		5.29		
17 Klosterman et al. (1954 and 1958)	10	10			10.99	- castrated at 1 mo (fed for same length of time)
		10			10.99	- castrated at weaning (fed for same length of time)
	12	12			25.00	- castrated at 1 mo (fed to same wt to necessitate greater degree of finish on steers (S-247 days; B-210 days))
		12			23.60	- castrated at weaning (fed to same wt to necessitate greater degree of finish on steers (S-247 days; B-210 days))
18 Lewis et al. (1965)	8	8			59.38	- weaning to 122 days beyond weaning (gain periods)
	8	8			22.58	- 122 days beyond weaning to 152 days beyond weaning (gain periods)
19 Marlowe et al. (1965)	2856	8727	6.60			- Angus and Hereford calves, no creep
	1995	1079	9.70			- Angus and Hereford calves, creep fed
20 Tanner et al. (1970)	139	121	1.48	8.00	14.66	- ADG is for feedlot
21 Tylecek, J. (1957)	3	4			26.14	- feedlot position
22 Urick, J. J. (1972)	102	101	2.29		20.16	- feedlot situation
23 Warwick et al. (1970)	29	29			23.08	
24 Williams et al. (1975)	23	11		4.88	4.31	- high protein (12-14%), 90% conc. ration; steers implanted once w/12 mg DES and 112 days later received 24 mg DES, 1/2 bulls implanted twice with 48 mg DES
	22	12		12.87	15.45	- standard protein (10-12%), 90% conc. ration, same DES treatment as the above group
25 Wilson et al. (1974)	10	10	8.37	12.16	15.93	

[a] In some instances the data from some references has been converted to a standardized tabular form.

representing bulls by those values representing steers and re-expressing this calculation in percent advantage (positive values) or disadvantage (negative values) for bulls when compared to steers. Pertinent remarks have been made for greater clarity for some references.

Weaning weight and preweaning ADG. Tabulated values for weaning weight ranged from a -0.48% disadvantage to a 12.92% advantage for bulls. With the exception of Brinks et al. (1961) and Wilson et al. (1974), all values shown in table 1 are either nonsignificant or were not statistically tested, including the one nonsignificant negative value obtained by Cobic' et al. (1968). The mean percentage value is a 5.30% advantage for bulls for the thirteen references listed. This trend is in agreement with Klosterman et al. (1954) who reported that bull calves were heavier at weaning than were steer calves. Also, Burgess et al. (1954) and Marlowe and Gaines (1958) noted weight advantages of 9.3 kg and 7.3 kg, respectively, for bull calves compared to steer calves at weaning. An exhaustive inquiry conducted by Marlowe et al. (1965), involving 2,766 bull calves and 6,019 steer calves, is in agreement with these earlier studies. In that study bull calves were 10.4 kg (non-creep fed) to 15.9 kg (creep fed) heavier than steer calves at weaning. Also observed was a highly significant preweaning ADG (90 to 299 days of age) advantage of 6.6% and 9.7% for non-creep fed and creep fed bull calves, respectively, when compared to non-creep fed and creep fed steer calves. A significant bull calf advantage for preweaning ADG is in general agreement with most workers (Brinks et al., 1961; Cobic', 1968;

Klosterman et al., 1954; Marlowe et al., 1965; Wilson et al., 1974; and many others) but not with all workers (Bailey and Hironaka, 1969; Bailey et al., 1966a; Glimp et al., 1971; and Tanner et al., 1970).

Yearling weight and postweaning ADG. Tabulated values for percent advantage or disadvantage of bulls compared to steers for yearling weights ranged from a -0.32% disadvantage to a significant 22.29% advantage. Of those studies (presented in table 1) which subjected yearling weight differences between bulls and steers to statistical tests, four (12, 14, 19, and 24) found bulls to have a significant advantage over steers. Three other studies (2, 7, and 10) noted nonsignificant advantages plus one nonsignificant disadvantage, observed by Arthaud et al. (1977), for bulls compared to steers for yearling weight. The mean percentage value for the ten references listed is an 8.3% favoring of bulls over steers for yearling weights. Jacobs et al. (1975b) reported a 36.2 kg advantage favoring bulls over steers for 18 months weights ($P < .05$). This result is in partial agreement with work conducted by Arthaud et al. (1977) who noted a highly significant advantage of 38.0 kg for bulls over steers when both were fed a low energy ration. However, when both sexes were fed a high energy ration the difference of 17.0 kg, although still in favor of the bulls, was nonsignificant.

Turton (1962), in a survey of primarily European contributors involving nine studies, calculated an 18.3% advantage in postweaning ADG for bulls compared with steers. Hedrick (1968), in a literature review, noted an 18% advantage for bulls compared to steers for postweaning ADG averaged across 14 references. Similarly, Field (1971) in another literature review averaged across 15 references and obtained a 17% postweaning ADG advantage for bulls over steers. A mean value of 16.9% advantage for bulls over steers for postweaning ADG was obtained from the 17 references listed in table 1. The values range from a nonsignificant 1.71% advantage to a nonsignificant 59.83% advantage. Most of the studies surveyed involved feedlot situations with finishing rations. Bailey et al. (1966) and Jacobs et al. (1975b) reported on postweaning ADG for animals on growing rations and obtained values of a significant 20.31% advantage and a nonsignificant 11.83% advantage for bulls, respectively. Of the studies (presented in table 1) that conducted statistical tests on postweaning ADG several researchers (4, 7, 8, 10, 15, 14, 17, 19, 20, 22, and 24) found those differences to be significant, with values ranging from 6.25% to 26.14%; while others (2, 8, 10, 14, and 18) found the differences to be nonsignificant, with values ranging from a 1.71% to a 59.38% advantage for bulls. Nichols et al. (1964), in a study involving Holstein bull and steer calves, looked at differences between bulls and steers for postweaning ADG for a period from four months of age to one of two constant slaughter weights, either 363 kg or 454 kg. They noted a significant advantage for bulls compared to steers for ADG. Bulls were favored over steers by 11.37% and 6.45% for the slaughter weights of 363 kg and 454 kg, respectively. However, there was no statistically significant difference in ADG between the 363- and 454-kg groups.

Periodic growth rates. Glimp et al. (1971) looked at differences in growth between bulls and steers for five different periods in time as follows: 1) preweaning, 2) weaning to 70 days beyond weaning, 3) 70 to 140 days beyond weaning, 4) 140 to 210 days beyond weaning, and 5) weaning to 210 days beyond weaning. During the first three periods of the animal's life no significant differences existed between bulls and steers for ADG. However, the last 70 days of the 210 day feeding trial revealed significant differences between bulls and steers castrated at either birth or weaning and favored bulls by either 0.12 kg or 0.07 kg ADG, respectively. Bulls exhibited a significant 0.07 kg ADG advantage over steers castrated at birth and a nonsignificant 0.02 kg. ADG advantage over steers castrated at weaning for the entire postweaning growth period from weaning (approximately 200 days of age) to the end of the feeding trial (approximately 410 days of age).

In another study involving growth periods from birth to slaughter, Bailey and Hironaka (1969) examined ADG's for four growth periods. The periods were 1) birth to weaning (approximately 181 days of age, 2) 181 to 279 days of age (all animals were on pasture during a particularly harsh winter), 3) 279 to 384 days of age (all animals received a growing ration during this period), 4) 384 days of age to approximately 440 kg liveweight (all animals received a fattening ration during this period). Castration did not significantly affect growth rate in the first growth period nor in the second growth period (when there was no appreciable gain in either bulls or steers during the extreme cold of winter). Bulls did exhibit a significantly superior growth rate for the growing phase, however, of 0.23 and 0.27

kg in ADG, respectively, when compared to steers castrated at two and six months of age. A significant 0.17 kg and a significant 0.21 kg in ADG advantage was noted for the intact males when compared to the early castrates and to the late castrates during the fattening phase of the animal's life. When both the growth period and the fattening period were combined, bulls had significant advantages of 0.24 kg and 0.29 kg in ADG over the early and late castrates, respectively.

Cobic' (1968) compared the influence of castration on growth and the level of energy (high and moderate) received during the growth phase (up to 240 days of age) of the animal's life. Five growth periods were examined for differences in ADG between bulls and steers within levels of energy in growth rations. The growth periods were as follows: 1) birth to 120 days of age (steers castrated at 90 days of age), 2) 120 to 240 days of age (growth phase), 3) 240 days of age to slaughter age (a range of 480 to 520 days of age), 4) 120 days of age to slaughter age (includes both the growth and fattening phase), and 5) birth to slaughter age. Consideration of the entire life of the animals revealed a significant 7.4% superior growth rate for bulls receiving the high energy growing ration but a nonsignificant 3% advantage for bulls receiving the moderate energy growing ration. The only period exhibiting any statistically significant difference in growth rate between bulls and steers was during the fattening period in which bulls displayed a significant 16.4% advantage for the high energy growing ration treatment and a nonsignificant 2.2% advantage for the moderate energy growing ration treatment. Cobic' further noted that differences between bulls and steers were more strongly expressed in the animals that received the high energy growing ration.

Arthaud et al. (1977) examined ADG differences between bulls and steers when fed either a high or low energy finishing ration and fed to different ages (12, 15, 18, and 24 months of age). In actuality, the low energy rations were expected to produce U.S.D.A. choice steers for each slaughter age group, and the use of the high energy rations was an attempt to produce bull carcasses that would exhibit similar carcass quality traits as those of steers fed the low energy ration. These researchers found that, regardless of the age at slaughter, bulls gained more rapidly than steers and that this advantage tended to be greater for those animals receiving the higher energy fattening ration. They also reported that differences in carcass composition of bulls and steers tended to be greater for those animals fed the high energy ration, although not significantly so.

Feed intake and utilization. Bailey and Hironaka (1969) reported a significantly greater daily feed intake of 8% to 10% for bulls when compared to steers on a growing ration. This increase tended to persist when expressed on a metabolic weight basis by the magnitude of 3% to 4% greater intake for bulls. Bulls were also found to consume a significant 8% to 13% more fattening ration daily furing the finishing phase of the animal's life when slaughtered at a constant 440 kg live weight. This is in agreement with Allen (1966), at least in direction if not in magnitude, as he reported a 1.8% greater daily feed intake for bulls than for steers. Nichols et al. (1964), in their study involving Holstein-Friesian calves, observed a 6.3% and

8.5% less total feed intake for bulls than steers when slaughtered at 363 kg and 454 kg, respectively, and that steers consumed 7.6% more feed than bulls when averaged across both constant slaughter weights. When feed intake was expressed as TDN intake, they found similar results, as steers consumed 7.52% and 9.64% more total TDN than did bulls for the 363 kg and the 454 kg slaughter weight groups, respectively. Although there seems to be some disparity between the findings of Bailey and Hironaka (1969) and Nichols et al. (1964), these differences may be due to the basis on which feed intake is expressed. Both studies fed bulls and steers to a constant weight in the finishing phase, resulting in a shorter period of time required by bulls to reach the constant slaughter weight. Also, steers are expected to be fatter than bulls upon reaching a constant slaughter weight (which will be discussed later), resulting in a greater feed requirement to put on fat than is required for lean tissue. If feed intake is expressed on a daily basis, as was done by Bailey and Hironaka, the increased fatness of steers at slaughter may not be enough to offset the more rapid growth rate of bulls, and consequently, feed intake would be greater for the bulls. However, if feed intake is expressed as total feed consumed, the shorter time required by bulls to reach a prescribed weight, in spite of a superior growth rate, may not offset the loss in efficiency displayed by steers as they deposit fat rather than lean tissue in reaching the prescribed weight, thereby resulting in a greater feed intake by steers.

Possibly a more enlightening calculation is the amount of feed units required to bring about a unit of weight gain which will be referred to as feed conversion. Klosterman et al. (1954) noted that although bulls consumed slightly more corn and cob meal per head daily than did steers, they required considerably less feed to produce a standard unit of weight gain than did steers. The superiority of bulls for feed conversion has been demonstrated by numerous researchers (Allen, 1966; Bailey et al., 1966; Brannang, 1960; Jacobs et al., 1975b; Lewis et al., 1965; Warwick et al., 1970; Wilson et al., 1974; and Nichols et al., 1964). Other workers (Champagne et al., 1964 and Champagne et al., 1969) looked at the comparative feed conversion between bulls and steers for amount of hay and concentrate consumed and found that bulls required less of either hay or concentrate to produce a unit gain in body weight. Similarly, Nichols et al. (1964) expressed these feed components on a per unit gain in full live weight, shrunk live weight and chilled carcass weight and found without exception that bulls required less of both hay and concentrate than did steers. Bailey and Hironaka (1969) looked at differences between bulls and steers for feed conversion at different periods of time in the animal's life. They found that bulls required significantly less feed per kg of gain (8.46% and 10.19%) than did steers castrated at two and six months of age, respectively, during the period of 279 to 384 days of age. During the finishing phase, bulls required 2.99% less feed per kg of gain than did steers castrated at two months of age and 11.72% less than steers castrated at six months of age. Furthermore, Cobic' (1968), in his study involving four previously mentioned periods in the animal's life, observed an overall feed conversion advantage for bulls over steers. Also, more efficient utilization of both digestible crude protein and starch equivalents in their conversion to kg of live weight gain was noted for bulls.

