COMPARISON OF CHAROLAIS AND LIMOUSIN AS TERMINAL CROSS SIRE BREEDS

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Bachelor of Science

North Dakota State University

Fargo, North Dakota

1978

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1984

COMPARISON OF CHAROLAIS AND LIMOUSIN

AS TERMINAL CROSS SIRE BREEDS

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ACKNOWLEDGMENTS

Sincere appreciation and thanks are extended to Dr. R. R. Frahm for providing me the opportunity to make this study, and for his excellent guidance and counsel as major adviser throughout the course of this study. Thanks are also extended to Dr. K. S. Lusby and Dr. R. P. Wetteman for serving on my graduate committee.

I would also like to express my gratitude to Dr. J. V. Whiteman and the Oklahoma State University Animal Science Department for the opportunity to continue my education.

I wish to thank Don Marshall and Debra Aaron for their assistance in collection of data, and all the other graduate students for their friendship and encouragement.

A special thanks to my wife Sharon for her much needed patience, understanding, and support. I wish also to express appreciation to my sister Marion, brother-in-law Kris, and family for their special friendship, love, and support.

Finally, I would like to thank my parents, Albert and Mary Lou Dhuyvetter, and brothers and sisters for their love, understanding, and support which have allowed me to continue my education and produce this manuscript.

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CHAPTER I

INTRODUCTION

Crossbreeding has become widely advocated and accepted as a system of mating in commercial beef production. Hybrid vigor in crossbred cattle has been well established through experimentation to be of economic importance for many component characters of productivity. In addition, major differences among breeds have been demonstrated for most characters contributing to production efficiency. Differences in genetic merit of breeds can contribute to increased productivity by combining breeds to synchronize levels of performance to production conditions. Also maternal and sire breeds, differentiated by selection for characters of greatest economic importance associated with their specialized function, can be crossed in a complementary way in order to further improve efficiency within the production system.

Breed differences associated with additive effects of genes are important considerations in selecting breeds to be used in a production system and in planning crossbreeding systems. Numerous research studies have been conducted and are currently underway to evaluate breed characteristics associated with maternal and paternal function and to identify specific breed combinations that are most productive and efficient under given mating systems and particular environmental and management conditions.

This study is a portion of an extensive research project in progress at the Oklahoma Agricultural Experiment Station designed to evaluate lifetime productivity of various two breed cross cows when mated to sires of a third breed. This study focuses on the selection of the terminal sire breed to maximize production from such a crossbreeding scheme.

CHAPTER II

REVIEW OF LITERATURE

Benefits of Systematic Crossbreeding

Heterosis Effects

In a review of crossbreeding experiments, Long (1980) summarized heterosis levels for various characters associated with beef production. Heterosis was significant for most characters related to reproduction, survivability, and growth rate associated with crossbred cows and calves as shown in Table I. These heterosis estimates indicate non-additive gene action is responsible for significant improvement in crossbreds relative to the average performance of purebreds for these characters. Most of the heterotic effects for carcass traits are a function of growth, and are absent when adjusted for carcass weight (Cundiff, 1970). The cumulative effects of heterosis on traits that contribute to the weight of calf weaned per cow exposed to breeding, increases productivity over 20 percent with crosses among breeds of Bos Taraus beef cattle (Gregory et al., 1965; Cundiff et al., 1974, 1980). Research suggests heterosis levels are greater between breeds with greater genetic diversity and productivity increases between

TABLE I

AVERAGE HETEROSIS AND MAXIMUM DIFFERENCE IN PERFORMANCE BETWEEN BREED CROSSES[a]

	Average Heterosis	Maximum Difference Between Breed Crosses[b]
Characters of Calf		
Calving rate of cows	0	16
Survival at birth	2	10
Survival to weaning	3	16
Gestation length	0	4
Calving difficulty	0-7	29
Birth weight	4	33
Preweaning ADG	4	38
Weaning weight	5	35
Postweaning ADG	6	28
Yearling weight	4	23
Mature weight	2.5	34
Dressing percent	0	4
Longissimus muscle area	3	25
Fat thickness	5	78
Quality grade	1	35
Characters of Cow		
Age at puberty	-3	29
Calving rate	9	10
Calf survival at birth	-1	3
Calf survival to weaning	1	6
Calf weaning weight	8	17
Milk yield	6	30

[a]Long, C. R. 1980. Crossbreeding for Beef Production. Review of crossbreeding experiments. J. Anim. Sci. 51:1197.

[b]% Maximum Difference = Maximum breed value - minimum breed value ÷ mean breed value X 100.

crosses among _Bos Taraus_ and _Bos Indicus_ breeds of cattle may be much greater (Cartwright et al., 1965; Koger et al., 1975). Over 60% of the cumulative heterosis contributing to increased productivity is attributable to heterosis effects on maternal characters. It is therefore particularly desirable to utilize crossbred females in commercial beef production breeding herds.

Combining Breed Characteristics

Additive genetic differences between breeds results in differences in the level of performance for various characters between breeds. As shown in Table I (Long, 1980), the difference between breed crosses with the highest and lowest mean level of performance for production traits from a review of breed diallels and sire characterization experiments can be substantial. Crossbreeding allows the combining of desired characteristics in crossbreeds that would not be possible in any parent breed alone. Through crossbreeding, performance characters can be more effectively synchronized to production conditions. In southern United States, crosses between heat-tolerant Brahman and British breeds with superior fertility and carcass characteristics, results in substantial heterosis and performance characteristics associated with greater productivity (Kincaid, 1962; Mason, 1966). Experiments with Charolais indicate the breed has greater pre- and post-weaning growth rate and higher cutability than British breeds, but a lower weaning rate. The primary benefit of crossing these breeds appears to be from combining the desirable characteristics of both (Klosterman et al., 1968; Damon et al., 1959, 1960).

Breed Complementarity

An array of characters associated with the sire, the dam, and the calf components of the production system contribute to production efficiency. All three of these components of the production system perform different functions, and the characters of importance to each display some antagonistic relationships with characters of greatest importance to the other components. Genetic correlations exist between characters which makes it difficult for any one breed or selected population to excel in all characters of importance to all components of the production system.

Rate of gain has a moderately high positive genetic correlation with mature size (Brinks et al., 1964; Cundiff, 1980). This may be an antagonistic relationship for efficient beef production. The advantages of faster more efficient growth of calves produced by selection will be partially offset by larger mature cows with increased nutrient requirements for maintenance. Also associated with larger mature size is an increased age at puberty, which may delay the age at which females begin production and reduce cow herd efficiency (Laster et al., 1972).

Such relationships suggest selection for the best compromise, or the alternative of crossing breeds or lines with desired performance for characters associated with maternal and paternal function. Anticipated response to selection for increased early growth rate without increased mature size would be small. The alternative of discriminately matching cow-breeds and sire-breeds that complement each other conotates specific breed crosses result in greater production efficiency, that is largely independent from and additive to heterosis effects.

Table II (Cundiff, 1980) illustrates characters of importance and emphasis of selection for general purpose, maternal and paternal breeds. The use of large growthy sire-breeds in crosses with smaller mature size maternal populations does, however, pose the concern of the antagonistic relationship between birth weight and calving difficulty. A high positive correlation exists between birth weight and the important growth rate character of paternal breeds and with calving difficulty. Calving difficulty tends to increase linearly with birth weight and results in increased calf mortality and lowered rebreeding performance of the cow (Laster, 1973; Anderson and Bellows, 1967; Bellows et al., 1982). Smith et al. (1978) estimates calving difficulty and perinatal mortality to have positive genetic correlations with birth weight of .83 and .55, respectively. The production efficiency associated with crosses contributing to different levels of calving difficulty and growth rate will be dependent on the

TABLE II

SELECTION EMPHASIS ASSOCIATED WITH FUNCTION[a,b]

	Population		
	General Purpose	Maternal	Paternal (Terminal Sire)
Reproduction	++	+++	+
Growth			
Birth weight	-	-	0
Weaning weight	+	++	++
Yearling weight	+	0	+++
Mature size	0	0	+
Carcass			
Cutability	0 or +	0	++
Marbling	0 or +	++	0

[a]Some emphasis in negative direction (-); no (0), some (+), strong (++) and very strong (+++) emphasis in positive direction.

[b]Cundiff, 1980.

production system, level of management, and input costs. Matings between large size sire breeds and medium to small size cows that increase the amount and value of product relative to cow and calf costs would be desirable in commercial beef production.

In an evaluation of economic efficiency associated with terminal sire breeds, Smith (1976) reported large growthy sire breeds were favored for economic returns in spite of greater calving difficulty and calf death losses.

Crossbreeding System

Alternative systems of crossbreeding utilize heterosis (nonadditive gene effects) and breed differences (additive gene effects) to different extents in contributing to increased production efficiency. A comparison of terminal sire, rotational, and combination terminal sire-rotational crossbreeding systems is presented in Table III (Gregory et al., 1980) with the estimated increased weight marketed per cow exposed associated with each system of crossbreeding.

Static Terminal Sire

Terminal sire crossbreeding systems involve the mating of crossbred females to a third sire breed to produce three breed cross calves. Such matings result in maximum maternal and individual heterosis; however, to follow this system all progeny would be marketed and replacement females would need to be obtained from other breeding programs. The

TABLE III

COMPARISON OF CROSSBREEDING SYSTEMS[a]

Mating Type	Percent of Herd[b]	Percent of Calves Marketed	Individual Heterosis[c]	Maternal Heterosis[c]	Terminal Sire Contribution	Est. Increase in Wt. Marketed/ Cow Exposed[bcd]
Two-breed rotation crossbreeding system						
A·B rotation	100	100	5.6	9.9	0	15.5
					Total	15.5
Three-breed rotation crossbreeding system						
A·B·C rotation	100	100	7.3	12.7	0	20.0
					Total	20.0
Static-Terminal-sire crossbreeding system						
A[e]·A	25	16.6	0	0	0	0
B[e]·A	25	16.7	8.5	0	0	1.4
C[e] x (B·A)	10	13.3	8.5	14.8	0	3.1
T x (B·A)	40	53.4	8.5	14.8	5.0	15.1
					Total	19.6

TABLE III (Continued)

Mating Type	Percent of Herd[b]	Perecnt of Calves Marketed	Individual Heterosis[c]	Maternal Heterosis[c]	Terminal Sire Contribution	Est. Increase in Wt. Marketed/ Cow Exposed[bcd]
Two-breed rotation and Terminal-sire crossbreeding system						
A•B rotation	50	33.3	5.6	9.9	0	5.2
T x (A•B rotation)	50	66.7	8.5	9.9	5.0	15.6
					Total	20.8
Three-breed rotation and Terminal-sire crossbreeding system						
A•B•C rotation	50	33.3	7.3	12.7	0	6.7
T x (A•B•C rotation)	50	66.7	8.5	12.7	5.0	17.5
					Total	24.2

[a] Gregory et al., 1980

[b] Assumes 80% calf crop weaned and 20% replacement rate.

[c] Based on heterosis effect of 8.5% for individual traits and 14.8% for maternal traits and assumes that loss of heterosis is proportional to loss of heterozygosity.

[d] Assumes a 10% increase in breeding value for calf weight produced per cow exposed to terminal sires (T).

