EVALUATION OF LIMOUSIN AND GELBVIEH BREEDS FOR USE AS TERMINAL CROSS SIRES

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CROSS SIRES

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NOMENCLATURE

avg	average
adg	average daily gain
cm	centimeters
d	days
df	degrees of freedom
g	grams
kg	kilograms
sq	square
mm	millimeters
wt	weight

CHAPTER I

INTRODUCTION

The economic hardships currently being experienced by livestock producers necessitates maximizing returns while minimizing inputs. For the cow-calf producer, efficiency can be increased by maximizing utilization of available forage and genetic resources through improved selection and management. From a genetics standpoint, Long (1980) stated two ways to increase the efficiency of beef production: 1) within breed selection, and 2) among breed selection and breed combination. Sole use of selection to increase production is slow, so different breeds need to be used in a crossbreeding program, as doing so can increase production per cow by 19-27 % (Cundiff, 1974).

Dickerson (1972) stated that while crossbred animals have better viability and performance traits, such as an increased growth rate, the greatest response to heterosis is in reproductive fitness. Since reproduction is the most important trait in determining profitability for a cow-calf operation the necessity of utilizing crossbred females is blatantly apparent. Numerous computer simulations (Cartwright et al., 1975; Wilton and Morris, 1976; Notter et al., 1979b) indicate maximum productivity can be attained by mating crossbred cows to large, growthy "terminal" sires of an unrelated breed, especially if attention is given to minimizing calving difficulty.

Proper utilization of available breeds is necessary to achieve the maximum benefits of both heterosis and breed complementarity. Breeds comprising the crossbred cow herd must be of practical size, possess above average reproductive performance and mothering ability and have adequate growth and carcass traits. The terminal sire breeds must demonstrate fast, efficient growth and sire offspring which produce desirable carcasses of high lean and low fat content. All breeds and types of cattle which may be useful for increasing the efficiency of producing lean, palatable beef must therefore be evaluated to determine how, or if, each can best be utilized in a crossbreeding program. Therefore this study, part of a long term project designed to evaluate the lifetime productivity of various two breed cross cows, was conducted to compare the Gelbvieh and Limousin breeds as terminal sires when mated to the F_1 cows, thereby producing three breed cross calves.

CHAPTER II

REVIEW OF LITERATURE

Overview of Crossbreeding for Increasing Production Efficiency

The debate over which breed of cattle is "best" has raged for many years. Most producers now agree that to maximize production efficiency crossbreeding with those "best" purebreds is a necessity, as crossbreeding now influences about 70 % of the cattle marketed in the United States (Koch and Algeo, 1983). The advantages of crossbreeding are due to the heterosis acquired through increased heterozygosity and the use of breeds which complement one another.

Cundiff (1970) summarized results from various crossbreeding studies and reported average heterosis values of 1.5, 3.0, 4.1, 4.6 and 0.7 percent for calving percent, calf survival, calf crop weaned, weaning weight and feed efficiency, respectively. Long (1980) reported similar values in another summarization of research results from crossbreeding experiments, and included values of 6.0 % for postweaning daily gain and 4.0 % for yearling weight. Carcass traits have generally been found to be highly heritable and exhibit only small amounts of heterosis. However, significant heterotic effects for traits related to growth have been reported (Cundiff, 1970). These effects are normally lost when the data are adjusted for carcass weight (Long, 1980).

Since maintenance costs for the cow herd comprise a considerable portion of the total costs of calf production (Klosterman and Parker, 1976), it is easy to see why Cartwright (1970) stated cow herd efficiency is more important than efficiency of the calves produced. Gregory and Cundiff (1980) stated cumulative traits, such as kg of calf weaned per cow exposed, show the greatest benefit from heterosis, which explains why crossbred cows account for more than half of the increased production due to crossbreeding (Cundiff, 1970, 1974). Therefore, use of a crossbred cow is essential for maximizing production efficiency. Dickerson (1969, 1972, 1974) has suggested using specialized crossbred female lines which have improved reproductive performance, due to heterosis, and specialized male lines developed for size and muscle growth. Doing so would increase the response from selection within each line due to the decreased number of traits being selected for within each line (Smith, 1964). Cartwright (1970) lists a number of desirable traits for each line, such as female fertility, early maturity and relatively small size for dam lines and high rate of gain and efficient feed conversion for sire lines.