Bidart et al. (1970) looked into the comparative energy utilization of bulls and steers. These workers were concerned primarily with two points of consideration: 1) maintenance requirements relative to growth rate and ultimately to body weight, and 2) energy utilization comparisons between bulls and steers expressed in terms of gain of body components. The study dealt with digestible energy (DE) units consumed which were associated with gains in edible product and carcass trim (estimated at 43% and 13% of live weight, respectively) and using an average live weight calculation as an indicator of maintenance requirements. They found, by partial regression techniques, that bulls and steers held at a constant 320 kg would be expected to consume 16.6 and 16.4 Mcal DE per day, respectively, to maintain that weight, excluding any gain in weight of either edible product or carcass trim. Also, bulls would be expected to consume 6.0 Mcal DE per kg of edible product as compared to a significantly different expected expenditure of 12.8 Mcal DE per kg edible product for steers. This difference was attributed to a higher proportion of fat (marbling) in the edible portion of steers, realizing that the energy expenditure for fat is greater than that for lean tissue. In conclusion, these workers determined that bulls produced 38% more edible product and 12% less trim per Mcal of DE consumed, even though bulls were heavier than steers during the feeding period. In agreement with this study, Almgreen _et al_. (1971) reported that bulls were more efficient in converting digestible energy to body weight than were steers.

Williams _et al_. (1975) conducted a study comparing a high crude protein ration (2 percentage units higher than the N.R.C. 1970 recommendations for steers and heifers) with a standard crude protein ration as they affected daily gains of bulls and diethylstilbestrol (DES) implanted steers. Their inquiry was based on the premise that the faster growth and increased lean tissue deposition of bulls might necessitate more ration protein than recommended for steers if bulls are to reach their maximum potential. However, no improvement in daily gain was observed for bulls receiving the high protein ration and only a slight increase in daily gain for steers was noted.

Feed efficiency can be defined as a unit of weight gain per unit of feed consumed. Several researchers have revealed a distinct advantage in feed efficiency for bulls over steers (Allen, 1966; Arthaud _et al_., 1969; Hedrick, 1968; and Prescott and Lamming, 1964).

Slaughter Traits

Comparisons between bulls and steers for slaughter age, slaughter weight, carcass weight, ribeye area, and backfat thickness are presented in table 2. Percent advantage or disadvantage in slaughter weight, carcass weight, ribeye area, and backfat thickness was determined by dividing the trait values representing bulls by those representing steers and expressing the ratio in percent advantage (positive values) or disadvantage (negative values) for bulls compared to steers. Actual average slaughter ages and weights for bulls and

TABLE 2. COMPARISON OF BULLS TO STEERS FOR SELECTED SLAUGHTER TRAITS[a]

	Reference	Animal number Bulls	Animal number Steers	Slaughter age Bulls	Slaughter age Steers	Slaughter weight Bulls	Slaughter weight Steers	Slaughter weight %[b]	Carcass weight (%)	Ribeye area (%)	Backfat thickness (%)	Pertinent remarks
	Constant Slaughter Ages											
1	Arthaud et al. (1969)	77	80	455-480	445-480				10.93	7.58	-35.71	- approx. equal nos. were represented for each sex in both early (445 da) and late (480 da) slgt. ages
2	Arthaud et al. (1977)	64	64			429	410	4.63	0.67		-27.27	- high energy ration, constant slaughter ages of 12, 15, 18 and 24 mo for both sexes
		64	64			432	387	11.63	14.65		-22.22	- moderate energy ration, constant slaughter ages of 12, 15, 18 and 24 mo for both sexes
3	Brannang, E. (1960)	11	10	763	763	483	451	7.10				
4	Brown et al. (1962)	11	11	397	397	330	308	7.07	9.13	19.99		
5	Carroll et al. (1975)	32	32	419	429	417	402	3.73	3.69	15.02	-14.29	- all steers were implanted with DES
6	Champagne et al. (1969)	20	10			419	386	8.55		18.99	-43.86	- castrated @ birth (slgt. @ comparable ages)
			10				390	7.44		18.32	-29.67	- castrated @ 2 mo (slgt. @ comparable ages)
			10				375	11.73		18.22	-35.35	- castrated @ 7 mo (slgt. @ comparable ages)
			10				372	12.63		31.18	-23.81	- castrated @ 9 mo (slgt. @ comparable ages)
7	Glimp et al. (1971)	20	20	427	427	470	464		8.60	25.25	-31.39	- castrated @ birth
			20		427		463		5.51	22.74	-33.80	- castrated @ weaning
8	Jacobs et al. (1977) &	16	19	559	555	464	426	8.92	3.16	14.15	-56.00	
	Jacobs et al. (1975)	17	17	589	585	503	454	10.79	9.09	18.35	-37.32	
9	Lewis et al. (1965)	8	8	397	397				2.62	4.47		
10	Prescott and Lamming (1964)			315	314	433	407	6.34	5.10		-70.41	
11	Tanner et al. (1970)	126	113	375	375				8.04	15.44	-25.52	
12	Watson, M. J. (1969)	10	10	300	300	195	185	5.13				

[a]In some instances the data from different references has been converted to a standardized tabular form.

[b]Percent values represent a ratio of bulls to steers, positive values for slaughter weight, carcass weight, and ribeye area represent a bull advantage. Negative values for backfat thickness represent a bull advantage.

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TABLE 2 (continued). COMPARISON OF BULLS TO STEERS FOR SELECTED SLAUGHTER TRAITS[a]

Reference	Animal number		Slaughter age		Slaughter weight			Carcass weight (%)	Ribeye area (%)	Backfat thickness (%)	Pertinent remarks
	Bulls	Steers	Bulls	Steers	Bulls	Steers	%[b]				
13 Williams et al. (1975)	23	22	392	392	467	445	4.88		26.17	-16.28	- protein (12-14%) all steers were implanted twice with 24 mg DES;
	11	12	392	392	485	430	12.87		24.67	+13.16	- protein (10-12%) 1/2 bulls implanted once with 48 mg DES
14 Wilson et al. (1974)	10	10	409	409	489	436	12.16	16.53	17.41	-33.33	
Constant Slaughter Weights											
15 Bailey and	18	18							6.03		- all animals were adj. to
Hironaka (1969)	18	18							6.37		250 kg carcass wt
16 Cobic, T. (1968)			480	512	477	472					- high energy ration
			514	520	472	463					- moderate energy ration
17 Gortsema et al. (1974)	13	13	476	506	467	457		0.17	23.85	-66.67	
18 Hedrick et al. (1969)	6	12	480	534	445	434			17.68	-33.33	
19 Jacobs et al. (1976)	20	20	439	469	480	463		2.81	13.16	-53.28	- 15% roughage, 85% concentrate, castrated @ 2-3 mo
20 Landon et al. (1978)	9	9	495	529	471	476			3.22	-47.32	- castrated @ birth Char x
		9		477		483			2.87	-29.76	- castrated @ weaning Her calves
	9	9	482	518	472	471			5.74	-31.58	- Hereford calves
21 Nichols et al.	15	15	303	337				0.13	13.80	-33.33	- slgt @ approx 363 kg
	15	15	395	420				-0.84	7.21	-21.05	- slgt @ approx 454 kg
22 Urick, J. J. (1972)	102	101							13.07	-44.90	- slgt @ comp. wt (454-476 kg)
23 Warwick et al. (1970)	29	29							9.92	-36.60	
Miscellaneous Slaughter Criteria											
24 Albaugh et al. (1975)	8	8	488-519	488-519	501	484		9.66	14.09	-16.15	- half of bulls and steers implanted with DES
25 Anderson, D. C. (1976)	62	73			503.5	470.4	7.04		18.24	-28.65	- slgt @504-522 kg or low choice whichever came first
26 Jacobs et al. (1975)	29	36	467	506	466	438	6.53	6.53			

[a]In some instances the data from different references has been converted to a standardized tabular form.
[b]Percent values represent a ratio of bulls to steers, positive values for slaughter weight, carcass weight, and ribeye area represent a bull advantage. Negative values for backfat thickness represents a bull advantage.

steers are given, and references are grouped according to constant slaughter ages, constant slaughter weights and miscellaneous slaughter criteria for the sake of clarity. The references have been numbered for convenience of discussion. Pertinent remarks have been made for some references when necessary for clarification.

Slaughter ages for bulls and steers are presented in table 2 for all studies that gave the ages of the two sexes at slaughter. For convenience and ease of comparisons, they have been divided into two groups: 1) those studies slaughtering animals at a constant weight (16, 17, 18, 19, 20, and 21); and 2) those slaughtered at a constant age (1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, and 14). In the first group, with the exception of Landon et al. (1978), all studies cited indicated that bulls would reach a constant weight in less time than would steers. Landon et al. (1978) fed both bulls and steers to a constant slaughter weight of 477 kg and found Charolais x Hereford steer calves (castrated at weaning) required 18 days less time than did the intact males of the same breeding and five days less time than Hereford bulls. The range of the studies listed ran from a 3.77% more time required by bulls to a 10.11% less time required by bulls to reach a constant slaughter weight than that required by steers. In the studies listed, bulls and steers averaged 452 and 482 days of age at slaughter, respectively. In other words, bulls required an average of 5.5% less time than did steers to reach a desired slaughter weight.

Among those studies cited in table 2 in which animals were fed to a constant slaughter age (1, 3, 4, 5, 6, 8, 10, 12, 13, and 14), several found bulls to be significantly heavier at slaughter than steers (1, 8, 10, and 14). Percentage values ranged from a 3.73% to a 12.87% advantage in slaughter weight for bulls compared to steers of approximately the same age. Bulls averaged 8.48% greater slaughter weights than steers of comparable ages for the ten references considered.

Likewise, carcass weight (presented in table 2) will be considered in two parts: 1) those studies slaughtering animals at constant ages (1, 2, 4, 5, 7, 8, 9, 10, 11, and 14); and 2) those slaughtering animals at constant weights (17, 19, and 21). Although some researchers (1, 7, 11, and 14) noted significantly greater carcass weights for bulls than for steers of comparable age, several others (1, 4, 5, 7, 8, 9, and 10) found this advantage to ge nonsignificant. The range in values are from a nonsignificant 0.67% to a significant 16.53% carcass weight advantage for bulls, with a mean value of 7.52% advantage for bulls among the ten references considered. It would be of some interest also to see if bulls would exhibit greater carcass weights than steers if both sexes were slaughtered at approximately the same live weight. The differences in carcass weights between bulls and steers were small and nonsignificant for the three references listed in table 2. Possibly a more revealing look at differences between bull and steer carcass weights would be to express it in terms of carcass weight per day of age. Carroll _et al_. (1963); Gortsema _et al_. (1974); Tanner _et al_. (1970); and Wilson _et al_. (1974) have all reported greater carcass weights per day of age ($P < .05$) for bulls than for steers, with values ranging from a 0.03 to 0.097 kg per day advantage for bulls. Several other workers have reported superior carcass weights per day of age for bulls compared to steers, although differences were nonsignificant (Arthaud et al., 1977; Jacobs et al., 1975a,b; Jones et al., 1964; Landon et al., 1978; and Urick, 1972). Landon et al. (1978) reported a .03 kg and a .01 kg greater carcass weight per day of age for Charolais x Hereford steers castrated at weaning than for bulls of the same breeding or for Hereford bulls, respectively. With the exception of their report, the literature overwhelmingly supports a carcass weight per day of age advantage for bulls, which is reasonable to expect in view of the previously discussed superior growth rate of bulls.

Ribeye area, as was carcass weight, will first be considered for bulls and steers slaughtered at a constant age and, secondly, for those animals slaughtered at a constant weight, as presented in table 2. Of those studies concerning ribeye comparisons for bulls and steers slaughtered at the same age (2, 4, 5, 6, 7, 8, 9, 11, 13, and 14), the majority found bulls to have significantly greater ribeye areas than steers (4, 5, 6, 7, 8, 11, and 14). This bull advantage ranged from 4.47% to a highly significant 31.18% value, with a mean advantage of 7.52% for the ten references listed. Similarly, of those studies that fed animals to a constant weight (15, 17, 18, 19, 20, 21, 22, and 23), several found bulls to have significantly greater ribeye areas than steers (17, 18, 19, 21, and 23). The mean advantage for bulls was 10.24% for the eight references considered, with a range of 2.87% to a significant 23.85% advantage for bulls compared to steers. These results are in agreement with those reported by Hedrick (1968) in a review of literature involving ten references. Another way to express ribeye area is to divide it by a unit of body weight (e.g., ribeye area per 100 kg live body weight). Nichols et al. (1964) observed that bulls maintain superiority of ribeye area when expressed on a per unit of body weight basis ($P < .05$). However, these researchers also noted a significantly greater ribeye area for animals slaughtered at 454 kg weight than for those slaughtered at 363 kg weight, suggesting a need for any sex differences in ribeye area to either be adjusted to a constant weight or expressed as a ratio to body weight. Anderson (1976) and Tanner et al. (1970) both noted greater ribeye areas per unit of body weight for bulls than for steers. This leads one to the conclusion that not only do bulls attain heavier weights quicker but also that there is enhanced growth of muscle tissue independent of this superior growth rate.

Kidney fat, conversely to ribeye area, is greater in steers, whether expressed in weight units (Arthaud et al., 1969) or as a percentage of carcass weight (Klosterman et al., 1954 and 1958). Prescott and Lamming (1964) and Tanner et al. (1970), respectively, noted percent kidney weight (percent of carcass weight) differences between bulls and steers of 1.31% ($P < .01$) and 0.90% ($P < .05$) for animals slaughtered at the same age. Warwick et al. (1970) noted a highly significant 0.57 percent kidney weight difference between bulls and steers slaughtered at essentially the same weight.

A review of literature by Hedrick (1968) noted a greater degree of finish, both internally and externally, for steers than for bulls.