[e] Breeds A, B and C are assumed to be approximately equal in size, milk production, and maturation rate. Females of cross (B•A) are bred to sires of breed C to produce their first calf crop because of likelihood of calving difficulty; after first calf crop they are mated to terminal sires (T), which are assumed to have a breeding value for increased calf weight produced per cow exposed of 10% greater than breeds A and B.

opportunity for a particular production unit to maximize heterosis by terminal crossbreeding would be limited by the availability of desirable crossbred females.

Considering all beef production necessary to sustain terminal crossbreeding systems, on the average calves marketed will have less than maximum individual and maternal heterosis (Cundiff, 1977). A straightbred population needs to be maintained to produce two breed cross females and replacements for the straightbred population. This results in some of the necessary matings to sustain the production of three-breed cross calves, producing calves exhibiting no individual and maternal or no maternal heterosis.

Static terminal-sire crossbreeding systems do allow the opportunity to exploit breed differences, utilizing relatively small, well adapted cows mated to sires of breeds superior in growth traits and carcass composition. Complementary matings between breeds differing in genetic merit for production characters allows greater efficiency in beef produced relative to feed inputs of cows and calves.

Rotational

Rotational crossing systems involve the cyclic crossing of two or more breeds, such that females are mated to purebred sires of the breed included in the system that is least represented in their breed composition. The rotational system is self perpetuating since replacement females produced by these matings are mated to another breed of sire included in the rotation. Since the breeding herd contains various age females of differing breed composition, separate breeding groups need to be maintained for each breed included in the rotation.

Heterosis levels will be somewhat less than maximum, since crossbreds are produced by matings between dams that have a portion of their breed composition in common with the breed of sire. Although heterosis levels will fluctuate in initial generations when the rotational system is being established, after seven generations the heterosis level is expected to stabilize in two-breed and three-breed rotation systems at 67% and 86% of maximum for both cows and calves (Dickerson, 1969, 1973). In a review of crossbreeding experiments evaluating the performance of straightbred, single-crosses, back crosses, and three-breed crosses by Gregory (1980), the level of heterosis expressed was found to be proportional to heterozygosity.

Advantages of rotational crossbreeding systems include substantial heterosis in cows and calves produced and the production and opportunity for selection of replacements within a production unit. However, since breeds used in the rotation are represented as sires and in the females in the breeding herd, dual purpose breeds reasonably comparable in additive genetic merit should be used to facilitate common management and desirable performance. Rotational crossing systems are therefore limited in utilizing complementary breed differences.

Combination Rotational-Terminal Sire

Combined breed rotation and terminal-sire crossbreeding systems can take advantage of heterosis produced by rotational systems and complementary provided by terminal sire systems. By utilizing a rotational crossing system on younger cows replacements would be produced and heterosis would be used in all production. As cows become older and fewer calving difficulties are expected, they would be mated to large size terminal sire breeds for their genetic contribution for increased growth.

Deterministic computer simulation models have been adapted to analyze alternative crossbreeding systems. Cartwright and Fitzhugh (1975) concluded from a simulation model of two-breed and three-breed crossing systems, both heterosis and complementarity add to net efficiency of production and greatest production efficiency was associated with three-breed crosses using large terminal sire breeds on either two-breed cross cows or rotational cross cows. Notter et al. (1979) modeled an integrated beef production system to investigate the biological and economic efficiency of beef production. Systems that combined the use of terminal sire breeds on mature cows from rotational cross systems were found more efficient than rotational cross systems with smaller breeds. Consideration of the optimal size of the sire breed as a function of the price of feed for the cow herd relative to the price of feed used in the feedlot, resulted in the conclusion that if large terminal breeds were used on mature cows in a manner designed to minimize calving difficulty, there is a substantial reduction in cost per unit of beef marketed even when the ratio of the price of feedlot TDN to cow herd TDN is high. Using a linear programming model, Wilton and Morris (1976) compared straight breeding, three-breed rotational crossbreeding systems and terminal-sire crossbreeding systems. Using farm gross margin for evaluating system efficiency, terminal-sire systems utilizing large breed bulls on small cows were more efficient than three-breed rotational crossing systems.

Clarke et al. (1984) modeled a 500-head spring calving, cow-calf enterprize, evaluating the relative economic efficiency of three-breed rotational, three-breed terminal, and a combination of two-breed rotational-terminal crossbreeding mating systems under several cow culling strategies. Terminal and combination rotational-terminal systems using very large terminal sire breeds surpassed the three-breed rotational system in economic efficiency. The combination system was superior to the three-breed terminal system when cow replacement age was less than 12 years, reflecting greater utilization of individual and maternal heterosis.

The management of crossbreeding schemes that combine rotational and terminal matings is more complex; however, maximum efficiency of pounds of beef produced per unit of feed consumed by calves and cows is possible.

Terminal Sire Breeds

It is of importance to evaluate the influence particular breeds used in terminal crossbreeding systems have on total production efficiency. In addition to impregnating the female, the terminal sire's function is to contribute additive gene effects to the crossbred offspring for rate and efficiency of growth and carcass cutability and quality. Therefore it is important to characterize breeds to be used as sires for genetic differences for these traits, the associated level of calving difficulty which contributes to increased costs, and the overall production efficiency associated with mating particular sire and dam breeds.

In recent years, considerable research has been undertaken to characterize the many breeds of beef cattle available. Two breeds of French origin are among those breeds which have been suggested and currently being used as terminal sire breeds. Frahm (1977) suggested the Limousin breed may be a desirable choice as a terminal sire breed, since Limousin cross calves were characterized as very muscular and yielding a high dressing percentage with a high-lean low-fat composition. In addition, calving difficulties associated with the use of Limousin sires were less than with many other large beef breeds.

The Charolais breed has been available in the United States for a much longer period of time, and has been characterized by a fast growth rate and large mature size

(Klosteman et al., 1968; Damon et al., 1959, 1963; Peacock et al., 1978). In addition to crosses with beef breeds, Charolais sires are often mated to dairy females in European countries to increase beef production (Turton, 1964). Sumption et al. (1970), in a review of breeds available to North American cattlemen, categorized both the Charolais and Limousin breeds as desirable sire breeds for producing terminal crossbred calves. Both breeds were characterized by favorable pre- and post-weaning growth and desirable carcass yield.

Charolais and Limousin Comparison

The comparison of Charolais and Limousin breeds as sires in terminal crossbreeding systems requires reliable estimates of the relative performance of calves sired by both breeds. The Charolais and Limousin breeds have been evaluated as sire breeds for producing crossbred calves by mating to various dam breeds in Europe and North America.

Characters Related to Female Reproduction and Calf Survival

Lunstra (1980) found testis size as measured by scrotal circumference to be similar for yearling Limousin and Charolais bulls, but less than for bulls of other breeds measured. The smaller yearling scrotal measurement was associated with later puberty in Charolais and Limousin bulls. Information is lacking which characterizes sires of the Charolais and Limousin breeds for serving capacity and conception rates.

Smith et al. (1976) reported crossbred calves produced by mating Limousin sires to Angus and Hereford dams, had on the average a 2.2 day longer gestation period than Charolais sired calves out of similar dams. Similar results have been reported by Bergstrom (1966) in crosses with Black Pied dams, and by Reichen (1966) using Simmental dams. In a comparison of purebred Limousin and Charolais calves, Pattie et al. (1976) found the Limousin calves to have a 4.1 day longer gestation period.

As summarized in Table IV, it has been reported by a number of researchers that a greater percentage of Charolais-sired calves experience more difficult parturitions than Limousin sired calves (Belic et al., 1968; Rowden, 1970; Pattie et al., 1976; Laster et al., 1973; Smith et al., 1973; Freeden et al., 1982; Vissac, 1976; and Carter, 1975).

Associated with the higher incidence of calving difficulty among Charolais sired calves are greater calf death losses. Death losses within 24 hours of birth and subsequent death losses from birth to weaning of Charolais cross calves were reported to be greater than for Limousin cross calves by Smith et al. (1976) out of Herford and Angus dams, and by Freeden et al. (1982) out of crossbred dams. Similar findings were reported by Carter et al. (1976), in which Charolais cross calves out of Hereford and Angus dams

TABLE IV

PERCENT CALVING DIFFICULTY OF CHAROLAIS AND LIMOUSIN SIRED CALVES

Reference	Breed of Dams	Age of Dams	Calving Difficulty (%) Breed of Sire: Charolais	Limousin
Belic and Menissier (1968)	Normandy, Fresion & Garonne	Mature	25.9	11.0
Rowden (1970)	Hereford & Angus	2 year olds	70.0	71.0
		3, 4 & 5 year olds	16	10
Pattie and Menisser (1976)	Charolais & Limousin	2 year olds	48.3	23.1
		All ages	22.6	5.3
Lasater (1973)	Hereford & Angus	2, 3, 4 & 5 year olds	30.9	30.8
Smith et al. (1976)	Hereford & Angus	All ages	34.0	24.0
Freeden et al. (1982)	Hereford X Angus, Simmental X Hereford, Simmental X Angus	2, 3 & 4 year olds	6.2	1.8
Vissac (1976)	Maine Anjou, Charolais, Limousine & Hereford	2 & 3 year olds	32	26
Carter et al. (1976)	Hereford & Angus	All ages	18	6

had a preweaning mortality rate of 14% in comparison to 7% for Limousin cross calves. The difference in death loss among Charolais and Limousin cross calves was reported by Rowden (1970) to be greater when sires are mated to two-year-old Hereford and Angus dams than if mated to older dams.

Size and Growth Characters

The birthweight of purebred Charolais calves was reported by Pattie et al. (1976) to be 5 kg heavier than purebred Limousin calves. Laster et al. (1973), Smith et al. (1976), Freeden et al. (1982), Carter (1976), and Anderson et al. (1977) reported birthweights on crossbred calves sired by Charolais and Limousin bulls out of various breed dams. Charolais sired calves were heavier at birth, as shown in Table V. Weight at one week of age was reported by Bergstrom (1966) for calves produced by mating Limousin and Charolais sires to Black Pied dams. Charolais cross calves were found to be 3.7 kg heavier. Charolais cross calves were reported to be 4.5 kg heavier than Limousin cross calves out of Sardinian dams by Bonelli et al. (1964) at 10 days of age.

Using Simmental dams, Reichen (1966) reported Limousin sired calves to be slightly heavier than Charolais sired calves at two weeks of age. Since the dam has a larger influence on birthweight than the sire, the influence of the Simmental dams for heavy birthweight may have reduced the

TABLE V

BIRTHWEIGHT OF CHAROLAIS AND LIMOUSIN SIRED CROSSBRED CALVES

Reference	Breed of Dam	Birthweight (kg) Breed of Sire Charolais	Limousin
Laster (1973)	Hereford & Angus	36.4	35.8
Smith et al. (1976)	Hereford & Angus	38.6	36.2
Freeden et al. (1982)	Crossbred	43.7	41.2
Anderson et al. (1977)	Danish Red & Black Pied	45	38.6
Carter et al. (1976)	Hereford & Angus	34.1	30.9

TABLE VI

WEANING WEIGHT OF CHAROLAIS AND LIMOUSIN SIRED CALVES

Reference	Breed of Dam	Weaning weight (kg) Breed of Sire Charolais	Limousin
Bonelli et al. (1964)	Sardinian	230	214
Smith et al. (1976)	Hereford & Angus	207	197
Freeden et al. (1982)	Crossbred	220.8	212.9
Vissac (1976)	Maine Anjou, Charolais, Limousin	211	207
Carter et al. (1976)	Hereford & Angus	179.1	166.8

opportunity for differences in sire breed effects to be expressed.