Cow size, as it relates to production efficiency, has been a much debated topic, both from experimental and computer simulation studies. When crossbreeding animals of similar size, as in a rotational program, large cows are generally more profitable (Smith, 1979). Long et al. (1975) used a systems analysis approach to evaluate economic efficiency of small, medium and large size straightbred cows on pasture and in a drylot regime. Their results indicated large cows were more economical in the drylot, whereas small frame cows had an advantage on pasture. Wilton and Morris (1976) used a linear model to evaluate cow size and reproductive rate. They found larger cows always gave better returns when compared to small cows at a constant reproductive rate. However Frahm and Marshall (1985) reported larger frame cows generally have lower reproductive rates. When all breeds involved in a crossbreeding system are of the same size, larger cows have an advantage because it is more profitable to produce large calves (Fitzhugh et al., 1975). But when breed complementarity is used to a fuller extent, large-framed "terminal" sires can be used on small-framed cows to produce the larger, growthier calves desired. Notter et al. (1979a), using a computer simulation which included various sire sizes, found that increasing sire size usually decreased feedlot total digestible nutrients per empty body weight, thus increasing efficiency. Smith (1979) stated that using large, terminal sires offset the advantage of larger cows and was the best way to increase efficiency. In a review of simulation models, Gregory and Cundiff (1980) indicated the most efficient systems were those which maximized the difference in size between the terminal sire and crossbred cows, thus maximizing complementarity (Fitzhugh et al., 1975). Doing so however, could cause problems with calving difficulty, as some of the breeds with superior growth rates and carcass characteristics which would likely be used as terminal sires increase calving difficulty (Cundiff, 1974). Some of the simulations which found systems utilizing terminal sires to be most efficient neglected to include calving difficulty (Cartwright et al., 1975; Wilton and Morris, 1976). Notter et al. (1979b) included calving difficulty and found the systems which were most efficient used large terminal sires and made attempts to minimize calving difficulty.

One mating system suggested for utilizing a terminal sire on smaller cows, yet minimizing calving difficulty, is a two or three breed rotational cross female mated to the terminal sire (Dickerson, 1969; Cundiff, 1974; Dickerson, 1974; Cartwright et al., 1975; Clarke et al., 1984). Two-, three- and four-year-old cows are used to produce replacement females, while the older cows are mated to the terminal sires, thus reducing calving difficulty. Individual heterosis for feedlot animals is nearly 100 % (some males and nonselected heifers are produced in the rotational cross) and most of the available maternal heterosis is utilized. The only replacement animals which need to be purchased are the purebred rotational and terminal sires.

Cattle breeds available today vary widely in their physical characteristics and performance attributes (Dickerson, 1972). These breeds have varying effects, depending on how they are used (sire or dam), and can have varying heterosis values depending upon which breeds they are crossed with (Gregory et al., 1965). With the final goal of maximum profitability always in mind, it is necessary to determine which combination of breeds will not only make the best use of complementarity and heterosis, but will also match performance levels to the production environment in which they will be raised. It is clear that well planned breeding systems utilizing properly selected terminal sires and efficient cows will maximize productivity in most environments. Therefore it is necessary to define what constitutes a desirable terminal sire, so a strong breeding system can be further strengthened by the quality of animals utilized in it.

Characterization of Terminal Sires

The use of selected lines or breeds specifically for sires or dams increases the potential for improvement in the traits important to each line. If the traits selected for improvement have a favorable genetic correlation, the benefit of maintaining and selecting within two separate lines is small. But if the genetic correlation is low or unfavorable, efficiency can be improved 15 to 50 % through use of specialized lines (Smith, 1964).

In beef cattle, use of a terminal sire allows maximum selection for growth and carcass traits within the sire line because reproductive traits are unimportant as long as the bull can settle an adequate number of females. Reproductive and maternal traits are of primary importance in the dam line and therefore must receive most of the selection pressure. But the dam also contributes half of the offspring's genes which affect growth and carcass traits, so some selection must be based on these traits also (Smith, 1964). Breeding programs utilizing a terminal sire also allow for maximum use of breed complementarity in crossbreeding programs.

Selection of terminal sires should be based on growth rate, feed efficiency and carcass characteristics. Increasing growth rate is economically important, as it can reduce the number of days required to attain a specific weight, and thus decrease interest, yardage and maintenance feed costs. Increased growth rate can also increase the amount of weight gained during a specific period. An increased market weight will decrease the cost per unit marketed (Dickerson, 1982). Unfortunately, increasing growth rate usually increases birth weight as well, thus causing more calving problems (Foulley, 1976). Koch et al. (1974) reported the increase in birth weight could be expected to be reduced 30 % if all selection pressure for growth was placed on postnatal growth rate instead of weaning or yearling weight. One method of lessening the effect of the increase in birth weight would be to breed only older cows to the terminal sire, as indicated in the breeding program described previously.