Also, Field (1971) reported mean fat thicknesses over the longissimus muscle of 9.3 and 14.3 mm for bulls and steers, respectively, averaged over twelve references. Backfat thickness is presented in table 2 and will be discussed in terms of those animals slaughtered at a constant age and those animals slaughtered at a constant weight. Negative percentage values in the table represent the degree to which bulls are less fat than steers and is to be considered an advantage rather than a disadvantage. Among the ten references (1, 2, 5, 6, 7, 8, 10, 11, 13, and 14) which slaughtered bulls and steers at a constant age, eight (1, 5, 6, 7, 8, 10, 11, and 14) found bulls to display significantly less fat cover than steers. Williams _et al_. (1975) reported one case where bulls exhibited more backfat than steers, but both bulls and steers were implanted with DES. The range in backfat thickness was from a 13.16% more fat cover in bulls to a significant 70.41% less fat cover in bulls. Bulls averaged a 30.77% less backfat than steers for the ten references listed. Similar results were obtained from the seven references (17, 18, 19, 20, 21, 22, and 23) which slaughtered animals at a constant weight, all of which reported significantly less fat cover in bulls than in steers. Values ranged from 21.05% to 66.67% significantly less backfat thickness in bulls, with a mean value of 39.78% less.

The literature, with few exceptions, supports the claim that bulls attain heavier slaughter weights than steers at comparable ages and furthermore that bulls reach a comparable target weight quicker than steers. Also, bulls appear to produce carcasses that generally exhibit greater ribeye areas and less fat, both internally and externally, than steer carcasses of either comparable age or weight.

Carcass Quantity and Quality

A comparison of bulls to steers for yield of lean cuts, marbling scores, carcass quality grades, and Warner-Bratzler shear tests (as an indicator of tenderness) is presented in table 3. As in preceding tables, the references are grouped according to slaughter criteria and numbered for convenience of discussion with pertinent remarks being made for greater clarity of particular studies.

In a review of primarily European literature concerned with comparisons between bulls and steers, Turton (1962) noted a higher dressing percent for bulls in five of the six references cited. However, all differences were less than 2 percentage points apart. Hedrick (1968) conducted a literature investigation and determined that no conclusions could be drawn about dressing percent differences between bulls and steers but does state that other factors influence dressing percent to a greater extent than does sex. Field (1971) pointed out that although it is reasonable to expect bulls to have lower dressing percents than steers due to less fat in bulls, such is not necessarily the case. Of the fourteen references he cited, eight showed bulls to exceed steers in dressing percent while the remainder of the references found the opposite to be true. This trend seems to be the case throughout the literature as several references (Anderson, 1976; Dahl, 1962; Glimp et al., 1971; Jacobs et al., 1975a; Prescott and Lamming, 1964; and Wilson et al., 1964) have reported bulls having higher dressing percents than steers, while others (Cahill et al., 1956; Carroll et al., 1975; Gortsema et al., 1974; Jacobs et al.,

TABLE 3. COMPARISON OF BULLS TO STEERS FOR SELECTED CARCASS QUANTITY AND QUALITY TRAITS[a]

Reference	Animal numbers		Slaughter age		Tenderness (%)[b]	Marbling scores[c]		Carcass quality grade[d]		Yield of lean cuts (%)	Pertinent remarks
	Bulls	Steers	Bulls	Steers		Bulls	Steers	Bulls	Steers		
<u>Constant Slaughter Ages</u>											
1 Arthaud et al. (1969)	77	80	445-480	445-480	26.00	21.0	25.5	10	11-12		- traits adj. to a 235 kg carcass wt
2 Arthaud et al. (1977)	64	64			25.42	11.8	16.0	11	13		- high energy ration, constant slgt ages of 12, 15, 18 and 24 mo for both sexes
	64	64			4.83	10.6	14.4	11	12		- moderate energy ration, constant slgt ages of 12, 15, 18 and 24 mo for both sexes
3 Brown et al. (1962)	11	11	397	397						1.75	
4 Carroll et al. (1975)	32	32	419	429	10.00	11.0	14.0	11	13		- all steers were implanted with DES
5 Champagne et al. (1969)	20	10			- 1.47	8.3	10.4	9	11	4.57A 9.28E	- castrated @ birth
		10			11.98		11.2		11	3.47A 9.36E	- castrated @ 2 mo
		10			9.54		11.4		11	3.47A 8.01E	- castrated @ 7 mo slgt. @ comparable ages
		10			10.14		9.8		10	2.75A 7.65E	- castrated @ 9 mo
6 Glimp et al. (1971)	20	20	427	427	15.07	8.5	13.0	8	11	6.53	- castrated @ birth
		20		427	26.89		13.0		11	6.05	- castrated @ weaning
7 Hunsley et al. (1971)	10	10			19.76						
8 Jacobs et al. (1977) &	16	19	559	555	17.89	12.0	18.0	11-12	13-14	17.33A	- A = actual
(1975)	17	17	589	585	11.94	9.0	15.0	10-11	13	7.23E	E = estimated
9 Klosterman et al. (1954)	10	10						11	14		
& (1958)		10							14-15		
10 Lewis et al. (1965)	8	8	397	397				10	11		
11 Reagan et al. (1971)	20	23	385	385	40.00			11-12	11-12		- Angus, Hereford and Brown Swiss breeding
	23	24	484	484	9.23			7	10		- Charolais and Santa Gertrudis crosses

[a] In some instances the data from different references has been converted to a standardized tabular form.
[b] Percent force required to shear (Warner-Bratzler) through a standardized core of bull beef relative to the force required for steer beef. An increase in force relates to a decrease in tenderness.
[c] 2-3 = practically devoid; 4-6 = traces; 7-10 = slight; 11-13 = small; 14-16 = modest; 17-19 = moderate; 20-22 = slightly abundant; 23-25 = moderately abundant; 26-28 = abundant.
[d] 6-8 = standard; 9-11 = good; 12-14 = choice; 15-17 = prime.

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TABLE 3 (continued). COMPARISON OF BULLS TO STEERS FOR SELECTED CARCASS QUANTITY AND QUALITY TRAITS[a]

Reference	Animal numbers		Slaughter age		Tenderness (%)[b]	Marbling scores[c]		Carcass quality grade[d]		Yield of lean cuts (%)	Pertinent remarks	
	Bulls	Steers	Bulls	Steers		Bulls	Steers	Bulls	Steers			
12 Tanner <u>et al</u>. (1970)	126	113	375	375		6.0	12.0			5.31		
13 Watson, M. J. (1969)	10	10	300	300	14.84							
14 Williams <u>et al</u>. (1975)	23	11	392	392		6.0	7.0	11	11		- protein (12-14%)	all steers were implanted twice with 24 mg DES; 1/2 bulls implanted once with 48 mg DES
	22	12	392	392		6.0	8.5	11	11		- protein (10-12%)	
15 Wilson <u>et al</u>. (1974)	10	10	409	409		8.5	10.0			0.97	- Holstein calves	
<u>Constant Slaughter Weight</u>												
16 Anderson, D. C. (1976)	62	73				10.0	12.0	11	12		- slaughtered @ comparable ages	
17 Gortsema <u>et al</u>. (1974)	13	13	476	506	38.51	10.0	15.0	11	12-13			
18 Hedrick <u>et al</u>. (1969)	6	12	480	534	- 9.36	6.0	11.0					
19 Jacobs <u>et al</u>. (1976)	20	20	439	469		10.0	15.0	11	13			
20 Landon <u>et al</u>. (1978)	9	9	495	529		6.0	12.0	10	13		- castrated @ birth	Charolais x Hereford calves
		9		477			10.0		12		- castrated @ weaning	
	9	9	482	518		8.5	10.0	10	12		- Hereford calves	
21 Nichols <u>et al</u>.	15	15	303	337		2.0	8.0	7	7		- Holstein-Friesian calves slgt. at 363 kg	
	15	15	395	420		5.0	10.0	7-8	7		- Holstein-Friesian calves slgt. at 454 kg	
22 Urick, J. J. (1972)	102	101						10	11-12	6.50	- slgt @ comp wts (454-476 kg)	
23 Warwick <u>et al</u>. (1970)	18	18			3.03	25.0	28.0	13	14-15		- involves 18 pairs of monozygotic twins where one twin was left as a bull and the other twin was castrated @ 5 mo of age	
24 Wierbicki <u>et al</u>. (1955)	10	10						11	14-15		- early castrates	
		10							14		- late castrates	
	12	12						9	13		- early castrates	
		12							13		- late castrates	

[a]In some instances the data from different references has been converted to a standardized tabular form.
[b]Percent force required to shear (Warner-Bratzler) through a standardized core of bull beef relative to the force required for steer beef. An increase in force relates to a decrease in tenderness.
[c]2-3 = practically devoid; 4-6 = traces; 7-10 = slight; 11-13 = small; 14-16 = modest; 17-19 = moderate; 20-22 = slightly abundant; 23-25 = moderately abundant; 26-28 = abundant.
[d]6-8 = standard; 9-11 = good; 12-14 = choice; 15-17 = prime.

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TABLE 3 (continued). COMPARISON OF BULLS TO STEERS FOR SELECTED CARCASS QUANTITY AND QUALITY TRAITS[a]

Reference	Animal numbers		Slaughter age		Tender- ness (%)[b]	Marbling scores[c]		Carcass quality grade[d]		Yield of lean cuts (%)	Pertinent remarks
	Bulls	Steers	Bulls	Steers		Bulls	Steers	Bulls	Steers		
Miscellaneous Slaughter Criteria											
25 Albaugh *et al.* (1975)	8	8	501	484	4.48	8.5	12.0	10	11		- 1/2 bulls and steers implanted with DES
26 Cahill *et al.* (1956)	10	10						10	13		- both sexes implanted twice with 84 mg DES
	10	10						11	12		
27 Jacobs *et al.* (1975)	29	36	467	506		12.0	15.0				

[a]In some instances the data from different references has been converted to a standardized tabular form.
[b]Percent force required to shear (Warner-Bratzler) through a standardized core of bull beef relative to the force required for steer beef. An increase in force relates to a decrease in tenderness.
[c]2-3 = practically devoid; 4-6 = traces; 7-10 = slight; 11-13 = small; 14-16 = modest; 17-19 = moderate; 20-22 = slightly abundant; 23-25 = moderately abundant; 26-28 = abundant.
[d]6-8 = standard; 9-11 = good; 12-14 = choice; 15-17 = prime.

1975b; Jacobs et al., 1976; Urick, 1972; and Wilson et al., 1969) observed the converse.

Throughout the literature, bulls have repeatedly exhibited a distinct advantage in carcass cutability when compared to steers regardless of how cutability is defined (Field, 1971, and Hedrick, 1968). Yield of lean cuts is presented in table 3 in terms of percent advantage for bulls. In all of the studies cited for yield of lean cuts, animals were slaughtered at a constant age, with the exception of Urick (1972), who found that bulls yielded 6.50% more lean cuts than did steers of comparable slaughter weights. Of the remaining references, most (5, 6, 8, and 12) reported bull carcasses yielding significantly more lean cuts than steer carcasses. It is interesting to note the difference in bull-steer comparisons between actual and estimated cutability. Although Champagne et al. (1969) observed highly significant differences favoring bulls over steers for yield of lean cuts, regardless if actual or estimated, these differences were maximized when yield was estimated and suggest a possible need for the re-evaluation of estimation procedures.

Carcass yield grades mirror the superiority of bulls for yield of lean cuts. Studies conducted by Anderson (1976) and Gortsema et al. (1974) revealed that bulls exhibited yield grades of 0.95 and 2.22 units ($P < .05$) less than steers, respectively, when both sexes were slaughtered at a common weight. Jacobs et al. (1975 and 1977) reported yield grades for bulls of 1.20 to 1.60 units ($P < .01$) less than those for steers when both sexes were slaughtered at a common age.

In the previous discussions it was pointed out that bulls produce leaner, more muscular carcasses of greater quantity than steers of either similar age or weight. Also, bulls exhibit less fat both internally and externally. However, the question of carcass quality now becomes paramount.

In the literature review conducted by Field (1971), it was found that marbling scores (as an indicator of quality) were one to two degrees higher in steers than in bulls for the eight references cited. Marbling scores for steers ranged from "slight" to "moderate"; whereas, for bulls the range was from "traces" to "modest". Marbling scores for bulls and steers are presented in table 3. Scores listed are conversions of actual scores into standardized scores for coherent discussion of the trait and may, therefore, lack accuracy in magnitude of bull-steer differences, but they adhere strictly to the direction of these differences. Of the references listed in which the animals were slaughtered at a constant age (1, 2, 4, 5, 6, 8, 12, 14, and 15), several reported that steers displayed significantly more marbling (2, 4, 5, 6, 8, and 12). As might be expected, those references concerned with animals slaughtered at a constant weight (16, 17, 18, 19, 20, 21, and 23) also had many reports of bulls exhibiting significantly less marbling than did steers (17, 18, 19, 20, 21, and 23). Regardless of slaughter criteria, bulls displayed a mean marbling score of "slight" compared to that of "small (+)" for steers when averaged across the sixteen references.

Carcass quality grades listed in table 3 are also conversions of actual grades and limitations inherent to the converted marbling scores also apply to these quality grades. Mean values were essentially equivalent for bulls and steers regardless of the slaughter criteria with carcass quality grades of "good" and "good (+)" for bulls and "choice (-)" for steers. Of the 18 references giving quality grades, most reported steers to grade significantly higher than bulls (2, 4, 5, 6, 8, 11, 17, 19, 20, and 23).