Weaning weight of Charolais and Limousin cross calves has been reported by Smith et al. (1976) and Freedem et al. (1982) adjusted to 200 days of age; by Bonelli (1964) adjusted to 180 days, and by Vissac (1976), Carter et al. (1976) and Joandet (1973). Across studies, Charolais cross calves were consistently found to be heavier at weaning than Limousin cross calves as summarized in Table VI. Charolais sired calves gained 0.04 kg/day and 0.022 kg/day more from birth to weaning than Limousin sired calves, as reported by Smith et al. (1976) and Freeden et al. (1982). Gregory et al. (1982) reported greater calf mortality of Charolais sired calves resulted in similar weight weaned per cow calving for cows bred to Limousin and Charolais sires.

Postweaning average daily gains and feed conversion for Charolais and Limousin sired crossbred calves are summarized in Table VII. (Frebling et al., 1967; Bergstrom, 1967; Reichen, 1966; Smith et al., 1976; Visac, 1976; Anderson et al., 1977; Adams et al., 1973). Six of seven studies, including both forage and grain based diets, reported Charolais sired calves had higher average daily body weight gains than Limousin sired calves to both body composition and age endpoints. Freblind et al. (1967), Reichen (1966), Vissac (1976) and Adams et al. (1973) found Limousin sired calves required fewer units of feed per unit of gain in contrast to Bergstrom (1966), Smith et al. (1976) and

TABLE VII

POST WEANING AVERAGE DAILY GAIN AND FEED CONVERSION OF CHAROLAIS AND LIMOUSIN SIRED CROSSBRED CALVES

Reference	Breed of Dam	Diet	Feeding Endpoint	Postwean ADG (kg/day)		Feed Conversion	
				Breed of Sire		Breed of Sire	
				Charolais	Limousin	Charolais	Limousin
Freblin et al. (1967)	Aubrac		Finish	1.27	1.16	8.0	7.6[a]
Bergstrom (1966)	Black Pied		Finish	1.03	.94	3293	3582[b]
Reichen (1966)	Simmental	Ab lib silage	Finish	.91	.83	3.75	3.65[a]
Smith et al. (1976)	Hereford & Angus	Corn silage concentrate protein supplement	217 days on feed 470 kg weight 5% longissimus fat	1.24	1.08	20.62 19.49 21.63	20.91[c] 21.23[c] 23.29[c]
Vissac (1976)	Maine Angou Charolais Limousin		15 months age	1.47	1.40	7.5	7.2[a]
Anderson et al. (1977)	Danish Black Pied Red		300 kg weight 12 months age 15 months age	1.27	1.18	3.97	4.23[d]
Adams et al. (1973)	Hereford	85% concentrate	Estimated Low Choice Grade	1.20	1.25	7.02	6.97[a]

[a]kg feed/kg grain; [b]starch equivalent/kg gain; [c]MCAL ME/kg gain; [d]Scandinavian feed units/kg gain

Anderson et al. (1977), which reported Charolais sired calves to be more efficient in converting feed to body gain.

Koch et al. (1976) reported the weight of Charolais and Limousin cross calves out of Hereford and Angus dams adjusted to a starting age of 240 days with 217 days on feed. Adjusted 457 day weight of Charolais cross calves was found to be 33 kg heavier than for Limousin crosses. Smith et al. (1976) reported the difference at 405 days of age to favor the Charolais cross calves by 42 kg. Vissac (1976) reported Charolais cross calves to be 34 kg heavier than Limousin crosses at 15 months of age. Charolais sired crossbred calves were also found to be heavier and younger at slaughter than Limousin sired calves when fed to an estimated finish or body composition endpoint. Charlois cross steers and heifers with an average age of 506 days and 3.8% carcass fat were reported by Reichen (1966) to be 26 kg heavier at slaughter than Limousin cross steers and heifers with an average age of 511 days and 4.2% carcass fat. Frebling et al. (1967), Koch et al. (1976) and Anderson et al. (1977) reported Charolais sired calves to be heavier at slaughter than Limousin sired calves at similar percentages of fat in carcasses produced by 61, 6, and 21 kg, respectively.

Carcass Characters

Frebling et al. (1967), Adams et al. (1976), Koch et al. (1976), Bonelli et al. (1964) and Anderson et al. (1977)

reported Charolais sired crossbreds produced heavier carcasses than Limousin sired crossbreds at an estimated common finish endpoint. Carcasses of Charolais crosses were also heavier at a common age endpoint (Koch et al., 1976; Vissac, 1976). Estimates of the dressing percentages of Limousin and Charolais sired crossbred cattle are summarized in Table VIII (Frebling et al., 1967; Bergstrom, 1967; Reichen, 1968; Koch et al., 1976; Vissac, 1976; Adams et al., 1973; and Anderson et al., 1977). Limousin crossbreds have been generally found to have a higher dressing percent.

Dumont et al. (1968), Bergstrom (1967), Reichen (1968) and Anderson et al. (1977) reported that carcasses of Limousin crossbreds had a greater ratio of muscle weight to bone weight than Charolais crosses. Adams et al. (1976) reported no difference in Charolais and Limousin Hereford-cross steers for the ratio of edible portion per bone. Reichen (1968), Vissac (1976) and Anderson et al. (1977) reported the percent muscle in carcasses of Limousin and Charolais sired crossbred cattle were similar; however, Limousin crosses were reported to have a higher % fat and a lower % bone in the carcass than Charolais crosses (Anderson et al., 1977; Koch et al., 1976).

Koch et al. (1976) reported on data obtained from the carcasses of steers produced by mating Limousin and Charolais sires to Hereford and Angus dams. Composition and quality characteristics of carcass were compared at a constant age (217 days on feed), constant weight (288 kg

TABLE VIII

DRESSING PERCENT OF CROSSBRED CATTLE SIRED BY CHAROLAIS AND LIMOUSIN SIRES

Reference	Breed of Dam	Feeding Endpoint	Carcass Composition		Dressing Percent	
			Breed of Sire		Breed of Sire	
			Charolais	Limousin	Charolais	Limousin
Frebling et al. (1967)	Aubrac	Finish	14.8	14.2[a]	60.2	58.9
Bergstrom (1967)	Normandy Fresian Garonne	Finish	19.8	23.5[b]	59.0	60.3
Reichen (1968)	Black Pied	Finish	3.8	4.2[b]	54.3	54.5
Koch et al.	Hereford Angus	217 days on feed	15.8	15.8[c]	63.6	64.7
		5% L. Fat	16.2	18.5[c]	63.6	64.4
		288 kg car. wt.	13.9	14.9	63.1	64.2
Vissac (1976)	Maine Anjou Charolais Limousin	15 months age			67.7	67.7
Adams et al. (1973)	Hereford	Body finish	27.0	27.8[b]	61.2	62.1
Anderson et al. (1977)	Danish Black	Weight & age	13.1	14.2[b]	54.8	56.0

[a]% Fat at 11th rib; [b]% Fat in carcass; [c]% Fat trim.

carcass weight), and constant percentage fat in longissimus muscle (5% equivalent to a marbling grade of Small). Limousin sired steers had more external and internal fat, larger longissimus muscle area and less longissimus fat than Charolais sired steers at all endpoints, with the exception of when fed to a constant longissimus fat content. To this endpoint Limousin sired steers required 36 days longer on feed than Charolais sired steers. After 217 days on feed, Charolais sired steers received a higher average marbling score, lean color score, quality grade, and lower Warner-Bratzler shear force rating. Taste panel evaluation for tenderness, flavor, juiciness, and acceptability found Limousin crosses to be slightly less tender than Charolais crosses; however, both were very acceptable.

Adams et al. (1977) made carcass composition and palatability comparisons on steers by Charolais and Limousin sires out of Hereford dams when fed to an estimated USDA Low Choice grade. External fat thickness, percent internal fat, longissimus muscle area, maturity score, marbling score, Warner-Bratzler shear force and USDA quality and yield grades were reported to be similar for steers by both breeds of sire. No significant differences were detected by taste panel evaluation for flavor, juiciness, tenderness and palatability. Anderson et al. (1977) reported young Limousin cross bulls to have greater longissimus dorsi area and more caudal fat than Charolais cross at common ages. Liberiussen et al. (1977) evaluated the physical, chemical, and palatability characteristics of the longissimus dorsi and semitendinous muscle of young crossbred bulls produced by mating beef sires to Danish dairy cows. Limousin cross bulls had slightly more intermuscular fat and lower collagen solubility than carcasses of Charolais cross bulls, while differences in lean color, tenderness, flavor, juiciness and overall acceptability were small and non-significant.

Berg et al. (1978) analyzed muscle weight distribution in young Limousin and Charolais crossbred bulls. Significant but small breed differences in the proportion of muscle in different joints at similar total muscle weight were reported. Koch et al. (1977) reported Limousin and Charolais breed groups to be similar in percentage of retail product, and stated that breeds do not greatly differ in distribution of muscle.

Summary

Research efforts have identified major differences between beef breeds for many characters and the cumulative effect of heterosis on traits contributing to production efficiency to be of major importance. Simulation and study of crossbreeding systems has documented the effectiveness of using large terminal sires to increase production efficiency. Limousin and Charolais have been characterized as having superior additive genetic merit for growth and carcass traits, suggesting their use as terminal sires.

Sire breed characterization studies have generally indicated crossbred calves sired by Charolais sires are heavier at birth than Limousin sired calves, and experience more calving difficulty and greater calf mortality. This is consistent with studies that have shown dystocia tends to increase with birthweight, and calves which experience dystocia have a lower survival rate. As would be expected from reported genetic correlations among measures of growth and weight at different ages, Charolais calves also grow faster and are heavier at weaning and slaughter. Reported differences in feed conversion between crossbred calves by Limousin and Charolais sires are inconsistent and nonclusive.

Although Charolais sired crossbreds have been found to be heavier at slaughter and produce heavier carcass, the Limousin crosses have been found to have a slightly higher dressing percent. Carcass quality and composition appear to be similar between Limousin and Charolais sired calves.

Smith (1976) evaluated economic efficiency associated with sire breeds in a terminal sire system. Consideration was given to calving difficulty, preweaning survival, growth rate, feed efficiency, carcass composition and quality grade in comparing sire breeds for retail product cost, profit per calf, and profit per cow at age (217 days on feed), weight (530 kg slaughter weight) and grade (5% *longissimus* fat) constant slaughter endpoints. Charolais crosses were reported to produce slightly more profit per calf; however, the Limousin crosses with greater calf survival produced slightly more profit per cow. Limousin and Charolais crosses were very similar in retail product cost at all slaughter endpoints.

Differences in growth rate, energetic efficiency, and carcass desirability between crossbred progeny of Limousin and Charolais sires are generally small. It appears both breeds have merit as sire breeds in terminal crossbreeding systems, which maximize conversion of beef resources by mating sires transmitting superior growth and carcass traits to small to medium size crossbred cows chosen to synchronize maternal performance to available feed and production resources. Economic advantage associated with either sire breed for producing terminal crossbred calves will likely be small and dependent on relative cost of feed, labor, and interest, and the type of cows to be mated to.