Koch et al. (1963) stated the most useful measure of feed efficiency may be the amount of edible product which is produced for a given energy intake. Such an evaluation would be very difficult to conduct, as individual energy consumption and individual carcass information must be collected. Therefore the common expression of feed conversion is kg of feed required per kg of live weight gain. However, this is also time consuming and expensive to evaluate on an individual animal basis. This has resulted in the greatest improvement in feed efficiency being due to its correlated response to selection for increased rate of gain (Foulley, 1976; Yuksel, 1979). Koch et al. (1963) reported a genetic correlation between feed efficiency and gain of .79, and selection for gain alone will yield as much as 81 % of the genetic improvement as selecting directly for feed efficiency. This is similar to the results of Swiger et al. (1962), who found selecting for a combination of weaning weight and postweaning daily gain would provide 73 % as much genetic improvement in net merit as when feed efficiency was also included in the index. Smith (1976) confirmed this in a study using various sire breeds as terminal sires. Those results showed faster gaining breeds were more efficient than slower gaining breeds, and leaner breeds were more efficient than fatter breeds. The latter is probably due to less feed being deposited as fat in leaner breeds, so the feed is used more efficiently. Dickerson (1982) suggested increased muscle growth in proportion to visceral organs and blood may reduce maintenance energy requirements. Since maintenance requirements are 50 % or more of feed costs (Hanset et al., 1986), such a reduction would have a beneficial effect on feed efficiency. With these factors in mind, there seems to be little reason to measure and select on feed efficiency. If terminal sires are selected for increased growth and muscularity, a correlated increase in feed efficiency should result.

Carcass composition is of vital importance in meat animals, as it largely determines carcass value. The goal is a carcass with a high proportion of muscle, low proportion of bone and optimum levels of fat (Berg et al., 1978). Koch et al. (1976) reported the faster growing breeds in their study also produced leaner carcasses. Large-framed breeds with fast, efficient growth of lean tissue would therefore be an excellent choice of terminal sire for smaller-framed cows. The offspring produced should exhibit fast, efficient growth, a somewhat heavier slaughter weight and a leaner carcass with enough fat for acceptable palatability.

Double Muscled Cattle

The preference of today's consumer is a tender, juicy and flavorful meat product with little excess fat. Implementing breeding programs which use a terminal sire is one method of producing such a product, since extremely lean and muscular bulls may be used. Extremely lean females may experience reproductive problems due to the decreased amount of fat, as Richards et al. (1986) reported cows with poor body condition tended to be anestrus. Bulls, however, can maintain reproductive function with low amounts of fat (Lindhe, 1976). With a goal of finding lean, muscular animals with good growth and feed efficiency, one type of animal which must be considered is that which is double muscled.

MacKellar (1960) described double muscled animals as having muscle hypertrophy most noticeable in the hindquarters, but also present throughout most of the body. Fat deposition was decreased, especially subcutaneously, and the skin was thinner. Long bones tended to be shorter, which made the condition more noticeable since more muscle mass was present in a shorter area. Carcass dissection studies by Rollins et al. (1969), Hanset et al. (1977) and Shahin and Berg (1985c) showed double muscled animals have hyperdevelopment of the proximal muscles of the limbs, whereas distal muscles are actually hypodeveloped as compared to normal animals.

Double muscled cattle do not really have double the number of muscles, as the term implies, but actually have hypertrophy of the individual muscles due to a greater number of muscle fibers (Dumont, 1982; Hanset et al., 1982). This increase in muscle fiber number is caused by cell hyperplasia, not cell hypertrophy (Hanset et al., 1982). Menissier (1982) reviewed the many studies and hypotheses concerning the control of the double muscled condition. Most studies agree the condition is controlled by a single locus, but the dominance relationship between the double muscle and normal genes has not been clearly established. A form of codominance is suspected, as the gene has varying degrees of penetrance (Menissier, 1982). Kidwell et al. (1952) reported animals known to be heterozygous carriers for the gene range from a normal appearance to exhibiting various degrees of the double muscled appearance. This has allowed the gene to exist in many breeds because the heterozygote is selected for because of its benefit in muscling (Shrode and Lush, 1947). MacKellar (1960) also reported the condition occurred much more frequently in South Devon herds selected for meat than in herds selected for milk.

Ansay and Hanset (1979) also reported the muscle hypertrophy occurred at the expense of other muscles and organs, particularly the visceral organs. Geay et al. (1982) suggested this lower gut percentage meant lower protein turnover and thus lower maintenance requirements. This would be supported by the many studies which found double muscled cattle to have better feed efficiency (Hanset et al., 1979; Geay et al., 1982; Hanset et al., 1986). These studies also reported decreased feed intake, which Hanset et al. (1979) suggested was due to a smaller digestive tract. Reports of rate of gain in comparison to normal cattle vary, as Hanset et al. (1979, 1986) reported no difference in two studies with Blue Belgian cattle, whereas Geay (1982) reported a decrease in Charolais cattle which were double muscled vs those that were not.