The Warner-Bratzler shear test is a measure of tenderness in that it is the measure of the amount of force necessary to cut (shear) through a standardized core of lean meat. Tenderness values presented in table 3 are actually the calculations of Warner-Bratzler shear forces for bulls divided by those for steers and expressed in terms of percent additional force required. Positive values are to be considered as percent additional force required to shear through a core of bull meat as compared to that necessary for steer meat with the opposite being true for negative values. The majority of the references listed slaughtered animals at comparable ages (1, 2, 4, 5, 6, 7, 8, 10, 11, and 13) of which five reported significantly greater Warner-Bratzler shear forces for bulls than for steers (2, 6, 7, 8, and 11). With the exception of Champagne _et al_. (1969), all references indicated bulls required more force than steers. These researchers found steers castrated at birth and slaughtered at the same age as their intact male counterparts were slightly tougher but not significantly so. Percentage values ranged from 1.47% more force required by steers to a significant 40.0% more force required by bulls. Mean percentage value averaged across 10 references was 15.75% more force for the Warner-Bratzler device to shear through a cube of bull beef. Three experiments (17, 18, and 23) slaughtered bulls at constant weights, one of which (17) reported bulls to be significantly tougher by Warner-Bratzler shear test, while the two remaining references noted nonsignificant differences between bulls and steers. Hedrick et al. (1969) reported 534-day-old steers to be tougher than 480-day-old bulls, but not significantly so. The mean tenderness value for these three references is a 10.73% more shear force required for bulls than for steers. Both these mean values are in general agreement with Field (1971), who reported bull beef to be less tender than steer meat for all seven references that he cited. Several workers have indicated that the age of the animal at slaughter contributes the most to tenderness and that sex of the animal is less important than age (Reagan et al., 1971; Warwick et al., 1970; and Wierbicki et al., 1955). Other workers have alluded to the chronological age of the animal having a greater adverse effect on tenderness of steaks from bulls than from steers. Arthaud et al. (1977), in a study which involved four slaughter ages of 12, 15, 18, and 24 months, failed to find any decrease in tenderness with increasing age or any decrease in tenderness peculiar to bulls with increasing age at slaughter.

Tenderness, as determined by taste panel, is very similar to those reports on tenderness determined by Warner-Bratzler shear test. However, most researchers found that the difference between bulls and steers for taste panel tenderness determination was small and nonsignificant (Albaugh et al., 1975; Bailey et al., 1966; Brown et al., 1962; Cahill et al., 1956; Glimp et al., 1971; Gortsema et al., 1974;

Jacobs et al., 1975b; Jones et al., 1964; Warwick et al., 1970; and Wilson et al., 1974). Although other workers noted steer meat to be significantly more tender than bull meat (Arthaud et al., 1977; Hedrick et al., 1969; Hunsley et al., 1971; and Watson, 1969), the vast majority of the references cited here indicated that bull meat was acceptably tender. Wierbicki et al. (1955) looked into the correlations between taste panel tenderness (after a 15-day aging period) and marbling and carcass quality grade. These workers observed that when bulls and steers were considered together a relationship between marbling and tenderness did exist, but when both sexes were studied independently, this relationship disappears. They concluded that marbling may indeed be an indicator of sex rather than tenderness of meat. Carcass quality grade tended to correlate rather well with tenderness when both sexes were considered jointly, but a bias did exist against bulls for carcass quality grade. When bulls and steers were considered separately, the bias was removed, and the correlation between tenderness and quality grade disappeared. Francis et al. (1977) compared marbling scores of "slight" and "modest" as they affected tenderness. These workers found that tenderness was not affected by either of these scores.

Possibly the best indicator of carcass quality is an overall acceptance rating determined by taste panels. Although one study (Wilson et al., 1974) did report a significant advantage for bulls over steers for overall acceptability, others (Reagan et al., 1971) have reported a significant favoring of steer meat. However, most investigations report small and nonsignificant favoring for steer meat when compared to bull meat (Glimp et al., 1971; Gortsema et al., 1974; Jacobs et al., 1975b; and Lewis et al., 1965).

OBJECTIVES

The general objective of this study was to explore existing differences, or lack of differences, between intact and castrated male beef cattle for a wide range of growth and carcass traits. Specifically, bulls and steers were compared at weaning, approximately 12 months of age, approximately 18 months of age, and at slaughter.

MATERIALS AND METHODS

Data for this study were collected at the Bland Correctional Center as a part of a long-range cooperative cattle breeding research project between the Animal Science Department of Virginia Polytechnic Institute and State University, Blacksburg, and five correctional centers under the Adult Division of the Virginia Department of Corrections, Richmond.

The Center is located in the Allegheny Mountains about 75 miles west of Roanoke, Virginia, on Virginia highway 42 and 15 miles east of Bland, Virginia. Pastures on the farm consist primarily of bluegrass and white clover and are grazed in the spring, summer, and fall of the year. The cows are wintered on corn silage and hay which is largely comprised of pasture clippings or orchard grass with some red clover. The cows maintain sufficient flesh and healthy condition on this feeding regime in both the summer and winter.

The cattle used for these comparisons were the male offspring of the phase I (sire breed evaluation) and phase II (cow breed evaluation) cows in the long range study. Phase II cows were produced from phase I matings, except that the 21 Charolais x Holstein cows were produced in other correctional farm herds. All phase I cattle were sired by Charolais, Hereford and Simmental bulls and out of Hereford cows except for the straight Angus which were out of a small straightbred Angus control herd. The phase II cattle were out of Angus, Hereford, Charolais x Hereford, Charolais x Holstein and Simmental x

Hereford cows sired by Angus, Charolais, Hereford and Simmental bulls. Phase I cattle were weaned during the years of 1970 through 1975, and the phase II cattle were weaned during 1972 through 1977. A detailed explanation of the mating scheme that produced the cattle used in this study can be found in the published reports by Marlowe and Saunders (1976) and Marlowe et al. (1979).

Preweaning Management of Calves

All male calves were left intact during the first two calf crops (1970 and 1971). A random half of all male calves in each breed group in the 1972 and 1973 calf crops were castrated at two to three months of age. All male calves produced in the 1974 and 1975 calf crop were also castrated at two to three months of age. Heifers were represented in all six years. The number of calves represented by each sex group within each year is presented in Appendix table 3. Split calving seasons were employed to provide a year round supply of beef to the prison cafeteria. Calves were weaned at two or three times during the year, necessitated by the split calving seasons, so that weaning ages were as near to seven months of age as possible. Weaning weights (WWT), preweaning average daily gains (WADG), weaning condition scores (WCOND), and weaning grades (WGR) were obtained on all animals.

Postweaning Management of Calves

Bull and steer calves were fed together on corn silage and hay, supplemented with .65 to .90 kg of protein supplement per head daily during the first winter. On or about March 1 of each year the larger bulls and/or steers were placed in separate feeding areas and were given a full feed of silage supplemented daily with 1 kg of concentrate per 100 kg of body weight until slaughtered. The concentrate ration was composed of 75% ground corn and 25% soybean oil meal. The remaining male cattle were grazed until they were pulled out for their short feeding period before slaughter. Animals were slaughtered as needed by the prison cafeteria generally within the age range of 18 to 27 months. The average slaughter age was 19.5 months. As additional animals were needed, they were pulled off pasture and placed on feed, so that they were on feed 60 to 90 days prior to slaughter.

Heifer calves were treated the same as the bulls and steers except that those selected for the breeding program were not placed on the 60 to 90 day finishing regime.

Data were collected at two times during the postweaning period, at approximately 12 and 18 months of age. Growth variables, measured or calculated, were yearling weight (YWT), yearling average daily gain (YADG), yearling weight per day of age (YWPDA), yearling condition score (YCOND), yearling grade (YGR), 18-months weight (FWT), 18-months average daily gain (FADG), 18-months weight per day of age (FWPDA), 18-months condition score (FCOND), and 18-months grade (FGR).

Carcass Data

Animals were slaughtered every two weeks or as beef was needed to feed the inmates. Slaughter groups were usually comprised of six to ten head of animals with an attempt to have all breeds represented in each kill. Slaughter and processing of the carcasses were performed at the Center's slaughter facility. Carcass traits recorded at the slaughter plant were live slaughter weight (LW), carcass weight (CW), kidney and kidney fat weight (KWT), ribeye area (RA), backfat thickness (BF), marbling score (MAR), and tenderness measurement with Armours' Tenderometer (ATEN). Additional variables were then calculated from these carcass traits as follows: carcass weight per day of age (CWPDA), percent kidney and kidney fat (PCKWT), ribeye area per hundredweight of carcass (RAPCW), percent lean cuts (PLC), carcass yield grade (CYG), and carcass quality grade (CQG).

Statistical procedures. The data analyses were divided in two stages. Since bulls and steers were not spread over all years, it was necessary to use the heifer data to obtain year effects for adjusting the bull and steer data. Therefore, the heifer data were utilized to obtain partial regression coefficients for year effects on all traits which were then used to adjust bull and steer data for year effects. The statistical model used for this purpose was:

$$Y_{ijklm} = u + A_i + W_j + S_k + D_l + b_1(X_{1ijklm} - \bar{X}_{1...}) + c_1(X_{1ijklm} - \bar{X}_{1...})^2 + B_2(X_{2ijklm} - \bar{X}_{2...}) + E_{ijklm}$$

Y_{ijklm} = the trait being studied

u = the effect common to all subclasses

A_1 = the effect of the $_i$th season of birth (i = 1 to 2)

W_j = the effect of the $_j$th weaning year (j = 1,...,6)

S_k = the effect of the $_k$th sire breed (k = 1,...,4)

D_l = the effect of the $_l$th dam breed (l = 1,...,5)

b_1 = the linear regression coefficient of the trait on cow age

$X_{1ijklm} - \bar{X}_{1...}$ = deviation of age of cow in years from mean cow age

c_1 = the quadratic regression coefficient of the trait on cow age

b_2 = the linear regression coefficient of the trait on calf age in days

$X_{2ijklm} - \bar{X}_{2...}$ = deviation of age of calf in days from mean calf age

E_{ijklm} = random error

After adjusting for year effects, the bull and steer data were subjected to least squares analyses using the second model to obtain least square means for all growth and carcass traits. This model was:

Model I

$$Y_{ijklm} = u + A_i + S_j + D_k + C_1 + (SC)_{j1} + (DC)_{k1} + b_1(X_{1ijklm} - \bar{X}_{1...}) + c_1(X_{1ijklm} - \bar{X}_{1...})^2 + b_2(X_{2ijklm} - \bar{X}_{2...}) + E_{ijklm}$$

Y_{ijklm} = the trait being studied

u = the effect common to all subclasses

A_1 = the effect of the $_i$th season of birth (i = 1 to 2)

S_j = the effect of the $_j$th sire breed (j = 1,...,4)

D_k = the effect of the $_k$th dam breed (k = 1,...,5)

C_1 = the effect of the $_1$th sex of calf (1 = 1 to 2)

$(SC)_{j1}$ = the interaction between the $_j$th sire breed and the $_1$th sex of calf

b_1 = the linear regression coefficient of various traits on cow age

$X_{1ijklm} - \bar{X}_{1...}$ = deviation of age of cow in years from mean cow age

c_1 = the quadratic regression coefficient of various traits on cow age

b_2 = the linear regression coefficient of various traits on calf age

$X_{2ijklm} - \bar{X}_{2...}$ = deviation of age of calf in days from mean calf age

E_{ijklm} = random error

Since inclusion of the sire breed X dam breed interaction resulted in confusing and virtually uninterpretable results due to missing and small subclass numbers, it was dropped from the model.

Analysis of variance tables for weaning data, yearling data, 18-months data and carcass data are presented in Appendix tables 4 through 7.

Mean differences between bulls and steers were subjected to a t-test of significance for all traits. A modified Duncan's Multiple Range Test (Duncan, 1953) was performed for mean separation on those traits that were significantly affected by the breed of sire x sex of calf interaction.

Simple correlation coefficients were obtained for all traits within sex subclasses. The traits within sex subclasses were adjusted by the linear regression of various traits on the age of the calf at which those traits were measured in a preliminary analysis. Within subclass simple correlations were obtained from the error term of the following model:

Model II

$$Y_{ijkl} = u + A_i + S_j + D_k + b_1\,(X_{1ijkl} - \bar{X}_{1...}) +$$
$$c_1(X_{1ijkl} - \bar{X}_{1...})^2 + E_{ijkl}$$

Y_{ijkl} = the trait being studied

u = the effect common to all subclasses

A_i = the effect of the $_i$th season of birth ($i = 1$ to 2)

S_j = the effect of the $_j$th sire breed ($j = 1,\ldots,4$)

D_k = the effect of the $_k$th dam breed ($k = 1,\ldots,5$)

b_1 = the linear regression coefficient of various traits on cow age

$X_{1ijkl} - \bar{X}_{i...}$ = deviation of age of cow in years from mean cow age

c_1 = the quadratic regression coefficient of various traits on cow age

E_{ijkl} = random error

Correlation coefficient differences between bulls and steers were tested by converting the correlations to z values, and then testing the significance of the difference between the two z's (Snedecor and Cochran, 1974).

Finally, the following model was used for the within sex prediction equations for effects on Armour tenderometer measurements.

Model III

$$Y_{ijkl} = u + A_i + S_j + D_k + b_1(X_{1ijkl} - \bar{X}_{1...}) +$$
$$c_1(X_{1ijkl} - \bar{X}_{1...})^2 + b_2(X_{2ijkl} - \bar{X}_{2...}) +$$
$$b_3(X_{3ijkl} - \bar{X}_{3...}) + b_4(X_{4ijkl} - \bar{X}_{4...}) +$$

$$b_5(X_{5ijkl} - \bar{X}_{5...}) + b_6(X_{6ijkl} - \bar{X}_{6...}) +$$
$$b_7(X_{7ijkl} - \bar{X}_{7...})$$

Y_{ijkl} = Armour tenderometer measurement (ATEN)

u = the effect common to all subclasses

A_i = the effect of the $_i$th season of birth ($i = 1$ to 2)

S_j = the effect of the $_j$th sire breed ($j = 1,...,4$)

D_k = the effect of the $_k$th dam breed ($k = 1,...,5$)

b_1 = the linear regression coefficient of ATEn on cow age

$X_{1ijkl} - \bar{X}_{1...}$ = deviation of age of cow in years from mean cow age

c_1 = the quadratic regression coefficient of ATEN on cow age

b_2 = the partial regression coefficient of ATEN on the calf age at slaughter

$X_{2ijkl} - \bar{X}_{2...}$ = deviation of age of calf in days from mean calf age

b_3 = the partial regression coefficient of ATEN on the calf carcass weight

$X_{3ijkl} - \bar{X}_{3...}$ = deviation of calf carcass weight in kg from mean calf carcass weight

b_4 = the partial regression coefficient of ATEN on calf ribeye area

$X_{4ijkl} - \bar{X}_{4...}$ = deviation of calf ribeye area in cm^2 from mean calf ribeye area

b_5 = the partial regression coefficient of ATEN on calf kidney and kidney fat weight

$X_{5ijkl} - \bar{X}_{5...}$ = deviation of calf kidney and kidney fat weight in kg from mean calf kidney and kidney fat weight

b_6 = the partial regression coefficient of ATEN on calf backfat thickness

$X_{6ijkl} - \bar{X}_{6...}$ = deviation of calf backfat thickness in mm from mean calf backfat thickness

b_7 = the partial regression coefficient of ATEN on calf marbling score

$X_{7ijkl} - \bar{X}_{7...}$ = deviation of calf marbling score from mean calf backfat thickness

With the exception of some tests of significance, all statistical analyses were performed through SAS 76 (Statistical Analysis System) of the SAS Institute, Inc.