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CHAPTER III

COMPARISON OF CHAROLAIS AND LIMOUSIN AS TERMINAL CROSS SIRE BREEDS

Summary

Birth, weaning, feedlot and carcass traits were evaluated on 1181 calves sired by Charolais and Limousin sires out of eight different crossbred dam groups (Hereford X Angus, Angus X Hereford, Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, Brown Swiss X Hereford, Jersey X Angus, Jersey X Hereford). Calves were born in the spring over a four year period in which dams ranged from 3 to 8 years of age. Charolais crosses were 2.7 kg heavier ($P<0.01$) at birth and had a 9.9% higher ($P<0.05$) incidence of difficult calvings and 4.6% greater ($P<0.05$) preweaning death loss than Limousin crosses. Charolais sired calves outgained Limousin sired calves by 34 g/day from birth to weaning and were 9 kg heavier ($P<0.01$) at weaning (231.7 ± 1.3 vs 222.7 ± 1.2 kg). Following weaning, calves were self-fed a finishing ration and slaughtered as each animal attained an estimated low choice grade. Charolais cross calves gained 61 g/day faster ($P<0.01$) than Limousin crosses, were fed 7 fewer days and were 17.3 kg heavier (521.1 ± 2.3 vs 503.8 ± 2.4 kg, $P<0.01$) at slaughter. Feed efficiency was similar for both sire breeds. On a grade equivalent basis Charolais crosses produced 7 kg heavier ($P<0.01$) carcasses and had more carcass weight per day of age ($71.6 \pm .5$ vs $69.3 \pm .5$ g, $P<0.01$). Charolais crosses had slightly less internal and external fat; however, dressing percent was higher for Limousin crosses (64.6 ± 0.1 vs 63.9 ± 0.1%, $P<0.01$). Longissimus area and carcass cutability were similar for crosses of both sire breeds.

(Key Words: Cattle, Charolais, Limousin, Crossbreeding, Terminal Sires.)

Introduction

Mating crossbred dams to sires of a third breed allows maximum utilization of heterotic effects and complementary breed differences. Computer simulations comparing beef cattle crossbreeding systems have indicated breeding programs which include matings to terminal sires with a high breeding value for growth rate, can maximize production efficiency (Cartwright et al., 1975; Fitzhugh et al., 1975; Wilton and Morris, 1976; Notter et al., 1979; Clarke et al., 1984). The choice of sire breed to produce terminal cross calves will be dependent on genetic differences between breeds for growth rate, energetic efficiency, and carcass desirability. The Limousin and Charolais breeds are among those used and suggested as sire breeds (Turton, 1964; Sumption et al., 1970; Vissac, 1976; Smith, 1976; Frahm, 1977). Crossbred progeny of Charolais sires have been characterized to be heavier at birth, experience more difficult births, and have greater calf mortality than Limousin sired calves out of similar dams (Belic et al., 1968; Pattie et al., 1970; Smith et al., 1976; Vissac, 1976; Anderson et al., 1977; Freeden et al., 1982). Charolais sired crossbred calves have also been reported to be heavier at weaning, gain more rapidly post-weaning, and be heavier at slaughter when fed to a constant grade endpoint, than Limousin sired cross calves (Bonelli, 1964; Bergstrom, 1966; Reichen, 1966; Frebling et al., 1967; Adams et al., 1973; Vissac, 1976; Smith et al., 1976; Anderson et al., 1977; Freeden et al., 1982). Smith et al. (1976) reported Charolais sired crossbred steers were more efficient in feedlot gains than Limousin crosses when fed to a constant carcass grade. Differences between Charolais and Limousin crosses for carcass composition, quality, and palatability have been small; however, Limousin crosses have been characterized by a slightly higher dressing percent with a lower proportion bone in the carcass (Frebling et al., 1967; Bergstrom, 1966; Reichen, 1966; Koch et al., 1976; Anderson et al., 1977). Dependent on economic conditions, the superior growth rate, feed efficiency, and carcass merit of cattle sired by very large terminal breeds such as Charolais can offset greater costs per calf weaned associated with increased calving difficulty (Smith, 1976). Increased calf mortality and lowered rebreeding performance of the cow are associated with calving difficulty (Laster et al., 1973;

Bellows et al., 1982), which tends to increase with birthweight, which is positively correlated to subsequent growth (Brinks, 1964). The objective of this study was to compare the birth to slaughter performance and carcass characteristics of crossbred progeny produced by mating Limousin and Charolais sires to various crossbred dam groups.

Materials and Methods

Data used in this study were collected from 1978 through 1982 as part of an extensive experiment in progress at the Oklahoma Agricultural Experiment Station to evaluate lifetime productivity of various two-breed cows wnen mated to sires of a third breed. The crossbred dams involved in this study were produced in 1973, 1974, and 1975 by mating Angus, Hereford, Simmental, Brown Swiss, and Jersey bulls to Angus and Hereford cows and retaining heifer calves. The cow herd has been described in detail by Belcher and Frahm (1979).

Experimental Design

Purebred Charolais and Limousin bulls were mated to eight different two-breed cross cow groups (Hereford X Angus, Angus X Hereford, Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, Brown Swiss X Hereford, Jersey X Angus, Jersey X Hereford) to produce a total of 589 steer and 592 heifer calves in the spring of 1978, 1979, 1980, and 1981. Cows were 3 to 5 years old in 1978, 4 to 6 years old in 1979, 5 to 7 years old in 1980 and 6 to 8 years old in 1981 at the time of calving. A different set of eight Limousin sires were used each year for a total of 32 different Limousin sires. Eight Charolais sires were used each year; however, some were used for two or three breeding seasons. Consequently, there were only 19 different Charolais sires. The number of sires repeated from previous years is presented in Table IX. Limousin sires were selected by the North American Limousin Foundation and used through artificial insemination with semen furnished by owners of the bulls, to produce 541 Limousin cross calves. Seventeen of the Charolais sires were purchased from Oklahoma breeders and selected on the basis of growth performance. The remaining two Charolais sires were from out of state and selected as representative of the Charolais breed. Semen from these two bulls was used to produce 61 of the 640 Charolais cross calves. Cows were randomly allotted to sires by breed type and age. The number of calves sired by a particular sire in a given year ranged from a low of 8 calves to a high of 24 calves.

Management and Data Collection

With the exception of 35 calves produced in 1978 that were reared in dry lot to weaning, calves were reared by their dams to an average age of 205 days on native and bermuda grass pasture at the Lake Carl Blackwell Research

TABLE IX

NUMBER OF SIRES BY YEAR

	Number of Sires[a]				
Sire Breed	1978	1979	1980	1981	Total[b]
Charolais	8	8 (3)	8 (4)	8 (6)	19
Limousin	8	8 (0)	8 (0)	8 (0)	32

[a]Number of sires previously used is shown in parentheses.

[b]Total number of different sires.

TABLE X

FINISHING RATION

Ingredient	Percent in Ration
Corn (IFN 4-02-931)	78
Alfalfa (IFN 1-00-063)	8
Cottonseed Hulls (IFN 1-01-599)	4
Molasses (IFN 4-00-668)	5
Supplemental pellets[a]	5
Total	100

[a]Supplemental pellets consisted of 67.6% soybean meal (44% IFN 5-04-604), 12% urea, 10% calcium carbonate, 8% salt plus Aurofac, Vitamin A and trace minerals.

Range west of Stillwater. Calves were born primarily during February and March each year. All calves were weighed within 24 hours of birth and assigned a calving difficulty score on a scale from 1 (no difficulty) to 5 (caesarean birth). Calving difficulty scores of 3, 4, and 5 were considered a difficult calving that required assistance from the herdsman. Calves were dehorned and castrated prior to one month of age. At an average age of 205 days, calves were weaned, weighed, and assigned a subjective condition and conformation score by a panel of at least three persons.

After weaning all calves were trucked to the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma, and placed in the feedlot the following day. Steers and heifers were placed in separate feeding barns, each consisting of fourteen 36 X 47 feet concrete floor pens. Twenty-one feet of each was covered under an open sided pole barn. All calves of a specific three-breed cross of the same sex were fed together in a pen assigned at random. Cattle were fed <u>ad libitum</u> the finishing ration presented in Table X. Feed was weighed as it was dispensed in the feeders and, after all animals had been removed from the feeding study, residual feed was weighed back. All calves received implants (Synovex-H for heifers and Synovex-S for steers) when entering the feedlot. In 1979 and 1980 a random half and in 1980 all calves in each pen were reimplanted after approximately 120 days on feed.

Cattle were weighed approximately every 30 days until the first animals were removed for slaughter. Adjusted yearling weights were calculated using weights obtained when cattle averaged one year of age. At this time cattle were subjectively scored for conformation. During the time cattle were being slaughtered, cattle were weighed and examined for degree of finish at two week intervals. Each animal was sent to slaughter when an estimated low choice carcass grade was attained. Visual appraisal of finish, lack of gain from the last weigh period, and carcass grade of previously slaughtered cattle were used by persons experienced in evaluating live slaughter cattle to determine when cattle reached the desired low choice carcass grade. Prior to shipment a shrunk weight was obtained.

Cattle were transported to a commercial slaughter plant in Tulsa and slaughtered the same or next day after arrival. Carcass data were obtained after a minimum of a 48 hour chill. Carcasses were evaluated for conformation, maturity, marbling, color, percent kidney, heart, and pelvic fat, and quality grade according to specifications outlined by U.S.D.A. (1965) by O.S.U. meat science faculty. Longissimus muscle area and external fat thickness was measured at the twelfth rib. Dressing percentage was calculatd by adjusting cold carcass weight to warm carcass weight and dividing by live shrunk weight at slaughter. Cutability was estimated by Murphey's equation [cutability = 51.34 - 5.784 (single fat thickness at 12th in inches) - 0.462 (% kidney, heart and pelvic fat) + 0.74 (rib eye area in square inches) -

0.0093 (hot carcass weight in pounds)].

Statistical Analysis

All traits except feed efficiency were analyzed by least squares, mixed model procedures (Harvey, 1977, 1982). The model for all traits analyzed by mixed model procedures included the fixed effects of sire breed, crossbred dam group, dam age, calf sex, and all two factor interactions. Three-factor interactions were assumed nonsignificant. Birth date was included as a covariate in the analysis of all traits, and marbling score was included as an additional covariate in the analyses of all carcass traits except marbling score. Random effects included in the model were years nested within sire breed and sires nested within year and sire breed. It would have been more descriptive of the design to consider sire breed and years crossclassified effects with sires nested in their interaction; however, programming limitations prevented the nesting within an interaction. Nonetheless, the model is appropriate since years within sire breed adjusts for year main effects and sire breed by year interaction effects (Smith et al., 1976b). Preliminary analyses with a model in which years were treated as a fixed effect and sire effects omitted, indicated two-way interactions with year and other fixed effects were not important. Significant sources of variation were determined from the analysis of each trait using full mixed models. The mean square for sires within year and sire breed was used to test sire breed and the years nested within sire breed. The residual mean square was used to test all other effects. Least square means were calculated from reduced models in which nonsignificant sources of variation were eliminated as shown in Tables XI, XII and XIII.