RESULTS AND DISCUSSION

Contrasts at Weaning

Least squares means for preweaning and weaning data are presented in table 4. Records on the 217 bulls and 211 steers were adjusted to a common age of 205 days. Bulls were 16 kg (7.8%) heavier ($P < .05$) than steers. This difference is somewhat larger than the 9.3 and 7.3 kg weight advantages for bulls reported by Burgess et al. (1954) and by Marlowe and Gaines (1958), respectively, but closely parallel those reported by Marlowe et al. (1965) and by the vast majority of reports in the literature. Bulls grew 0.08 kg per day faster ($P < .05$) than steers. Even though these animals did not receive creep feed, their performance agrees closely with those observed by Marlowe et al. (1965) for creep fed bulls and steers. The sire breed x sex of calf interaction was significant for preweaning ADG (table 5). Bull-steer differences were significantly greater for the Hereford, Simmental and Charolais sire breeds than for the Angus sire breed. Because most of these calves were crossbreds, direct comparisons to literature sources are difficult. Tanner et al. (1970) reported no significant difference between bulls and steers in preweaning growth of Angus calves. Glimp et al. (1971) also failed to observe a sex difference in preweaning ADG of Angus and Hereford calves. However, Marlowe et al. (1965) found a distinct preweaning ADG advantage for bull calves of the Angus and Hereford breeds relative to steer calves. Marlowe and

TABLE 4. LEAST-SQUARES MEANS AND STANDARD ERRORS
BY SEX OF CALF FOR WEANING TRAITS

Sex of calf	Number	Age	Traits: Weaning weight (kg)	Weaning ADG (kg/day)	Weaning condition[a]	Weaning grade[b]
Bulls	217	205	220 ± 3.84^{c}	0.90 ± .02^{c}	8.41 ± .21^{c}	12.60 ± .19
Steers	211	205	204 ± 2.92^{d}	0.82 ± .02^{d}	7.18 ± .16^{d}	12.98 ± .14

[a] 6-8 = Standard; 9-11 = Good.
[b] 12-14 = Choice.
[cd] Figures with different superscripts in each column are significantly different ($P < .05$).

TABLE 5. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF SIRE BY SEX OF CALF INTERACTIONS FOR PREWEANING AVERAGE DAILY GAIN (kg/DAY)

Breed of sire	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	36	0.78 ± .04	43	0.80 ± .03	-0.02
Hereford	82	0.86 ± .03	83	0.77 ± .02	0.09
Simmental	31	0.98 ± .03	27	0.86 ± .03	0.12
Charolais	68	0.96 ± .03	58	0.83 ± .02	0.13

[ab]Figures with different superscripts in each column are significantly different (P <.05).

Gaines (1958) found that Angus, Hereford, and Shorthorn bulls grew faster during preweaning period than steers. Evaluation of preweaning growth rate between sexes of Hereford breeding has yeilded conflicting results with some workers reporting a significant bull calf advantage (Brinks et al., 1961 and Klosterman et al., 1954) while others have reported no sex difference (Bailey et al., 1966a and Bailey and Hironaka, 1969). Studies involving the larger cattle breeds (e.g., Yugoslav Simmental and Holstein) found a significant preweaning growth advantage for bull calves relative to steer calves (Cobic', 1968 and Wilson et al., 1974). Data in table 5 suggest that the difference between bulls and steers for preweaning ADG increases as the size of the calf sire breed increases.

Weaning grade (type score) is composed of several considerations (e.g., frame structure, muscling, symmetry and balance, lack of coarseness, condition, thriftiness, and structural soundness) and is discussed in detail in the Virginia Agricultural Experiment Station Bulletin 283. Weaning grades for bulls and steers are presented in table 4. Grades at weaning were in the choice range and did not differ significantly for bulls and steers. However, the analysis of variance revealed a significant breed of dam x sex of calf interaction for weaning grade, which appeared to be associated with the offspring of Charolais x Hereford cows. Least squares means for this interaction are presented in table 6. The lack of a distinct advantage of bulls over steers for weaning grade, particularly in calves with Hereford dams, fails to agree with other reports (Marlowe, 1962; Marlowe and Gaines, 1958; and Marlowe et al., 1965).

TABLE 6. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR WEANING GRADE SCORES[a]

Breed of dam	Bull: Number of observations	Bull: Least-squares means	Steer: Number of observations	Steer: Least-squares means	Bull-steer difference
Angus	22	13.01 $\pm$ .36	21	12.84 $\pm$ .33	0.17
Hereford	157	11.47 $\pm$ .14	119	12.21 $\pm$ .14	-0.74
Charolais x Holstein	6	12.77 $\pm$ .55	9	12.61 $\pm$ .44	0.16
Simmental x Hereford	5	13.70 $\pm$ .60	16	13.77 $\pm$ .34	-0.07
Charolais x Hereford	27	12.05 $\pm$ .27	46	13.45 $\pm$ .20	-1.40

[a]9-11 = Good; 12-14 = Choice.

The breed of dam x sex of calf interaction significantly influenced several other traits throughout this study, all of which were seemingly associated with the offspring of either Charolais x Holstein or Simmental x Hereford cows. These interactions and any subsequent interpretations are suspect due to the small numbers of bulls and steers with Charolais x Holstein and Simmental x Hereford dams. Therefore, the remainder of this text will omit any discussion of the breed of dam x sex of calf interaction. The interested reader may refer to appendix tables 12 through 23 for the least squares means of all traits significantly influenced by this interaction.

Weaning condition scores are presented in table 4 and indicate that bulls were significantly fatter at weaning than steers. The overall higher condition scores of bulls was not expected.

Contrasts as Yearlings

Least squares means for yearling data are presented in table 7. The 217 bulls and 211 steers were adjusted to a common age of 377 days. Bulls 37 kg (13.6%) heavier ($P < .05$) than steers as yearlings. Bulls grew 12 kg/day (30.8%) faster from weaning to yearling age than steers ($P < .05$). On a weight per day of age basis, bulls gained 0.10 kg faster ($P < .05$). The magnitude of the bull-steer difference reported here for ADG is greater than that reported by Bailey et al. (1966) and Jacobs et al. (1975b). Yet the direction of these differences in this study is in agreement with their work with animals on growing rations.

Yearling grades were very similar to those received at weaning. Although bulls graded higher than steers ($P < .05$) the difference was

TABLE 7. LEAST-SQUARES MEANS AND STANDARD ERRORS BY SEX OF CALF FOR YEARLING TRAITS

Sex of calf	Number	Age	Traits				
			Yearling weight (kg)	Yearling ADG (kg/day)	Yearling[a] WPDA (kg/day)	Yearling[b] condition	Yearling[c] grade
Bulls	217	377	310 ± 6.44^{e}	$0.51 \pm .03^{e}$	$0.83 \pm .02^{e}$	$7.42 \pm .13$	$12.41 \pm .18^{e}$
Steers	211	377	273 ± 4.86^{f}	$0.39 \pm .02^{f}$	$0.73 \pm .01^{f}$	$7.11 \pm .10$	$12.85 \pm .14^{f}$

[a]Yearling weight per day of age.
[b]6-8 = Standard.
[c]12-14 = Choice.
[ef]Figures with different superscripts in each column are significantly different ($P < .05$).

small (less than a third of a grade). Grades of both bulls and steers fell into the low to middle choice range. Bulls and steers did not differ in condition at yearling age.

The faster growth rate of bulls was further emphasized at 18 months of age. Least squares means for bulls and steers at 18 months of age are presented in table 8. The average age, designated as 18 months, was 533 days. Bulls averaged 68 kg heavier at this period than did steers (P <.05). Similar differences, but smaller, were reported by Arthaud et al. (1977) and Jacobs et al (1975b). The weight advantage of bulls was apparent, whether expressed as total weight or as weight per day of age, in that bulls exhibited 0.13 kg more weight per day of age than did steers (P <.05). Weight per day of age was significantly affected by the sire breed x sex of calf interaction (table 9). Bulls were heavier than steers on a per day of age basis for all sire breeds. However, this difference was greater for calves sired by Simmental bulls than for calves sired by Angus or Hereford bulls (P <.05). In general, bull calves sired by the two exotic breeds had greater postweaning gains than those sired by either of the two English breeds. This may account for the bull-steer differences in weight per day of age being greater in calves sired by Simmental and Charolais bulls. Nevertheless, the sex differences in calves sired by Charolais bulls were not significantly different from those sired by Angus bulls or Hereford bulls. Bulls gained 0.16 kg more per day from weaning to 18 months than did steers (P <.05). The 18% advantage in postweaning ADG of bulls over steers is almost identical to the 17% and 18% average advantages reported

TABLE 8. LEAST-SQUARES MEANS AND STANDARD ERRORS BY SEX OF CALF FOR 18-MONTHS TRAITS

Sex of calf	Number	Age	Traits: 18-mos Weight (kg)	18-mos ADG (kg/day)	18-mos[a] WPDA (kg/day)	18-mos[b] condition	18-mos[c] grade
Bulls	217	533	449 ± 7.55[e]	0.70 ± .02[e]	0.85 ± .01[e]	9.06 ± .21[e]	12.40 ± .18[e]
Steers	211	533	381 ± 5.72[f]	0.54 ± .02[f]	0.72 ± .01[f]	7.46 ± .16[f]	13.11 ± .13[f]

[a]18-months weight per day of age.
[b]6-8 = Standard; 9-11 = Good.
[c]12-14 = Choice.
[ef]Figures with different superscripts in each column are significantly different (P <.05).

TABLE 9. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF SIRE BY SEX OF CALF INTERACTIONS FOR 18-MONTHS WEIGHT PER DAY OF AGE (kg/DAY)

Breed of sire	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	32	0.81 ± .02	43	0.72 ± .02	0.09[a]
Hereford	82	0.77 ± .02	83	0.67 ± .01	0.10[a]
Simmental	31	0.90 ± .02	27	0.73 ± .02	0.17[b]
Charolais	68	0.90 ± .02	58	0.76 ± .01	0.14[ab]

[ab]Figures with different superscripts in each column are significantly different ($P < .05$).

by Field (1971) and Hedrick (1968), respectively. Table 10 presents the least squares means for the breed of sire x sex of calf interaction, which significantly affected ADG to 18 months of age. The largest sex differences occurred in calves sired by Simmental bulls. This difference is significantly greater than that of calves sired by either Angus or Charolais bulls, which was significantly greater than calves sired by Hereford bulls. The least squares means for steers sired by the different breeds are all very similar to the overall least squares mean of 0.54 kg per day for steers. However, the least squares mean for bull calves sired by Hereford bulls is substantially lower than that of bull calves sired by other breeds, as well as the overall value of 0.70 kg for bulls.

Steer calves at 18 months of age graded middle choice and graded one-third of a grade higher than bull calves at 18 months of age ($P < .05$). At earlier ages, weight was positively correlated (30 to 40%) with grade; however, at 18 months of age bulls exhibited only a 25% correlation between weight and grade and steers exhibited a lack of association between the two traits (nonsignificant negative correlation coefficient of .13). The correlation differed significantly between sexes. Weight of the animal still played an inherent part in the grading of bulls at 18 months of age; yet, the weight of the animal was not associated with the grade the animal receives for steers and suggests that the extra weight that steers gain is possibly fat. Once again, bulls received higher condition scores that steers at 18 months of age ($P < .05$). Condition scores at 18 months of age were significantly affected by the breed of sire x sex of calf inter-

TABLE 10. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF SIRE BY SEX OF CALF INTERACTIONS FOR 18-MONTHS AVERAGE DAILY GAIN (kg/DAY)

Breed of sire	Bull: Number of observations	Bull: Least-squares means	Steer: Number of observations	Steer: Least-squares means	Bull-steer difference
Angus	36	0.73 ± .04	43	0.55 ± .03	0.18[a]
Hereford	82	0.59 ± .03	83	0.51 ± .02	0.08[b]
Simmental	31	0.72 ± .04	27	0.51 ± .03	0.21[c]
Charolais	68	0.76 ± .03	58	0.58 ± .02	0.18[a]

[abc]Figures with different superscripts in each column are significantly different (P <.05).

action. Least squares means for this interaction are presented in table 11. Bull-steer differences for calves sired by Charolais bulls were less than those sired by Hereford or Simmental bulls. However, regardless of the breed of the sire, bulls were scored slightly higher for condition than were steers. Similarly, the disparity of sex differences between sire breeds was not large.

Summary of Growth Contrast

Without question, bulls were heavier than steers at each weighing, whether expressed as total weight or as weight per day of age. Preweaning ADG and the two postweaning ADG's found bulls to have an advantage over steers. With the exception of calves at weaning, steers graded higher than did bulls ($P < .05$). Although at 12 and 18 months of age steers graded significantly higher than bulls from a statistical point of view, the difference between them was so small as to make the biological implications questionable. Surprisingly, bull calves received significantly higher condition scores than did steers at weaning and at 18 months. One explanation is that bulls were more aggressive in their eating habits, both in terms of obtaining milk from their dams and in the feedlot, resulting in heavier weights and thriftier appearances at each weighing. At weaning, the association between weight and condition score was greater in bulls (.63) than in steers (.24) ($P < .05$). (Correlation coefficients are presented in Appendix tables 8 through 11.) Condition scores did not differ between sexes at 12 months, but the association between condition score and growth rate from weaning to 12 months did differ in bulls (.50) and steers (.24) ($P < .05$).

TABLE 11. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF SIRE BY SEX OF CALF INTERACTIONS FOR 18-MONTHS CONDITION SCORES[a]

Breed of sire	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	32	9.04 ± .35	43	7.97 ± .27	1.07[bc]
Hereford	82	9.57 ± .26	83	7.53 ± .22	2.04[b]
Simmental	31	9.10 ± .33	27	6.82 ± .33	2.28[b]
Charolais	68	8.55 ± .27	58	7.53 ± .23	1.02[c]

[a]6 to 8 = Standard; 9 to 11 = Good.
[bc]Figures with different superscripts in each column are significantly different ($P < .05$).

Neither bulls nor steers displayed any great degree of external fat at weaning or yearling age, indicating that condition scores would not be based solely on the amount of external fat the animal displayed. The degree of relatedness between weight and condition score at 18 months was different in bulls (.26) and steers (.67) ($P < .05$). The greater association of the two traits in steers coupled with objective carcass fat measurements suggest that as steers became heavier they also became fatter and that condition scores in steers were more reflective of the greater degree of external fat. Apparently, the weight of bulls at 18 months was not necessarily related to a greater degree of external fat deposition. Consequently, condition scores in bulls at 18 months were not any more reflective of external fat than they were at weaning or 12 months.

Carcass Data

Animals were adjusted to 593 days of age for sex comparisons of live slaughter weight, carcass weight and carcass weight per day of age and to 598 days for all other carcass trait comparisons except for Armour tenderometer measurements which were adjusted to 588 days. Least squares means and standard errors for all carcass traits of bulls and steers are presented in table 12. Bulls were 87 kg heavier at slaughter than were steers which equates to a 21% weight advantage in favor of bulls ($P < .05$). Although this difference is slightly greater than most reports, it is in general agreement with previous studies and more recently with Arthaud *et al.*, (1977); Carroll *et al.*, (1975); Jacobs *et al.*, (1975); Williams *et al.*, (1975); and Wilson *et al.*, (1974). Bull-steer differences in carcass

TABLE 12. LEAST-SQUARES MEANS AND STANDARD ERRORS BY SEX OF CALF FOR CARCASS TRAITS

Sex of calf	No.	Age	Traits: Live slaughter weight (kg)	Traits: Carcass weight (kg)	Traits: Carcass WPDA (kg)[a]	Sex of calf	No.	Age	Traits: Kidney and Kidney fat weight (kg)	Traits: Percent kidney (%)[b]	No.	Age	Traits: Ribeye area (cm^2)	Traits: Ribeye area[c] per cwt (cm^2/kg)
Bulls	217	593	501 ± 7.67[g]	281 ± 5.10	0.48 ± .01[g]	Bulls	199	598	4.02 ± .24[g]	1.59 ± .01[g]	198	598	34.06 ± .65[g]	12.21 ± .20
Steers	211	593	414 ± 5.83[h]	219 ± 3.88[h]	0.39 ± .01[h]	Steers	211	598	5.35 ± .18[h]	2.58 ± .01	211	598	26.42 ± .48[h]	12.21 ± .15

Sex of calf	No.	Age	Backfat thickness (mm)	Marbling[d] score	No.	Age	Trait: Armour Tenderometer (kg)	Sex of calf	No.	Age	Carcass quality grade[e]	No.	Age	Traits: Percent lean cuts (%)	Traits: Carcass yield grade[f]
Bulls	198	598	2.79 ± .33	2.87 ± .17	176	588	8.25 ± .17[g]	Bulls	198	598	9.17 ± .20[g]	198	598	53.9 ± .19[g]	1.29 ± .08[g]
Steers	211	598	3.56 ± .25	2.69 ± .13	138	588	7.09 ± .15[h]	Steers	209	598	9.71 ± .15[h]	211	598	52.5 ± .14[h]	1.90 ± .06[h]

[a]Carcass weight per day of age.
[b]Percent kidney and kidney fat per carcass weight.
[c]Ribeye area per hundredweight of carcass.
[d]2 = traces; 3 = slight.
[e]9-11 = Good; 12-14 = Choice.
[f]1 = leanest carcass; 5 = fattest carcass.
[gh]Figures with different superscripts in each column are significantly different (P < .05).

weights essentially mirrored the situation in live slaughter weights; bulls had a 62 kg advantage in carcass weight over steers ($P < .05$). This bull-steer difference in carcass weight was in general agreement with the vast majority of previous studies. Carcass weight per day of age further emphasizes the superior growth rate of bulls. Bulls weighed 0.09 kg more per day than steers at 593 days of age ($P < .05$). This value falls in the range of significant bull advantages of 0.03 to 0.10 kg reported by many researchers (Carroll et al., 1963; Gortsema et al., 1974; Tanner et al., 1970; and Wilson et al., 1974). However, Landon et al., (1978) reported slightly greater carcass weights per day of age for Charolais x Hereford steers when compared to bulls of the same breeding.

For the kidney and kidney fat weight (actual or percentage of carcass weight) comparison there were 199 bulls and 211 steers. Bulls had 25% less kidney and kidney fat weight than steers ($P < .05$). When kidney and kidney fat weight was expressed as a percentage of the carcass weight, the kidney and kidney fat accounted for almost 1% less of the carcass weight in the bull carcasses than in the steer carcasses ($P < .05$). The greater amount of peritoneal fat in steers agrees with Arthaud et al. (1969), Klosterman et al. (1954 and 1958), Prescott and Lamming (1964), Tanner et al. (1970) and Warwick et al. (1970).

Bulls yielded 7.6 cm^2 more ribeye than did steers when adjusted to the same age ($P < .05$). The greater ribeye area of bulls agrees with Hedrick's (1968) review of literature and more recently with Albaugh et al. (1975), Carroll et al. (1975), and Williams et al.

(1975). When ribeye area was expressed on a per 100 kg of carcass weight basis, sex differences disappeared in this study. This finding fails to agree with Anderson (1976), Nichols et al. (1964), or Tanner et al. (1970). These researchers all found bulls to have greater ribeye areas per 100 kg of carcass weight. Nichols et al. (1964) also noted that animals slaughtered at 454 kg exhibited larger ribeyes on a per unit of carcass weight basis than did animals slaughtered at 363 kg. Bulls in this study were also heavier than steers at slaughter, yet no difference in ribeye area per 100 kg of carcass weight was noted between the sexes. Based upon suggestions by Nichols et al. (1964) that ribeye area either be adjusted to a constant carcass weight or expressed as a ratio to carcass weight, the preceding discussion concerning greater ribeye areas in bulls of this study becomes questionable. Presumably, if the bulls and steers in this study had been slaughtered at the same weight, rather than adjusted to the same age, no appreciable difference in the size of the ribeye would have been detected between the sexes. No explanation is forthcoming as to why the findings of this study are at variance with the findings of other researchers.

There were 198 bulls and 211 steers on which backfat thickness was measured and marbling scores were assigned. Bulls exhibited a nonsignificant 0.77 mm less backfat than did steers. However, neither bulls nor steers in this study were fat. They displayed fat cover thicknesses of only 2.79 and 3.56 mm, respectively. This is not in total agreement with the literature reviews of Hedrick (1968) and Field (1971). Had the animals received a high concentrate fattening ration, the expected degree of finish on steers most likely would have been expressed. Similarly, the degree to which animals in this study were not allowed to be fattened may explain the lack of any sex difference in marbling scores. The literature over the past 25 years indicates that steers will achieve higher marbling scores than bulls if given the opportunity to do so.

Armour tenderometer measurements were available on 176 bulls and 138 steers for comparisons. Bulls required 1.16 kg more force to penetrate their carcasses than did steers ($P < .05$). The variation in Armour tenderometer values was greater for bull carcasses as indicated by standard deviations of 2.56 kg and 1.64 kg for bulls and steers, respectively. Producers of this device have indicated a force below 8.2 kg is sufficient for the carcass to fall into the choice grade. The significantly greater force required to penetrate bull beef is in agreement with several researchers using the Warner-Bratzler shear device (Arthaud et al., 1977; Glimp et al., 1971; Hunsley et al., 1971; Jacobs et al., 1977; and Reagan et al., 1971). Prediction equations for Armour tenderometer measurements indicate that the traits affecting tenderness were different for bulls than for steers. Tenderness decreased as carcass weight increased for both bulls ($b = .0067$, $P < .05$) and steers ($b = .0040$, $P < .05$) but increased for bulls as kidney and kidney fat weight in bulls and steers increased ($b = -.4212$, $P < .05$). After adjustment for main effects and age of dam, carcass weight accounted for 2.99% and 4.63% of the residual variation in tenderness in bulls and steers, respectively. Kidney and kidney fat weight accounted for 32.65% of the residual variation in tenderness in bulls, after adjustment for main effects and age of dam. After adjustment to a constant carcass weight and a constant kidney and kidney fat weight in bulls, neither age at slaughter, rib-eye area, backfat thickness nor degree of marbling significantly influenced tenderness in bulls or steers. Backfat thickness and the degree of marbling were not allowed to be expressed fully in bulls or steers, but the omission of kidney fat, as an indicator of peritoneal fat, in influencing tenderness in steers bears closer scrutiny. Carcass weight of steers is correlated (47%) with kidney and kidney fat, indicating that an increase in kidney fat is closely associated with an increase in carcass weight. (Correlation coefficients are presented in appendix tables 8 through 11.) The close association of these two traits, plus the negative influence of carcass weight increases on tenderness, seemingly mask the positive influence of kidney fat increases on tenderness. However, kidney fat did exert a positive influence on tenderness in bulls. Carcass weight in bulls is not associated with kidney fat (nonsignificant negative .07), indicating that an increase in carcass weight is not necessarily accompanied by an increase in kidney and kidney fat weight. What appears to be happening in bulls is that individuals that are fatter at a given carcass weight are exhibiting a true propensity to lay down peritoneal fat independent of carcass weight increases and, therefore, the fatter bulls will tend to be more tender.

Carcass quality grades were available on 198 bulls and 209 steers. Although bulls graded significantly lower than steers statistically, the sex difference was less than one-third of a quality grade. Since both bulls and steers graded from low good to middle good, little, if any, biological significance can be attached to sex differences in quality grade. However, other researchers have noted a significant two-thirds of a grade to a whole grade difference between bulls and steers (Arthaud et al., 1977; Champagne et al., 1969; Gortsema et al., 1974; and Landon et al., 1978).

Percent of lean cuts and carcass yield grade were computed on 198 bulls and 211 steers. Bulls yielded 1.4% more lean cuts per carcass than did steers ($P < .05$). Carcass weight was positively correlated (27%) with percent lean cuts yield in bulls, whereas these two traits were negatively correlated (-29%) in steers. Carcass weight increases in steers were accompanied by or composed of increased fat deposition, resulting in a decrease in percent lean cut yield per carcass. However, carcass weight gains in bulls were composed of lean tissue gain, resulting in an increase in percent lean cuts per carcass. The findings reported here are in complete agreement with literature reviews by Field (1971) and Hedrick (1968) who reported an overwhelming bull advantage for yield of lean cuts.

Although both bulls and steers exhibited favorable carcass yield grades, bulls graded .61 of a grade point more favorable than steers ($P < .05$). The bull advantage in percent lean cuts yield is mirrored by carcass yield grade. Similar relationships exist between carcass weight and yield as did between carcass weight and percent lean cuts yield. Carcass yield grade results reported here are in agreement with previous reports by Anderson (1976), Gortsema et al. (1974), and Jacobs et al. (1977).

Bulls in this study attained heavier slaughter weights than did steers and produced greater percentages of lean cuts in their carcasses. Comparisons for sex differences in degrees of fatness are not appropriate since neither bulls nor steers were fat at slaughter. On the other hand, the animals did deposit peritoneal fat (e.g., kidney and kidney fat weight) and this trait revealed a significantly greater deposition of fat by steers. As steers attained heavier weights, the composition of their gain was an increasing percentage of fat, thus lowering percentage yields of lean cuts and raising carcass yield grades, while producing higher carcass quality grades. For the efficient production of lean, acceptable beef bulls exceed steers, provided that adequate facilities are available and that the bulls are managed in such a way as to be slaughtered prior to 16 months of age.

SUMMARY AND CONCLUSIONS

The purpose of this study was to explore existing differences, or lack of differences, between intact and castrated male beef cattle from birth to slaughter and included several carcass traits. Data for this study were collected from 217 bulls and 211 steers at the Bland Correctional Center, Bland, Virginia. Since neither bulls nor steers were represented in all six years of the study (1970 through 1975) it was necessary to remove weaning year effects from all male cattle. Weaning year adjustments were accomplished through regression analysis on 453 heifers represented in all six years of the study. The adjusted bull and steer data were subjected to least squares analysis and least squares means were obtained for all growth and carcass traits.

Bulls and steers were weighed, graded and scored for condition at weaning, approximately a year of age and at approximately 18 months of age. Bulls weighed more than comparably aged steers at all three weigh periods ($P < .05$) and exhibited superior growth rates for the preweaning period and both postweaning periods ($P < .05$). A significant weight per day of age advantage favored bulls at yearling ages. There was no difference in grades received by bulls and steers at weaning. Steers graded significantly higher than bulls at approximately 12 and 18 months of age, but the difference was small (less than one-third of a grade) and lacked biological significance. Bulls were scored higher for condition than steers at the weaning and 18 month weigh periods ($P < .05$).