Feed efficiency was measured on a pen basis and had balanced subclass numbers, thus it was analyzed by analysis of variance procedures available in the Statistical Analysis System (Helwig and Council, 1979). The model included the fixed effects of sire breed, crossbred dam group, calf sex, and all two-way interactions between effects. Three-way interactions were assumed to be nonsignificant. The residual mean square was used to test the significance of all effects. Least square means were calculated from a reduced model in which nonsignificant effects were omitted as shown in Table XIV.

Results and Discussion

Analysis of Variance

Mean squares and degrees of freedom from analyses of variance for birth and weaning traits are shown in Table XV. Breed of sire was significant for birth weight, calving difficulty score, percent difficult calvings, preweaning ADG, 205-day weight, weaning condition score ($P<0.01$), and preweaning death loss ($P<0.10$). Sire breed was not significant for weaning conformation score. The sire breed

TABLE XI

SOURCES OF VARIATION INCLUDED IN REDUCED MODEL FOR BIRTH AND WEANING TRAITS

Source	Birth Weight	Calving Difficulty Score	Percent Calving Difficulty	Preweaning Death Loss	Birth to Weaning Average Daily Gain	205-day Weaning Weight	Weaning Conformation Score	Weaning Condition Score
Sire breed (B)	X	X	X	X	X	X	X	X
Year (Y)/B	X	X	X	X	X	X	X	X
Sire/Y/B	X	X	X	X	X	X	X	X
Crossbred Dam Group (D)	X				X	X	X	
Dam Age (A)	X	X		X	X	X		
Sex (S)	X	X	X		X	X	X	X
B X D								
B X A								
B X S								
D X A	X	X						
D X S								
A X S								
b_1 (birthdate)				X	X	X	X	X

X = Source of variation was included in reduced model.

TABLE XII

SOURCES OF VARIATION INCLUDED IN REDUCED MODEL FOR FEEDLOT TRAITS

Source	Initial Feedlot Weight	365-day Weight	Yearling Conformation Score	Average Daily Gain After 1st 120 days	Average Daily Gain After 120 Days	Average Daily Gain Entire Feeding Period	Days on Feed
Sire breed (B)	X	X	X	X	X	X	X
Year (Y)/B	X	X	X	X	X	X	X
Sire/Y/B	X	X	X	X	X	X	X
Crossbred Dam Group (D)	X	X	X	X		X	X
Dam Age (A)	X	X	X				
Sex (S)	X	X	X	X		X	
B X D							X
B X A							
B X S		X					
D X A							
D X S		X	X			X	
A X S							
b_1 (birthdate)	X	X	X	X		X	X

X = Source of variation was included in reduced model.

TABLE XIII

SOURCES OF VARIATION INCLUDED IN REDUCED MODEL FOR CARCASS TRAITS

Source	Final Weight	Carcass Weight/ day of age	Hot Carcass Weight	Dressing Percent	Single Fat Thickness	Average Fat Thickness	Carcass Grade	Longissimus Area	Kidney, Heart & Pelvic Fat	Cutability	Marbling Score
Sire breed (B)	X	X	X	X	X	X	X	X	X	X	X
Year (Y)/B	X	X	X	X	X	X	X	X	X	X	X
Sire/Y/B	X	X	X	X	X	X	X	X	X	X	X
Crossbred Dam Group (D)	X	X	X	X	X	X		X	X	X	X
Dam Age (A)								X			
Sex (S)	X	X	X					X	X	X	
B X D											
B X A											
B X S		X						X		X	
D X A								X			
D X S											
A X S											
b_1 (birthdate)	X	X	X					X			X
b_2 (marbling score)	X	X	X	X	X	X	X		X	X	

X = Source of variation was included in reduced model.

TABLE XIV

SOURCES OF VARIATION INCLUDED IN REDUCED MODEL FOR FEED EFFICIENCY

Source	
Sire breed (B)	X
Crossbred Dam Group (D)	X
Year (Y)	X
Sex (S)	X
B X D	
B X Y	X
B X S	
D X Y	
D X S	
Y X S	X

X = Source of variation was included in reduced model.

TABLE XV

MEAN SQUARES FOR BIRTH AND WEANING TRAITS

Source	df	Birth Weight (kg^2)	Difficult Calvings ($\%^2$)	Calving Difficulty Score	Preweaning Death Loss ($\%^2$)	205-day Weight (kg^2)	Preweaning ADG (kg/day^2)	Weaning Condition Score	Weaning Conformation Score
Sire breed (B)	1	1671.86**	2.59**	20.60**	.37+	20518.43**	.27**	1.99**	.32
Year (Y)/B	6	230.93**	.05	.63	.22+	32027.29**	.75**	6.81**	26.72**
Sire/Y/B	56	69.60**	.11*	1.03**	.11**	687.29**	.01*	.26*	.69**
Crossbred Dam Group (D)	7	658.15**	.12	.98	.07	10859.77**	.20**	.13	16.40**
Dam Age (A)	5	103.64**	.09	1.25+	.04	2137.82**	.04**	.13	1.23**
Sex (S)	1	1758.23**	.54**	4.65**	.03	35443.93**	.54**	1.03*	9.74**
B X D	7	4.50	.11	.89	.02	54.51	.00	.33+	.63
B X A	5	34.13	.06	.33	.03	281.83	.01	.36+	.13
B X S	1	55.07	.11	.65	.08	64.63	.00	.01	.52
D X A	35	37.75*	.07	.60	.05	377.27	.01	.17	.49
D X S	7	19.87	.13	1.32+	.10	346.50	.01	.26	.27
A X S	5	35.14	.01	.10	.12+	437.81	.01	.29	.41
b_1 (birthdate)	1	1.871	.11	.60	.30*	1892.83*	.03**	19.73**	74.02**
Residual[a]	954	25.74	.08	.67	.06	400.83	.01	.19	.38

[a] 1043 residual df for birthweight, difficult calvings, calving difficulty score, and preweaning death loss.

+ $p<0.10$

* $p<0.05$

** $p<0.01$

by crossbred dam group and sire breed by age of dam interactions were significant (P<0.10) for weaning condition score.

Presented in Table XVI are mean squares and degrees of freedom from analyses of variance for feedlot traits. Sire breed was significant for initial weight, adjusted yearling weight, yearling conformation score, ADG for the first 120 days on feed, ADG over the entire feeding period (P<0.01) and days on feed (P<0.10). Breed of sire was not significant for ADG for the period from 120 days on feed to slaughter. The breed of sire by sex of calf interaction was significant for adjusted yearling weight (P<0.10) and the breed of sire by crossbred dam group interaction was significant for days on feed (P<0.10).

Mean squares and degrees of freedom from analyses of variance for carcass traits are shown in Tables XVII and XVIII. Breed of sire was significant for live weight at slaughter, carcass weight per day of age, hot carcass weight, longissimus fat thickness (P<0.01), dressing percent (P<0.05), and percent kidney, heart, and pelvic fat (P<0.10). Sire breed was not significant for longissimus area, marbling score, and carcass grade. The breed of sire by sex interaction was significant for carcass grade, longissimus area, cutability (P<0.05) and carcass weight per day of age (P<0.10).

Mean squares and degrees of freedom from analyses of variance for feed efficiency is presented in Table XIX.

TABLE XVI

MEAN SQUARES FOR FEEDLOT TRAITS

Source	df	Initial Weight (kg^2)	Adjusted 365-day Weight (kg^2)	Yearling Conformation Score	ADG First 120 Days on Feed $(kg/day)^2$	ADG after First 120 Days on Feed $(kg/day)^2$	ADG over Entire Feeding Period $(kg/day)^2$	Days on Feed
Sire breed (B)	1	19888.29**	88581.07**	23.12**	.81**	3.98	.74**	9613.03+
Year (Y)/B	6	38306.932**	31022.52**	.43	1.28**	3.26	.93**	28313.76**
Sire/Y/B	56	665.93**	2987.49**	.45**	.06**	5.29**	.07**	2260.19**
Crossbred Dam Group (D)	7	10884.18**	35368.39**	.901**	.46**	1.48	.26**	8006.23**
Dam Age (A)	5	2159.00**	2376.13*	.55+	.05	.50	.01	1619.41
Sex (S)	1	33664.11**	317332.60**	4.26**	5.72**	2.26	5.11**	14.24
B X D	7	75.96	534.72	.24	.06	1.78	.03	2165.60+
B X A	5	245.99	1753.36	.27	.04	.33	.04	1111.46
B X S	1	33.07	4057.96+	.16	.07	1.35	.06	838.06
D X A	35	350.86	958.13	.25	.03	1.44	.02	1003.77
D X S	7	389.61	2077.19+	.46+	.05	1.77	.06*	976.66
A X S	5	498.09	1841.50	.14	.03	1.72	.05+	604.16
b_1 (birthdate)	1	440775.43**	3588.87+	8.17**	.47**	.41	.22**	37814.53**
Residual	895	416.43	1161.99	.25	.03	1.64	.02	976.82

+p<0.10
*p<0.05
**p<0.01

TABLE XVII

MEAN SQUARES FOR CARCASS TRAITS

Source	df	Slaughter Weight (kg^2)	Carcass Weight (kg^2)	Carcass Weight per Day of Age (kg^2)	Dressing Percent	Single Fat Thickness (cm^2)	Average Fat Thickness (cm^2)	Kidney, Heart & Pelvic Fat Fat ($\%^2$)	Longissimus Area (cm^4)	Cutability ($\%^2$)	Carcass Grade
Sire breed (B)	1	56214.55**	10934.39**	.138**	.009**	3.03**	2.06**	2.47+	12.90	8.67	.005
Year (Y)/B	6	24363.50**	8347.19**	.120**	.001	1.23**	2.45**	3.34**	621.09*	31.65**	.006+
Sire/Y/B	56	2751.10**	1451.92**	.014**	.001+	.387**	.39**	.81**	236.70**	5.26**	.003**
Crossbred Dam Group (D)	7	81926.50**	45091.54**	.110**	.003**	1.35**	.84**	1.18**	1324.54**	5.51*	.003
Dam Age (A)	5	1233.97	785.88	.006	.000	.13	.06	.46	143.10+	3.26	.002
Sex (S)	1	545574.26**	215811.74**	1.004**	.001	.13	.01	1.13+	574.50**	29.16**	.000
B X D	7	979.85	757.48	.008	.000	.06	.13	.36	45.37	1.15	.000
B X A	5	1607.62	872.49	.006	.001	.13	.19	.67	14.57	1.13	.002
B X S	1	3298.54	1701.71	.014+	.000	.39	.26	.02	547.87**	10.72*	.011*
D X A	35	1166.94	752.55	.004	.001	.13	.19	.66*	89.02+	3.02+	.002
D X S	7	2256.39	1120.63	.008	.001	.26	.26	.64	40.37	3.37	.001
A X S	5	3827.32*	1086.23	.004	.001	.06	.06	.48	14.98	1.49	.004+
b_1 (birthdate)	1	82463.44**	37268.72**	.068	.001	.01	.01	.00	1125.40**	.01	.003
b_2 (marbling score)	1	9761.12**	10671.15**	.014+	.007**	4.00**	5.87**	10.54**	33.71	77.83**	8.131**
Residual	891	1340.14	717.96	.004	.001	.13	.19	.41	66.592	2.26	.002

+p<0.10
*p<0.05
**p<0.01

TABLE XVIII

MEAN SQUARES FOR MARBLING SCORE

Source	df	Marbling Score
Sire breed (B)	1	.011795
Year (Y)/B	6	3.619213
Sire/Y/B	56	1.923395**
Crossbred Dam Group (D)	7	1.850108**
Dam Age (A)	5	.844877
Sex (S)	1	1.163414
B X D	7	.480457
B X A	5	.446843
B X S	1	.566760
D X A	35	.676616
D X S	7	1.128529^{+}
A X S	5	.511383
b_1 (birth date)	1	1.673894
Residual	891	.635303

$^{+}P<0.10$; $^{*}P<0.05$; $^{**}P<0.01$

TABLE XIX

MEAN SQUARES FOR FEED EFFICIENCY

Source		Feed Efficiency (kg feed/kg gain)[2]
Sire breed (B)	1	685.08
Crossbred Dam Group (D)	6	32948.36**
Year (Y)	3	123032.17**
Sex (S)	1	141219.01**
B X D	6	1391.61
B X S	1	2259.01
B X Y	3	15582.74**
D X Y	6	8397.68
D X S	18	24418.64
Y X S	3	8855.53^{+}
Residual	63	1148.54

Sire breed was not significant but the sire breed by year interaction was significant (P<0.01).

Birth and Weaning Traits

Breed of sire least square means for birth and weaning traits are presented in Table XX. Charolais sired calves were 2.7 kg heavier at birth and experienced more dystocia than Limousin sired calves. Charolais sired calves had a 9.9 percent higher incidence of difficult calvings requiring assistance, than Limousin sired calves, and a higher mean calving difficulty score (1.42 ± 0.05 vs 1.13 ± 0.05). Charolais cross calves had a 4.6 percent (9.3 ± 1.3 vs $4.7 \pm 1.4\%$) greater preweaning death loss than Limousin cross calves, which is likely associated with the increased calving dificulty experienced by Charolais cross calves. Since cows were closely observed during the calving period, the difference in preweaning death loss associated with sire breeds may be smaller than under less intensely managed calving.

Charolais sired crossbred calves were significantly heavier at weaning (231.7 ± 1.3 kg vs 222.7 ± 1.2 kg). This heavier weaning weight is attributable to the 2.7 kg heavier birthweight of Charolais calves compared to Limousin calves and a 34 g/day greater preweaning average daily gain. Charolais sired calves received higher subjective condition scores (5.17 ± 0.02 vs 5.03 ± 0.02) than Limousin sired calves at weaning. Weaning conformation scores were similar for

TABLE XX

LEAST SQUARE MEANS FOR BIRTH AND WEANING TRAITS

Sire Breed	Birth Weight (kg)	Difficult Calvings (%)	Calving[a] Difficulty Score	Preweaning Death Loss (%)	205-day Weight (kg)	Preweaning ADG (g/day)	Weaning[b] Condition Score	Weaning[c] Conformation Score
Charolais	38.6±.4	13.8±1.5	1.42±.05	9.3±1.3	231.7±1.3	945±13	5.17±.02	13.60±.04
Limousin	35.9±.4	3.9±1.5	1.13±.05	4.7±1.4	222.7±1.2	911±11	5.03±.02	13.60±.04
P<	.01	.01	.01	.05	.01	.01	.01	NS

[a]Calving difficulty: 1 = no difficulty, 2 = little difficulty, 3 = moderate difficulty, 4 = major difficulty, 5 = caesarian.

[b]Condition score equivalents: 1 = very thin, 5 = average, 8 = very fat.

[c]Conformation score equivalents: 12 = low choice, 13 = average choice, 14 = high choice.

calves by both sire breeds (13.6±0.04 vs 13.6±0.04).

Feedlot Traits

Breed of sire least square means for feedlot traits are presented in Table XXI. Initital feedlot weight was actual weaning weight rather than shrunk weight after trucking. Initial feedlot weight of Charolais cross calves was 9 kg heavier than Limousin cross calves. Average daily gain of Charolais sired calves was significantly greater than Limousin sired calves for the first 120 days on feed (1257±11 vs 1202±11 g/day), but nonsignificantly greater for the remaining feedlot period (1084±102 vs 944±101 g/day). The overall feedlot ADG of Charolais sired calves was 61 g/day greater than Limousin sired calves. On the basis of a constant carcass grade, Charolais sired calves were 17.3 kg heavier at slaughter and fed 7.0 fewer days than Limousin sired calves. There was a significant (P<0.10) sire breed by dam breed interaction for days on feed. The sire breed by crossbred dam subclass means (Table XXII) revealed this interaction for days on feed resulted from Charolais cross calves out of Hereford X Simmental and Hereford X Brown Swiss cross calves being on feed more days than Limousin sired calves out of Hereford X Simmental and Hereford X Brown Swiss cross dams. This reversal in rank for sire breeds for these particular crossbred cow groups is not readiy explainable.

Feed efficiency was not significantly different for

TABLE XXI

LEAST SQUARE MEANS FOR FEEDLOT TRAITS

Sire Breed	Initial Feedlot Weight (kg)	ADG First 120 Days on Feed (g/day)	ADG after First 120 Days on Feed (g/day)	ADG over Entire Feeding Period (g/day)	Final Feedlot Weight (kg)	Days on Feed	Feed Efficiency (kg feed/ kg gain)	Adjusted 365-day Weight (kg)	Yearling[a] Conformation Score
Charolais	231.7±1.2	1257±11	1084±102	1122±11	521.1±2.3	260±.98	7.88±.05	428.8±2.6	13.52±.03
Limousin	222.7±1.2	1202±11	944±101	1061±11	503.8±2.4	267±1.01	7.83±.05	408.9±2.6	13.19±.03
P<	.01	.01	NS	.01	.01	.05	NS	.01	.01

[a]Conformation score equivalents: 12 = low choice, 13 = average choice, 14 = high choice.

TABLE XXII

LEAST SQUARE MEANS BY SUBCLASS FOR TRAITS WITH SIGNIFICANT BREED OF SIRE INTERACTIONS

Sire breed	Crossbred Dam Group	Days on Feed	Adjusted 365-day Weight (kg)	Longissimus Area (cm^2)	Cut-ability (%)	Feed Efficiency (kg feed/ kg gain)
Charolais	Angus X Hereford	268±12.2				
	Hereford X Angus	252±12.5				
	Angus X Simmental	270±11.3				
	Hereford X Simmental	279±12.6				
	Angus X Brown Swiss	263±11.9				
	Hereford X Brown Swiss	265±12.3				
	Angus X Jersey	242±11.2				
	Hereford X Jersey	242±11.2				
Limousin	Angus X Hereford	274±12.4				
	Hereford X Angus	262±12.8				
	Angus X Simmental	273±11.1				
	Hereford X Simmental	275±13.2				
	Angus X Brown Swiss	268±12.4				
	Hereford X Brown Swiss	263±12.9				
	Angus X Jersey	259±10.7				
	Hereford X Jersey	261±10.4				

TABLE XXII (Continued)

		Days on Feed	Adjusted 365-day Weight (kg)	Longissimus Area (cm^2)	Cut-ability (%)	Feed Efficiency (kg feed/ kg gain)
<u>Sire breed</u>	<u>Sex of Calf</u>					
Charolais	Steer		449.5±9.4	84.5±1.29	50.0±.3	
	Heifer		408.2±9.4	84.5±1.29	50.7±.3	
Limousin	Steer		432.3±9.5	86.3±1.29	50.0±.3	
	Heifer		385.5±9.4	83.2±1.29	50.3±.3	
<u>Sire breed</u>	<u>Year</u>					
Charolais	1978					7.76±.10
	1979					8.37±.10
	1980					7.55±.10
	1981					7.84±.10
Limousin	1978					7.35±.10
	1979					8.33±.10
	1980					7.54±.10
	1981					8.09±.10

crossbred calves sired by Limousin and Charolais sire breeds (7.88±0.05 vs 7.83±0.05 kg feed/kg gain). Examination of the significant sire breed by year interaction found feed efficiency to be very similar in 1979 and 1980; however, Limousin sired calves were more efficient in 1978 and Charolais sired calves were more efficient in 1981 (Table XXII). This reversal may be mostly due to a different set of sires being used each year.

Adjusted yearling weight of Charolais cross calves was 19.9 kg heavier than Limousin cross calves. Breed of sire by sex subclass means (Table XXII) revealed their interaction resulted from the breed of sire difference being greater for heifers than steers (22 kg vs 18 kg). Charolais cross calves received higher yearling conformation scores than Limousin calves (13.52±0.03 vs 13.19±0.03).

Carcass Traits

Least square means by sire breed for carcass traits are presented in Table XXIII. With the exception of marbling score, least square means for carcass traits were adjusted to the average marbling score of 4.91 by linear regression. This is slightly below the equivalent of a marbling score of small, the minimal requirement for the U.S.D.A. choice grade.

Charolais sired cattle had a 0.7 percent lower dressing percentage than Limousin sired cattle, but since they were heavier at slaughter, yielded carcasses 7 kg heavier.

TABLE XXIII

LEAST SQUARE MEANS FOR CARCASS TRAITS

Sire breed	Carcass Weight (kg)	Carcass Weight per days of age (g)	Dressing Percent (%)	Single Fat Thickness (cm)	Average Fat Thickness (cm)	Kidney, Heart & Pelvic Fat (%)	Longissimus Area (cm^2)	Cutability (%)	Marbling Score	Carcass Quality Grade
Charolais	332.8±1.7	71.6±.5	63.9±.13	1.12±.03	1.57±.03	2.99±.04	84.7±.75	50.37±.10	4.93±.06	9.78±.002
Limousin	325.8±1.8	69.3±.5	64.6±.14	1.24±.03	1.67±.04	3.11±.04	84.8±.79	50.15±.10	4.89±.06	9.76±.002
P<	.01	.01	.01	.01	.05	.05	NS	NS	NS	NS

Charolais crosses produced 2.3 g more carcass weight per day of age than Limousin crosses (71.6±0.5 vs 69.3±0.5 g), reflecting the superior growth rate of Charolais cross calves. Charolais crosses were found to have slightly less internal fat (2.99±0.04 vs 3.11±0.04% kidney, heart, and pelvic fat) and external *longissimus* fat at the twelfth rib (1.57±0.03 vs 1.67±0.04 cm) than Limousin crosses at a constant amount of marbling. Carcass grade was not significantly different between Charolais and Limousin sired calves at a constant amount of marbling as would be expected, since carcass quality grade is primarily determined by marbling. The slightly lower carcass grade of Limousin sired calves might reflect a greater percentage of cattle being identified as dark cutters since carcass grade as determined by marbling was discounted for excessively dark *longissimus* muscle color. Since marbling score was not significantly different between cattle by both sire breeds, cattle were accurately identified as reaching a low choice grade. *Longissimus* area and cutability were not significantly different between sire breeds; however, significant breed of sire by sex of calf interactions existed (Table XXII). Examination of breed of sire by sex subclass means revealed the *longissimus* area was the same in Charolais sired steers and heifers but greater in Limousin sired steers than heifers. Cutability differences associated with sire breed were also inconsistent across sexes (Table XXII).