The growth and weight superiority of bulls compared to steers of comparable age was further emphasized in terms of live slaughter weight, carcass weight, and carcass weight per day ($P < .05$). Although bulls displayed larger ribeye areas than did steers ($P < .05$), this advantage disappeared when ribeye area was expressed on a per 100 kg carcass weight basis. Kidney and kidney fat weight, conversely to ribeye area, was greater in steers than bulls of comparable age when expressed either as total weight or as a percentage of carcass weight ($P < .05$). However, neither bulls nor steers in this study were fat. No sex differences were present in terms of backfat thickness or marbling scores. Bulls received significantly lower carcass quality grades than steers, yet this difference accounted for less than a third of a grade with bulls grading low good and steers grading low to middle good. Bulls were significantly less tender than steers as determined by Armour tenderometer measurements ($P < .05$) but both were acceptably tender according to the manufacturers of the tenderometer device. Bulls produced more lean cuts yield and the lower carcass yield grades ($P < .05$). Nevertheless, the percentage of lean cuts yielded was favorable for both bulls and steers.

Based upon the minimal sex differences in carcass quality and the added advantage for bulls in terms of faster growth rates and greater weights, the present market bias against bull beef is unjustified. The demand for leaner, more efficient beef may best be served by the production of intact male cattle, provided that adequate facilities are available and that the bulls are managed in such a way as to be slaughtered prior to 16 months of age.

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APPENDIX

TABLE 1. NUMBER OF CALVES REPRESENTED IN EACH BREED OF SIRE BY SEX OF CALF SUBCLASS

Breed of sire	Sex of calf			Total
	Bulls	Heifers	Steers	
Angus	36	83	43	162
Hereford	82	175	83	340
Simmental	31	76	27	134
Charolais	68	119	58	245
Total	217	453	211	880

TABLE 2. NUMBER OF CALVES REPRESENTED IN EACH BREED OF DAM BY SEX OF CALF SUBCLASS

Breed of dam	Sex of calf			Total
	Bulls	Heifers	Steers	
Angus	22	50	21	93
Hereford	157	296	119	572
Holstein x Charolais	6	15	9	30
Simmental x Hereford	5	45	16	65
Charolais x Hereford	27	47	46	120
Total	217	453	211	880

TABLE 3. NUMBER OF CALVES REPRESENTED IN EACH YEAR OF WEANING BY SEX OF CALF SUBCLASS

Year of weaning	Sex of calf			Total
	Bulls	Heifers	Steers	
1970	70	65	--	135
1971	81	48	--	129
1972	26	78	39	143
1973	40	83	44	166
1974	--	104	98	202
1975	--	75	30	105
Total	217	453	211	880

TABLE 4. ANALYSIS OF VARIANCE OF PREWEANING AND WEANING DATA

		Mean squares			
Source of variation	d.f.	Weaning weight	Preweaning ADG	Weaning condition	Weaning grade
Season of birth	1	3542.2	0.04	0.34	0.001
Sire breed (S)	3	79535.5**	1.26**	4.21	33.099**
Dam breed (D)	4	65176.3**	1.32**	10.00**	20.571**
Sex of calf (C)	1	39828.8**	1.05**	48.26**	4.528
S x C	3	8651.4	0.30*	2.26	3.043
D x C	4	2407.6	0.11	10.50**	4.519*
Linear regression					
Age of dam	1	82880.4**	1.01**	1.50	29.689**
Age of calf	1	838865.6**	0.40*	3.61	3.294
Quadratic regression					
Age of dam	1	65605.3	0.58*	1.08	35.068**
Residual	408	7765.8	0.10	2.11	1.707

*$P < 0.05$.
**$P < 0.01$.

TABLE 5. ANALYSIS OF VARIANCE OF YEARLING DATA

Source of variation	d.f.	Mean squares: Yearling weight	Yearling ADG	Yearling WPDA	Yearling condition	Yearling grade
Season of birth	1	103721.0**	1.43**	1.19**	16.98**	3.820
Sire breed (S)	3	34573.7**	2.69**	1.87**	2.09	25.010**
Dam breed (D)	4	78252.8**	0.38	0.51**	6.74**	13.770**
Sex of calf (C)	1	216505.7**	2.23**	1.44**	3.05	6.060*
S x C	3	9328.2	0.07	0.11	0.71	1.740
D x C	4	18044.1	0.57*	0.14	2.76**	0.250
Linear regression						
Age of dam	1	48259.5*	0.14	0.32*	0.33	26.280**
Age of calf	1	208755.1**	0.30	4.02**	7.26**	8.990*
Quadratic regression						
Age of dam	1	37988.8*	0.16	0.25	0.42	22.370**
Residual	408	9650.7	0.18	0.08	0.81	1.550

*P< 0.05.
**P < 0.01.

TABLE 6. ANALYSIS OF VARIANCE OF 18-MONTHS DATA

Source of variation	d.f.	Mean squares 18-mos. weight	18-mos. ADG	18-mos. WPDA	18-mos. condition	18-mos. grade
Season of birth	1	75538*	0.74**	0.21*	32.38**	0.75
Sire breed (S)	3	391188**	1.55**	1.42**	7.85*	30.26**
Dam breed (D)	4	34411*	0.11	0.12**	7.31**	16.62**
Sex of calf (C)	1	671183**	3.95**	2.45**	79.36**	15.77**
S x C	3	29222	0.38*	0.15*	8.89**	2.85
D x C	4	46808**	0.43	0.16*	5.49*	0.45
Linear regression						
Age of dam	1	37303	0.04	0.16	1.24	9.48*
Age of calf	1	765716**	0.63	1.34**	13.07*	14.23**
Quadratic regression						
Age of dam	1	32432	0.03	0.14	1.33	8.06*
Residual	408	13166	0.11	0.05	2.08	1.47

*P < 0.05.
**P < 0.01.

TABLE 7. ANALYSIS OF VARIANCE OF CARCASS DATA

Source of variation	d.f.	Mean squares: Live slaughter weight	Carcass weight	Carcass WPDA	Kidney weight	Kidney percent
Season of birth	1	18689	32865*	0.05	75.30*	0.021
Sire breed (S)	3	518065**	204374**	0.59**	101.27**	0.008
Dam breed (D)	4	36771*	28641**	0.07**	8.89	0.008
Sex of calf (C)	1	1178478**	596492**	1.52**	267.55**	0.305**
S x C	3	11173	4420	0.02	22.63	0.016
D x C	4	34071*	13853	0.04	18.49	0.018*
Linear regression						
Age of dam	1	28006	38832*	0.10*	0.25	0.001
Age of calf	1	1523023**	573444**	0.87**	596.13**	0.288*
Quadratic regression						
Age of dam	1	23764	35051*	0.09*	1.67	0.0001
Residual	408	13806	6117	0.02		
Residual	390				13.32	0.007

*P < 0.05.
**P < 0.01.

TABLE 7 (continued). ANALYSIS OF VARIANCE OF CARCASS DATA

Source of variation	d.f.	Mean squares				
		Ribeye area	Ribeye area/cwt	Backfat thickness	Marbling score	Armour Tenderometer
Season of birth	1	20.1**	0.023	0.041*	15.12**	1.5
Sire breed (S)	3	34.0**	0.388**	0.015	9.38**	6.9
Dam breed (D)	4	5.1	0.018	0.023*	7.19**	8.4
Sex of calf (C)	1	281.6**	0.000	0.026	1.03	137.5**
S x C	3	0.3	0.043	0.009	1.59	5.3
D x C	4	8.0	0.078	0.009	1.91	4.5
Linear regression						
Age of dam	1	1.6	0.263*	0.007	0.02	10.5
Age of calf	1	17.5*	2.418**	0.414**	17.45**	24.6*
Quadratic regression						
Age of dam	1	0.7	0.276*	0.009	0.00	11.7
Residual	389	3.0	0.060	0.008	1.35	
Residual	294					5.1

*P <0.05.
**P <0.01.

TABLE 7 (continued). ANALYSIS OF VARIANCE OF CARCASS DATA

Source of variation	d.f.	Mean squares: Carcass quality grade	Percent lean cuts	Carcass yield grade
Season of birth	1	29.7**	0.59	0.09
Sire breed (S)	3	15.3**	1.82	0.39
Dam breed (D)	4	5.2*	0.49	0.15
Sex of calf (C)	1	9.0*	56.81**	11.64**
S x C	3	1.6	0.04	0.01
D x C	4	3.4	6.78**	1.20**
Linear regression				
Age of dam	1	0.1	2.40	0.49
Age of calf	1	73.0**	104.63**	20.55**
Quadratic regression				
Age of dam	1	0.0	2.91	0.62
Residual	387	1.9		
Residual	389		1.65	0.33

*P < 0.05.
**P < 0.01.

TABLE 8. SELECTED CORRELATION COEFFICIENTS FOR GROWTH TRAITS[a]

	Sex[b]	Growth traits												
		WADG	WCOND	WGR	YWT	YADG	YWPDA	YCOND	YGR	FWT	FADG	FWPDA	FCOND	FGR
WWT	B	–	.63*	–	–	.33*	.70*	–	–	.54*	–	.56*	–	–
	S	–	.24*	–	–	–.21*	.52*	–	–	.35*	–	.34*	–	–
WADG	B	–	.66*	–	–	.33*	–	–	–	–	–	.55*	–	.02*
	S	–	.22*	–	–	–.17	–	–	–	–	–	.34*	–	.27*
WCOND	B			–	.78*	.66*	.77*	–	–	.54*	–	.55*	.59*	–
	S				.29*	.03	.34*	–	–	.28*	–	.25	.34*	–
WGR	B				–	–	–	–	.44*	–	–	–	.21*	–
	S				–	–	–	–	.71*	–	–	–	–.12	–
YWT	B					.86*	.995*	–	–	.63*	–	.64*	.57*	.04
	S					.49*	.95*	–	–	.46*	–	.45*	.39*	.30*
YADG	B						.87*	.50*	–	.44*	–	.44*	.56*	–
	S						.44*	.24*	–	.13	–	.13	.21*	–
YWPDA	B							–	–	.73*	–	.63*	–	–
	S							–	–	.46*	–	.42*	–	–
YCOND	B								–	–	.34*	–	–	–
	S								–	–	.11	–	–	–
YGR	B									.38*	.29*	.39*	–	–
	S									.08	–.14	.07	–	–
FWT	B										–	–	.26*	.25*
	S										–	–	.67*	–.13
FADG	B											–	.10	–
	S											–	.57*	–
FWPDA	B												.26*	.24*
	S												.67*	–.13
FCOND	B													–
	S													–

[a]Only correlation coefficients that differ significantly between bulls and steers are shown ($P < .05$).
[b]B = bulls; S = steers.
*$P < .05$.

TABLE 9. SELECTED CORRELATION COEFFICIENTS FOR GROWTH AND CARCASS TRAITS[a]

		Growth traits													
	Sex[b]	WWT	WADG	WCOND	WGR	YWT	YADG	YWPDA	YCOND	YGR	FWT	FADG	FWPDA	FCOND	FGR
LW	B	.57*	.58*	.56*	.28*	.67*	.52*	.66*	–	.41*	–	–	–	.47*	–
	S	.38*	.37*	.18*	–.03	.45	.23*	.41*	–	.02	–	–	–	.69*	–
CW	B	.57*	.58*	.54*	.30*	.67*	.55*	.67*	.42*	.44*	–	–	–	–	–
	S	.38*	.36*	.12	.02	.47*	.27*	.40*	.19*	.08	–	–	–	–	–
CWPDA	B	–	–	.53*	.29*	.69*	.58*	.68*	.42*	.44*	–	–	–	–	–
	S	–	–	.12	.01	.50*	.28*	.44*	.18*	.09	–	–	–	–	–
KWT	B	–	–	–.20*	–	–.24*	–.35*	–.24*	–	–	–	–	–	–.32*	–
	S	–	–	.06	–	.26*	.13	.22*	–	–	–	–	–	.25*	–
PCKWT	B	–	–	–	–	–.46*	–.54*	–.45*	–	–	–	–	–	–.44*	–
	S	–	–	–	–	.09	.01	.03	–	–	–	–	–	–.16	–
RA	B	–	–	.47*	–	–	–	–	–	–	.58*	–	.58*	–	–
	S	–	–	.34*	–	–	–	–	–	–	.40*	–	.40*	–	–
RAPCW	B	–	–	–.19*	–	–	–.29*	–.32*	–.18*	–	–	–	–	–	–
	S	–	–	.23*	–	–	–.05	–.04	.20*	–	–	–	–	–	–
BF	B	–	–	–	–	–	–	–	–	.15*	–	–	–	–	–
	S	–	–	–	–	–	–	–	–	–.12	–	–	–	–	–
MAR	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ATEN	B	.25*	.26*	.34*	.23*	.43*	.44*	.43*	–	–	–	–.11	–	.42*	–
	S	.01	.01	.08	–.05	.06	.00	.12	–	–	–	.20*	–	.20*	–
CQG	B	–	–	–	–	–	–	–	–	–	–	.51*	–	.06	–
	S	–	–	–	–	–	–	–	–	–	–	.25*	–	.41*	–
PLC	B	–	–	–	–	.29*	.28*	.28*	–	–	.28*	.21*	.27*	.16*	–
	S	–	–	–	–	.01	–.05	.05	–	–	.00	–.05	–.02	–.11	–
CYG	B	–	–	–	–	–.30*	–.30*	–.29*	–	–	–.27*	–.20*	–.26*	–.17*	–
	S	–	–	–	–	–.01	.03	–.05	–	–	–.01	.04	.01	.10	–

[a]Only correlation coefficients that differ significantly between bulls and steers are shown ($P < .05$).
[b]B = bulls; S = steers.
*$P < .05$.