Economic Efficiency

An evaluation of production efficiency associated with sire breed requires consideration of calving difficulty, calf survival, growth rate, feed efficiency, carcass composition and carcass quality. Sire breed effects on economic efficiency were evaluated on a spring calving, terminal crossbreeding, production system using biological data obtained from this study by comparing net returns resulting from the use of Charolais and Limousin sire breeds.

Returns to the cow-calf phase of production were estimated by an enterprize budget (Lusby and Walker, 1983) in which the land resource was fixed at 405 hectares of native range, supporting a cow on 4.05 hectares and a yearling heifer on 2.03 hectares per year with protein supplementation during the winter months. The cow-calf budget simulated the selling of open and cull cows in the fall and the purchase of two-breed cross yearling heifers for replacements in the spring. Replacement rate was a function of an assumed 1% death rate, 3% management culls, and 8% plus an additional 15.9% of cows or first calf heifers experiencing calving difficulty (Laster et al., 1976) not becoming bred.

Yearling replacement heifers were bred to Shorthorn sires for their first calf and then subsequently to Charolais or Limousin sires. Belcher et al. (1979) reported two-breed cross first calf heifers experienced approximately

20% calving difficulty and weaned calves with an average weight of 193 kg when bred to Shorthorn sires. Cottonseed meal protein supplement and prairie hay were assumed to be fed at levels recommended for desired range management and cattle performance common to central Oklahoma. Prices prevailing in February 1984 were used to value breeding herd, purchased heifers, purchased bulls, cull cows, cull heifers, and calves; and also to set feed, pasture, and other cash costs. Fixed costs were based on a machinery, equipment, and facility investment of $35,000.00. Labor costs were set at $5,000.00 plus an additional $10.00 per difficult calving. It was assumed 75% of the operating capital was borrowed for a period of nine months. Equity in cattle, equipment, and facilities was set at 80% and the interest rate at 13%.

Feedlot returns were estimated for Charolais cross, Limousin cross, and Shorthorn cross calves by a cost of gain calculator developed by Gill (1983). Calves were assumed to be placed directly in the feedlot at weaning and sold at a low choice, yield grade 3, carcass grade at carcass prices prevailing in February 1984. Calf purchase cost was set equal to receipts generated in the cow-calf phase by selling the calf. As in the cow-calf phase, equity was set at 80% and interest rate at 13%. Cash costs were set by prevailing prices and labor costs were assumed to be $0.20 per day. Calves were ab libitum fed a ration containing 1.87 Mcal NEm/kg and 1.17 Mcal NEg/kg on a dry matter basis, which was

87.5% dry matter and cost \$.176 per kg dry matter. Shorthorn cross calves were assumed to be fed 283 days to produce a 301 kg low choice carcass on 7.85 kg feed per kg of gain. Feedlot returns per calf multiplied by the number of calves weaned from the cow-calf phase estimated the total feedlot returns. Cow-calf returns added to total feedlot returns allowed comparison of economic efficiency of beef production associated with sire breed.

As shown in Table XXIV, a 405 hectare cow-calf operation using Charolais sires was unable to maintain as many mature cows as compared to using Limousin sires, since more heifers have to be carried for replacements. In spite of the greater calf weight of Charolais cross calves and the sale of more cull cows, the use of Limousin sires produced slightly greater cow-calf receipts (\$54.84) due to a higher weaning rate and a larger proportion of the calf crop produced by mature cows mated to terminal sires. The greater replacement rate and level of calving difficulty associated with the use of Charolais sires also increased costs (\$679.01) resulting in the use of Limousin sires reducing losses in the cow-calf operation (-\$7909.58 vs -\$8643.43).

Feedlot returns per calf were greatest for Limousin crosses (minimum loss) and least for Shorthorn crosses. Although Charolais gained faster, were fed fewer days, and were heavier at slaughter, Limousin crosses returned \$10.09 more to costs, attributable to a slightly higher dressing

TABLE XXIV

COMPARISON OF COW-CALF AND FEEDLOT RETURNS
ASSOCIATED WITH SIREBREED

	Herd using Charolais Sires			Herd using Limousin Sires		
Cow-Calf	Cows	1st Calf Heifers	Yearling Heifers	Cows	1st Calf Heifers	Yearling Heifers
Numbers to stock 405-hectare operation	73.4	17.0	18.9	76.6	15.1	16.8
Annual costs						
Variable costs ($)		35244.47			34569.46	
Fixed costs ($)		3805.00			3801.00	
Total costs ($)		39049.47			38370.46	
Receipts						
Sale of calves ($)		24584.04			25177.78	
Sale of cull cows ($)		5031.60			4575.90	
Sale of cull heifers ($)		790.40			707.20	
Total receipts ($)		30406.04			30460.88	
Cow-calf returns ($)		-8643.43			-7909.58	

TABLE XXIV (Continued)

	Herd using Charolais Sires		Herd using Limousin Sires	
Feedlot	Charolais Cross	Shorthorn Cross	Limousin Cross	Shorthorn Cross
Number of calves produced in cow-calf operation	59.9	15.3	65.7	13.6
Feedlot costs				
Feed costs ($)	20956.61	5268.56	22369.54	4683.16
Non feed costs ($)	7147.87	1891.85	7916.20	1681.50
Interest costs ($)	1344.16	520.05	1147.12	462.26
Cattle costs ($)	20162.34	4421.70	21247.38	3930.40
Total costs ($)	49611.42	12102.16	52680.24	10757.32
Receipts ($)	46485.99	10732.64	49914.92	9540.13
Feedlot returns ($)	-4494.96		-3982.51	
Returns per calf ($)	-52.17	-89.50	-42.08	-89.50
Beef Production				
Returns ($)	-13138.39		-11892.09	

percent and lower interest costs. The use of Limousin sires also produced greater total feedlot returns (-$3982.51 vs -$4494.96) since fewer Shorthorn cross calves were produced and Limousin cross calves were most profitable.

Since the use of Limousin sires resulted in slightly greater cow-calf and feedlot returns, the total economic return to beef production was greater (-$11892.09 vs -$13138.39) than returns associated with the use of Charolais sires. The $1246.30 economic advantage associated with the use of Limousin sires is small in comparison to total costs and receipts, and is likely to be sensitive to the input costs of labor, feed, management, and capital.

General Conclusions

Although mated to a diverse group of crossbred cows, both sire breeds produced calves that were uniform with quite acceptable conformation, performance, and carcass desirability. It appears the economic advantage associated with less calving difficulty and greater calf survival of Limousin crosses would be at least partially offset by the greater growth rate of Charolais crosses and the difference in economic efficiency between sire breeds would likely be small. Limousin sires would be expected to have the greatest advantage when mated to small or younger cows and the least advantage when mated to large, mature cows where anticipated calving difficulty would be minimal. The selection of available bulls within the Limousin and

Charolais breeds and their relative cost may be as important as the choice of sire breed. It appears both the Charolais and Limousin breeds have merit as sire breeds in terminal crossbreeding systems.

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APPENDIX

TABLE XXV

DESCRIPTION OF CALVING DIFFICULTY SCORES

Numerical Score	Description
1	No difficulty
2	Little difficulty
3	Moderate difficulty
4	Major difficulty
5	Caesarean delivery

TABLE XXVI

DESCRIPTION OF WEANING CONDITION SCORES

Numerical score	Description
1	Low thin
2	Thin
3	High thin
4	Low average
5	Average
6	High average
7	Low fat
8	Fat
9	High fat

TABLE XXVII

DESCRIPTION OF CONFORMATION SCORES

Numerical score	Grade
17	High prime
16	Average prime
15	Low prime
14	High choice
13	Average choice
12	Low choice
11	High good
10	Average good
9	Low good
8	High standard
7	Average standard
6	Low standard
5	High utility
4	Average utility
3	Low utility

TABLE XXVIII

DESCRIPTION OF MARBLING SCORES

Numerical Score	Description
2	Marbling practically devoid
3	Traces of marbling
4	Slight amount of marbling
5	Small amount of marbling
6	Modest amount of marbling
7	Moderate amount of marbling
8	Slightly abundant amount of marbling
9	Moderately abundant amount of marbling
10	Abundant amount of marbling
11	Very abundant amount of marbling

TABLE XXIX

DESCRIPTION OF CARCASS GRADES

Numerical Score	USDA Quality Grade
15	High Prime
14	Average Prime
13	Low Prime
12	High Choice
11	Average Choice
10	Low Choice
9	High Good
8	Average Good
7	Low Good
6	Standard

TABLE XXX

MODEL FOR ANALYSES OF SELECTED CHARACTERISTICS[a]

$Y_{ijklmno} = M + B_i + Y_{j(i)} + R_{k(ji)} + D_l + A_m + S_n + BD_{il} + BA_{im} + BS_{in} + DA_{lm} + DS_{ln} + AS_{mn} + b_1 X_{ijklmno} + e_{ijklmno}$

Where:

Y_{ijklmn} = o^{th} observation of the n^{th} sex, m^{th} age of dam, l^{th} crossbred dam group, k^{th} sire, in the j^{th} year and i^{th} sirebreed.

M = population mean.

B_i = fixed effect of the i^{th} sire breed, i = 1,2.

$Y_{j(i)}$ = random effect of the j^{th} year within the i^{th} breed of sire, j = 1,2,3,4.

$R_{k(ji)}$ = random effect of the k^{th} sire within the j^{th} year within the i^{th} breed of sire, K = 1,2,3,4,5,6,7,8.

D_l = fixed effect of the l^{th} crossbred dam group, l = 1,2,3,4,5,6,7,8.

A_m = fixed effect of the m^{th} age of dam, m = 1,2,3,4,5,6.

S_n = fixed effect of the n^{th} sex of calf, n = 1,2.

BD_{il} = interaction of the i^{th} sire breed and the l^{th} crossbred dam group.

BA_{im} = interaction of the i^{th} sire breed and m^{th} age of dam.

BS_{in} = interaction of the i^{th} sire breed and n^{th} sex of calf.

DA_{lm} = interaction of the l^{th} crossbred dam group and m^{th} age of dam.

DS_{ln} = interaction of the l^{th} crossbred dam group and n^{th} sex of calf.

AS_{mn} = interaction of the m^{th} age of dam and n^{th} sex of calf.

b_1 = partial regression coefficient.

$X_{ijklmno}$ = date of birth of the ijklmnoth observation.

$e_{ijklmno}$ = random error associated with ijklmnoth observation.

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[a]Selected characteristics include: birthweight, calving difficulty score, percent calving difficulty, percent preweaning death loss, 205-day weight, preweaning ADG, weaning condition score, weaning conformation score, initial feedlot weight, yearling weight, yearling condition score, ADG first 120 days on feed, ADG after 120 days on feed to slaughter, ADG over entire feeding period, days on feed.

TABLE XXXI

MODEL FOR ANALYSES OF SELECTED CHARACTERISTICS[a]

$Y_{ijkl} = M + B_i + Y_{j(i)} + R_{k(ji)} + D_l + A_m + S_n + BD_{il} + BA_{im} + BS_{in} + DA_{lm} + DS_{ln} + AS_{mn} + b_1X_{ijklmno} + b_2Z_{ijklmno} + e_{ijklmno}$

Where:

$Y_{ijklmno}$ = o^{th} observation of the n^{th} sex, m^{th} age of dam, l^{th} crossbred dam group, k^{th} sire, in the j^{th} year and i^{th} sirebreed.

M = population mean.

B_i = fixed effect of the i^{th} sirebreed, i = 1,2.

$Y_{j(i)}$ = random effect of the j^{th} year within the i^{th} breed of sire, j = 1,2,3,4.

$R_{k(ji)}$ = random effect of the k^{th} sire within the j^{th} year within the i^{th} sirebreed, k = 1,2,3,4,5,6,7,8.

D_l = fixed effect of the l^{th} crossbred dam group, l = 1,2,3,4,5,6,7,8.

A_m = fixed effect of the m^{th} age of dam, m = 1,2,3,4,5,6.

S_n = fixed effect of the n^{th} sex of calf, n = 1,2.

BD_{il} = interaction of the i^{th} sirebreed and l^{th} crossbred dam group.

BA_{in} = interaction of the i^{th} sirebreed and m^{th} age of dam.

BS_{in} = interaction of the i^{th} sirebreed and n^{th} sex of calf.

DA_{ln} = interaction of the l^{th} crossbred dam group and m^{th} age of dam.

DS_{ln} = interaction of the l^{th} crossbred dam group and n^{th} sex of calf.

AS_{mn} = interaction of the m^{th} age of dam and n^{th} sex of calf.

b_1, b_2 = partial regression coefficients.

$X_{ijklmno}$ = date of birth of the ijklmnoth observation.

$Z_{ijklmno}$ = marbling score of the ijklmnoth observation.

$e_{ijklmno}$ = random error associated with the ijklmnoth observation.

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[a]Selected characteristics include: final feedlot weight, carcass weight, carcass weight per day of age, dressing percent, average fat thickness, single fat thickness, percent kidney, heart and pelvic fat, Longissimus area, cutability, and carcass grade.

TABLE XXXII

MODEL FOR ANALYSIS OF MARBLING SCORE

$Y_{ijklmno} = M + B_i + Y_{j(i)} + R_{k(ji)} + D_l + A_m + S_n + BD_{il} + BA_{im} + BS_{in} + DA_{lm} + DS_{ln} + AS_{mn} + b_l X_{ijklmno} + E_{ijklmno}$

Where:

$Y_{ijklmno}$ = o^{th} observation of the n^{th} sex, m^{th} age of dam, l^{th} crossbred dam group, k^{th} sire, in the j^{th} year and the i^{th} sirebreed.
M = population mean.
B_i = fixed effect of the i^{th} sirebreed, i = 1,2.
$Y_{j(i)}$ = random effect of the j^{th} year within the i^{th} breed of sire, j = 1,2,3,4.
$R_{k(ji)}$ = random effect of the k^{th} sire within the j^{th} year within the i^{th} breed of sire, k = 1,2,3,4,5,6,7,8.
D_l = fixed effect of the l^{th} crossbred dam group, l = 1,2,3,4,5,6,7,8.
A_m = fixed effect of the m^{th} age of dam, m = 1,2,3,4,5,6.
S_n = fixed effect of the n^{th} sex of calf, n = 1,2.
BD_{il} = interaction of the i^{th} sirebreed and l^{th} crossbred dam group.
BA_{im} = interaction of the i^{th} sirebreed and m^{th} age of dam.
BS_{in} = interaction of the i^{th} sirebreed and n^{th} sex of calf.
DA_{lm} = interaction of the l^{th} crossbred dam group and m^{th} age of dam.
DA_{ln} = interaction of the l^{th} crossbred dam group and n^{th} sex of calf.
AS_{mn} = interaction of the m^{th} age of dam and n^{th} sex of calf.
b_l = partial regression coefficients.
$X_{ijklmno}$ = date of birth of the $ijklmno^{th}$ observation.
$e_{ijklmno}$ = random error associated with the $ijklmno^{th}$ observation.

TABLE XXXIII

MODEL FOR ANALYSIS OF FEED EFFICIENCY

$Y_{ijkl} = M + B_i + D_j + R_k + S_l + BD_{ij} + BR_{ik} + BS_{il} + DR_{jk} + DS_{jl} + RS_{kl} + e_{ijkl}$

Where:

Y_{ijkl} = pen feed efficiency of the i^{th} breed of sire, j^{th} crossbred dam group, in the k^{th} year and of the l^{th} sex.
M = population mean.
B_i = fixed effect of the i^{th} sirebreed, i = 1,2.
D_j = fixed effect of the j^{th} crossbred dam group, j = 1,2,3,4,5,6,7,8.
R_k = fixed effect of the k^{th} year, k = 1,2,3,4.
S_l = fixed effect of the l^{th} sex, l = 1,2.
BD_{ij} = interaction of the i^{th} sirebreed and j^{th} crossbred dam group.
BR_{ik} = interaction of the i^{th} sirebreed and k^{th} year.
BS_{il} = interaction of the i^{th} sirebreed and l^{th} sex.
DR_{jk} = interaction of the j^{th} crossbred dam group and k^{th} year.
DS_{jl} = interaction of the j^{th} crossbred dam group and l^{th} sex.
RS_{kl} = interaction of the k^{th} year and l^{th} sex.
e_{ijkl} = random error associated with the $ijkl^{th}$ pen feed efficiency.

TABLE XXXIV

COW-CALF INPUTS USED IN ECONOMIC EVALUATION

INVENTORY, PRODUCTION, AND CATTLE VALUES

	Herds using Charolais Sires			Herds Using Limousin Sires		
	Cows	1st Calf Heifers	Yearling Heifers	Cows	1st Calf Heifers	Yearling Heifers
Number	73.4	17.0	18.9	76.6	15.1	16.8
Value, $/hd	500	475	400	500	475	400
Calving difficulty, %	13.8	20.0		3.9	20.0	
Open cows, %	10.2	11.2		8.6	11.2	
Death loss, %	1	1		1	1	
Unsound, %	3	3		3	3	
Number culled	9.7	2.4	1.9	8.9	2.1	1.7
weight, kg/hd	477	432	364	477	432	364
price, $/kg	.88	.92	1.14	.88	.92	1.14
Weaning rate, %	.816	.90		.858	.90	
Number weaned	59.9	15.3		65.7	13.6	
weight, kg/hd	232	193		223	193	
price, $/kg	1.45	1.50		1.95	1.50	

FEED AND CASH COSTS

	Cows	1st Calf Heifers	Yearling Heifers
Cotton seed meal, $0.26/kg			
kg/head/day	3.0	3.5	2.0
days fed	180	180	20
Hay, $0.05/kg			
kg/head/day	20	20	0
days fed	25	25	
Sprays, dips, vaccine, drugs	6.50	6.50	4.00
Pasture, $3.64/hectare			
hectare/head	4.05	4.05	2.03
Replacement heifer cost, $/hd			360.00

TABLE XXIV (Continued)

BREEDING BULLS

	Charolais or Limousin Sires	Shorthorn Sires
Number	3	1
Purchase cost, $/hd	1200	1100
Years in use	4	4
Maintenance cost, $/yr	75.00	75.00
Salvage value, $/hd	750.00	750.00

TABLE XXXV

SUMMARY OF COSTS (PER HEAD) USED IN ECONOMIC EVALUATION OF COW-CALF PHASE

	Herds using Charolais Sires			Herds Using Limousin Sires		
	Cows	1st Calf Heifers	Yearling Heifers	Cows	1st Calf Heifers	Yearling Heifers
Annual Cash Costs						
Cotton Seed Meal Supp.	56.16	64.80	4.80	47.24	64.80	4.80
Hay	9.73	9.68		9.96	9.68	
Minerals & Salt	3.00	3.00	1.50	3.00	3.00	1.50
Pasture Rent	90.00	90.00	45.00	90.00	90.00	45.00
Pasture Spraying	15.00	15.00	7.50	15.00	15.00	7.50
Pest Control	2.00	2.00	1.00	2.00	2.00	1.00
Medical & Vet	3.50	3.50	2.00	3.50	3.50	2.00
Marketing	.88	1.05	360.75	.88	1.05	360.75
Facilities, Fences, Buildings	11.44	11.44	11.44	11.52	11.52	11.52
Vehicles & Machinery	22.42	22.42	22.42	22.58	22.58	22.58
Misc. Costs	3.20	3.20	3.20	3.23	3.23	3.23
Labor	47.03	47.03	47.03	46.64	46.64	46.64
Bulls	3.07		3.97	2.94		4.46
Operating Interest	10.43	10.65	19.91	10.47	10.65	19.93
Total Variable Costs/Head	277.85	283.76	530.51	278.95	283.63	530.91
Fixed Costs (Depreciation, insurance, taxes, interest on borrowed capital)						
Vehicles	13.09	13.09	13.09	13.19	13.19	13.19
Equipment & Fence	4.12	4.12	4.12	4.15	4.15	4.15
Bulls	4.63		6.06	4.43		6.82
Cow Herd.	14.00	13.35	11.40	14.00	13.35	11.40
Total Fixed Costs/Head	35.84	30.56	34.67	35.77	30.69	35.55
Total Variable Costs, $			35244.47			34569.46
Total Fixed Costs, $			3805.00			3801.00
Total Costs, $			39049.47			38370.46

TABLE XXXVI

SUMMARY OF RECEIPTS USED IN ECONOMIC EVALUATION OF COW-CALF PHASE

	Charolais Herd			Limousin Herd		
	No.	$ per Animal	Total %	No.	$ per Animal	Total $
Charolais cross calves	59.9	336.60	20162.34			
Limousin cross calves	0			65.7	323.40	21247.38
Shorthorn cross calves	15.3	289.00	4421.70	13.6	289.00	3930.40
Cull cows	9.7	420.00	4074.00	8.9	420.00	3738.00
Cull 1st calf heifers	2.4	399.00	957.60	2.1	399.00	837.90
Cull yearlings	1.9	416.00	790.40	1.7	416.00	707.20
Total receipts, $			30406.04			30460.88

TABLE XXXVII

FEEDLOT INPUTS USED IN ECONOMIC EVALUATION AND SUMMARY OF COSTS AND RECEIPTS (PER HEAD)

	Charolais sired calves	Limousin sired calves	Shorthorn sired calves
Days on feed to low choice	260	267	283
ADG, kg/day	2.45	2.32	2.21
Feed/gain, kg	6.87	6.87	6.87
Death loss, %	1	1	1
Yardage cost, $/day	.05	.05	.05
Labor cost, $/day	.20	.20	.20
Selling weight, kg	1147	1109	1050
Dressing %	63.9	64.6	63.0
Carcass price, $/kg	2.33	2.33	2.33
Medical cost, $	7.00	7.00	7.00
Interest rate, %	13.0	13.0	13.0
Feed cost, $/kg as fed	.154	.154	.154
Ration - NEm 1.87 per kg dry matter			
Neg 1.17 per kg dry matter			
Feed cost, $	349.86	340.48	344.35
Non feed costs, $	119.33	120.49	123.64
Cattle cost, $	336.60	323.40	289.00
Interest cost on cattle, $	22.44	17.46	33.99
Total costs, $	828.23	801.83	790.98
Total Receipts, $	776.06	759.74	701.48
Returns, $	-52.17	-42.08	-89.50

VITA 2

John Micheal Dhuyvetter

Candidate for the Degree of

Master of Science

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Major Field: Animal Science

Biographical:

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