TABLE 10. CORRELATION COEFFICIENTS FOR SELECTED GROWTH AND CARCASS TRAITS

	Sex[a]	Traits											
		WCOND	WGR	YCOND	YGR	FCOND	FGR	KWT	PCKWT	RA	RAPCW	BF	MAR
WCOND[b]	B		–	–	–	.59*	–	–.20*	–	.47*	–.19*	–	–
	S		–	–	–	.34*	–	.06	–	.34*	.23*	–	–
WGR	B	.35*		–	.44*	.21*	–	–	–	–	–	–	–
	S	.30*		–	.71*	–.12	–	–	–	–	–	–	–
YCOND	B	.61*	.24*		–	–	–	–	–	–	–.18*	–	–
	S	.45*	.26*		–	–	–	–	–	–	.20*	–	–
YGR	B	.24*	.44*	.29*		–	–	–	–	–	–	.15*	–
	S	.12	.71*	.35*		–	–	–	–	–	–	–.12	–
FCOND	B	.59*	.21*	.40*	.11		–	–.32*	–.44*	–	–	–	–
	S	.34*	–.12	.27*	–.08		–	.25*	–.16	–	–	–	–
FGR	B	–.05	.39*	.11	.78*	–.15*		–	–	–	–	–	–
	S	–.05	.50*	.22*	.67*	–.23*		–	–	–	–	–	–
KWT	B	–.20*	–.12	.11	.08	–.32*	.18*		.81*	–.18*	–	–	–.01
	S	.06	.06	.11	.04	.25*	.04		.68*	.29*	–	–	.29*
PCKWT	B	–.45*	–.22*	–.13	.02	–.44*	.11	.81*		–.47*	–	–	–
	S	–.33*	.05	–.10	.16	–.16	.26*	.68*		–.13	–	–	–
RA	B	.47*	.23*	.31*	.28*	.33*	.19*	–.18*	–.47*		.31*	–.04	–
	S	.34*	.11	.35*	.07	.43*	.05	.29*	–.13		.54*	.28*	–
RAPCW	B	–.19*	–.12	–.18*	–.21	–.26*	–.01	–.07	–.01	.31*		–	–
	S	.23*	.08	.20*	–.02	–.15	.02	–.14	–.16	.54*		–	–
BF	B	.05	–.10	.12	.15*	.31*	–.11	.30*	.33*	–.04	–.33*		.27*
	S	.12	–.12	.13	–.12	.36*	–.11	.36*	.21*	.28*	–.22*		.52*
MAR	B	.36*	–.01	.24*	.03*	.31*	–.10	–.01	–.31	.45*	–.08	.27*	
	S	.25*	–.05	.22*	–.08	.45*	–.20*	.29*	–.12	.39*	–.11	.52*	

[a] Correlation coefficients above the diagonal are those that differ significantly between bulls and steers ($P < .05$).
[b] Correlation coefficients below the diagonal represent the degree of relatedness between two traits, either significant or nonsignificant, and do not necessarily differ between sexes.
*$P < .05$.

TABLE 11. WITHIN SEX CORRELATION COEFFICIENTS FOR CARCASS TRAITS[a]

Carcass traits[b]	Sex[c]	Carcass traits[b]											
		CW	CWPDA	KWT	PCKWT	RA	RAPCW	BF	MAR	ATEN	CQR	PLC	CVG
LW	B	.95	–	–.07	–.41	–	–	.17	–	–	.28	.33	.33
	S	.92	–	.39	–.09	–	–	.42	–	–	.48	–.15	.15
CW	B		.97	–.07	–.37	–	–	.23	–	–	.24	.27	–.27
	S		.99	.47	.07	–	–	.54	–	–	.49	–.29	.28
CWPDA	B			–.09	–.36	–	–	.23	–	–	.18	.24	–.24
	S			.43	.04	–	–	.50	–	–	.47	–.27	.26
KWT	B				.81	–.18	–		.01	–.53	–	–	–
	S				.68	.29	–		.29	–.04	–	–	–
PCKWT	B				–	–.47	–	–	–	–.59	–	–.70	.70
	S				–	–.13	–	–	–	–.21	–	–.48	.50
RA	B						.31	–.04	–	–	–	.78	–.79
	S						.54	.28	–	–	–	.43	–.44
RAPCW	B							–	–	–	–	.57	–.57
	S							–	–	–	–	.76	–.77
BF	B								.27	–	–	–	–
	S								.52	–	–	–	–
MAR	B										.88	.31	–.31
	S										.96	–.18	.18
ATEN	B										–.17	–.39	.38
	S										.15	–.11	.12
CQG	B											.10	–.11
	S											–.13	.13
PLC	B												–.99
	S												–.995

[a]Only selected correlation coefficients that were significantly different between sexes are listed.

[b]LW = live slaughter weight; CW = carcass weight; CWPDA = carcass weight per day of age; KWT = kidney and kidney fat weight; PCKWT = percent kidney weight; RA = ribeye area; RAPCW = ribeye area per hundredweight of carcass; BF = backfat thickness; MAR = marbling score; ATEN = Armour tenderometer; CQG = carcass quality grade; PLC = percent lean cuts; CYG = carcass yield grade.

[c]B = bulls; S = steers.

TABLE 12. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR WEANING CONDITION SCORES[a]

Breed of dam	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	9.99 ± .40	21	7.68 ± .36	2.31
Hereford	157	8.95 ± .16	119	7.04 ± .15	1.91
Charolais x Holstein	6	7.86 ± .61	9	6.27 ± .49	1.59
Simmental x Hereford	5	7.32 ± .67	16	7.54 ± .38	-0.22
Charolais x Hereford	27	7.94 ± .30	46	7.38 ± .23	0.56

[a]6-8 = Standard; 9-11 = Good.

TABLE 13. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR YEARLING AVERAGE DAILY GAIN (kg/DAY)

Breed of dam	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	0.65 ± .05	21	0.43 ± .05	0.22
Hereford	157	0.55 ± .02	119	0.32 ± .02	0.23
Charolais x Holstein	6	0.39 ± .08	9	0.37 ± .06	0.02
Simmental x Hereford	5	0.47 ± .09	16	0.42 ± .05	0.05
Charolais x Hereford	27	0.50 ± .04	46	0.42 ± .03	0.08

TABLE 14. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR YEARLING CONDITION SCORES[a]

Breed of dam	Bull: Number of observations	Bull: Least-squares means	Steer: Number of observations	Steer: Least-squares means	Bull-steer difference
Angus	22	8.57 ± .25	21	7.40 ± .23	1.17
Hereford	157	7.72 ± .10	119	7.03 ± .09	0.69
Charolais x Holstein	6	6.24 ± .38	9	6.31 ± .31	-0.07
Simmental x Hereford	5	7.03 ± .41	16	7.64 ± .24	-0.61
Charolais x Hereford	27	7.56 ± .18	46	7.18 ± .14	0.38

[a] 6-8 = Standard; 9-11 = Good.

TABLE 15. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR 18-MONTHS WEIGHTS

Breed of dam	Bull		Steers		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	453 ± 14.34	21	367 ± 12.99	86
Hereford	157	454 ± 5.61	119	349 ± 5.43	105
Charolais x Holstein	6	429 ± 21.73	9	406 ± 17.67	23
Simmental x Hereford	5	444 ± 23.96	16	398 ± 13.51	46
Charolais x Hereford	27	463 ± 10.59	46	389 ± 8.20	74

TABLE 16. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR 18-MONTHS WEIGHT PER DAY OF AGE (kg/DAY)

Breed of dam	Bulls		Steers		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	0.85 ± .03	21	0.69 ± .02	0.16
Hereford	157	0.85 ± .01	119	0.66 ± .01	0.19
Charolais x Holstein	6	0.81 ± .04	9	0.77 ± .03	0.04
Simmental x Hereford	5	0.84 ± .05	16	0.75 ± .03	0.09
Charolais x Hereford	27	0.87 ± .02	46	0.73 ± .01	0.14

TABLE 17. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR 18-MONTHS AVERAGE DAILY GAIN (kg/DAY)

Breed of dam	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	0.70 ± .04	21	0.49 ± .04	0.21
Hereford	157	0.79 ± .02	119	0.51 ± .01	0.28
Charolais x Holstein	6	0.60 ± .06	9	0.57 ± .05	0.03
Simmental x Hereford	5	0.69 ± .07	16	0.58 ± .04	0.11
Charolais x Hereford	27	0.72 ± .03	46	0.54 ± .02	0.18

TABLE 18. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR 18-MONTHS CONDITION SCORES[a]

Breed of dam	Bull: Number of observations	Bull: Least-squares means	Steer: Number of observations	Steer: Least-squares means	Bull-steer difference
Angus	22	10.31 ± .40	21	7.74 ± .36	2.57
Hereford	157	9.46 ± .16	119	7.33 ± .15	2.13
Charolais x Holstein	6	8.69 ± .60	9	7.36 ± .49	1.33
Simmental x Hereford	5	8.40 ± .66	16	7.61 ± .37	0.79
Charolais x Hereford	27	8.46 ± .29	46	7.26 ± .23	1.22

[a]6-8 = Standard; 9-11 = Good.

TABLE 19. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR LIVE SLAUGHTER WEIGHT (kg)

Breed of dam	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	22	515 ± 14.86	21	403 ± 13.26	112
Hereford	157	505 ± 5.80	119	391 ± 5.58	114
Charolais x Holstein	6	471 ± 22.27	9	440 ± 18.09	31
Simmental x Hereford	5	488 ± 24.41	16	415 ± 13.83	73
Charolais x Hereford	27	527 ± 10.82	46	421 ± 8.33	106

TABLE 20. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR PERCENT KIDNEY AND KIDNEY FAT PER CARCASS WEIGHT (%)

Breed of dam	Bull: Number of observations	Bull: Least-squares means	Steer: Number of observations	Steer: Least-squares means	Bull-steer difference
Angus	18	1.11 ± .02	21	2.66 ± .02	-1.55
Hereford	146	1.23 ± .01	119	2.64 ± .01	-1.41
Charolais x Holstein	6	2.01 ± .03	9	2.43 ± .03	-0.42
Simmental x Hereford	5	2.05 ± .04	16	2.55 ± .02	-0.50
Charolais x Hereford	24	1.56 ± .02	46	2.63 ± .01	-1.07

TABLE 21. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR RIBEYE AREA (cm^2)

Breed of dam	Bull		Steer		Bull-steer difference
	Number of observations	Least-squares means	Number of observations	Least-squares means	
Angus	17	35.74 $\pm$ 1.32	21	26.06 $\pm$ 1.09	9.68
Hereford	146	34.49 $\pm$ .48	119	24.33 $\pm$ .46	10.16
Charolais x Holstein	6	33.55 $\pm$ 1.85	9	26.82 $\pm$ 1.50	6.73
Simmental x Hereford	5	31.57 $\pm$ 2.03	16	27.64 $\pm$ 1.14	3.93
Charolais x Hereford	24	34.93 $\pm$ .94	46	27.15 $\pm$ .69	7.78

TABLE 22. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR PERCENT LEAN CUTS (%)

	Bull		Steer		
Breed of dam	Number of observations	Least-squares means	Number of observations	Least-squares means	Bull-steer difference
Angus	17	54.37 ± .39	21	52.23 ± .32	2.14
Hereford	146	54.32 ± .14	119	52.06 ± .13	2.26
Charolais x Holstein	6	53.78 ± .54	9	52.92 ± .44	0.86
Simmental x Hereford	5	53.01 ± .59	16	52.87 ± .33	0.14
Charolais x Hereford	24	53.97 ± .27	46	52.60 ± .20	1.37

TABLE 23. LEAST-SQUARES MEANS AND STANDARD ERRORS BY BREED OF DAM BY SEX OF CALF INTERACTIONS FOR CARCASS YIELD GRADE

	Bull		Steer		
Breed of dam	Number of observations	Least-squares means	Number of observations	Least-squares means	Bull-steer difference
Angus	17	1.08 ± .17	21	2.03 ± .14	-0.95
Hereford	146	1.13 ± .06	119	2.11 ± .06	-0.98
Charolais x Holstein	6	1.28 ± .24	9	1.73 ± .19	-0.45
Simmental x Hereford	5	1.70 ± .26	16	1.77 ± .15	-0.07
Charolais x Hereford	24	1.25 ± .12	46	1.86 ± .09	-0.61

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BULL-STEER COMPARISONS FOR GROWTH
AND CARCASS TRAITS

by

Wayne E. Wyatt

(ABSTRACT)

Data for this study was collected over a six-year period (1970 through 1975) on 217 bulls and 211 steers at the Bland Correctional Center, Bland, Virginia. Animals of this study were primarily crossbreds of Angus, Charolais, Hereford, Holstein and Simmental breeds. The objective of this study was to compare bulls and steers for growth and carcass traits. Bulls (220, 310, 449 kg) weighed more than did steers (204, 273, 381 kg) at weaning, 12 and 18 months of age, respectively, ($P < .05$), and scored higher on condition at weaning and 18 months of age ($P < .05$). Bulls (501, 281, 0.48 kg) were also heavier than steers (414, 219, 0.39 kg) for live slaughter weight, carcass weight, and carcass weight per day of age, respectively, ($P < .05$). Bulls and steers did not differ in ribeye area per 100 kg of carcass weight, backfat thickness, and marbling scores. Percent kidney and kidney fat per carcass weight was less in bulls (1.59%) than steers (2.58%) ($P < .05$). Bull carcasses graded low good whereas steer carcasses graded low to middle good. Armour tenderometer measurements were 8.25 kg and 7.09 kg for bulls and steers, respectively, ($P < .05$), with any reading below 8.2 kg being of acceptable tenderness. Carcass yield grades were 1.29 and 1.90 for

bulls and steers, respectively, ($P < .05$). The superior growth rate of bulls and the minimal sex differences in carcass quality renders the present market bias against bull beef questionable.