Studies report a greater rate of lean tissue deposition (Hanset, 1979; Shahin and Berg, 1985a; Hanset, 1986) and decreased fat deposition (Hanset, 1979; Geay, 1982; Shahin and Berg, 1985a; Hanset, 1986), which resulted in greater dressing percentage for the double muscled cattle than for the normal cattle. MacKellar (1960) and Hanset et al. (1979) suggest this change in rate of tissue deposition is the reason for better feed efficiency, as more energy is required to deposit fat than an equivalent amount of lean. Based on endocrinological studies, Michaux et al. (1982) determined double muscled animals have delayed puberty, which Novakofski and Kauffman (1980) suggested was the reason for their extreme leanness. Their study demonstrated that when given adequate time in the feedlot, double muscled animals will deposit a similar amount and lipid composition of fat as normal animals, although the double muscled animals will weigh more. Michaux et al. (1982) also found lower insulin levels in double muscled animals, which they suggested may be the reason for decreased fat deposition, since insulin tends to promote lipogenesis while inhibiting lipolysis.

Studies on carcass composition showed double muscled animals had a 40-50 % increase in total muscle and a 30-40 % decrease in total carcass fat when evaluated with comparable normally muscled animals (Butterfield, 1966; Rollins et al., 1969). Butterfield (1966) commented that the low amount of dissectable fat from a double muscled carcass was more similar to an emaciated carcass than one with such a desirable muscle:bone ratio. Bailey et al. (1982) reported double muscled animals had the same number of fat cells as normal animals, but the cells were smaller. Close examination of muscle tissue from double muscled animals showed a less developed connective tissue framework which caused a coarser muscle texture (Dumont, 1982). Bailey et al. (1982) confirmed this with reports of a much finer perimysium in double muscled meat. They also reported double muscled meat had half the collagen, was slightly more tender and had similar cooking losses, flavor and juiciness as meat from normally muscled animals.

There are however numerous disadvantages associated with double muscled cattle. Of primary concern is increased birth weight and therefore increased calving difficulty with double muscled calves, along with double muscled calves being less able to recover from difficult births (MacKellar, 1960; Menissier, 1982). This is even more pronounced when the dam is also double muscled, as those females normally have a decreased pelvic area (McKellar, 1968 and Vissac, 1968, both reported by Menissier, 1982). Michaux et al. (1982) reported on endocrinological studies which showed double muscled bulls had delayed puberty. Menissier (1982) in a review of research of double muscled cattle confirmed such results with bulls, and also reported delayed puberty in heifers, reduced fertility in cows and a 15-30 % decrease in milk production of double muscled cows. Such a reduction in milk production is often insufficient to meet the needs of double muscled calves with greater growth potential. Double muscled animals often have leg problems (Bibe et al., 1977; Thiessen and Rollins, 1982) which may interfere with the breeding ability of bulls or lead to more fractures.

Holmes et al. (1972) reported double muscled cattle are more excitable, and double muscled cattle are more prone to sudden death in response to minor stresses (Holmes et al., 1973). Therefore studies have been conducted to evaluate the ability of double muscled cattle to adapt to stress. Holmes and Robinson (1970) reported double muscled animals have a decreased ability to mobilize fatty acids, and therefore have more muscle breakdown to provide energy and glucose. Holmes et al. (1972) confirmed this with a study which showed both adrenalin injection and exercise caused a greater increase in blood lactate in double muscled cattle. In a followup study, Holmes et al. (1973) looked at how the elevated blood lactate level affected meat quality. When exercised, one double muscled animal died and another would have died, if the exercise had continued, while the third of four animals was a dark cutter at time of slaughter. Only one of four normal animals had dark meat, with this animal becoming extremely agitated during the study. When a nutritional stress was imposed, all four double muscled animals had higher carcass pH values than the four nutritionally stressed normal animals, and two of those double muscled animals were dark cutters. Earlier reports of double muscled cattle mentioned a problem with dark cutting meat (Kidwell, 1952; MacKellar, 1960). Weber and Ibsen (1934) and MacKellar (1960) also reported the low amount of fat cover on double muscled carcasses allowed the meat to dry out, causing it to be dry and tough when cooked. As with all other fat deposits, marbling in double muscled cattle is also decreased (West et al., 1973), resulting in a lower quality grade.

When double muscled bulls are used as terminal sires on normal cows, all calves are heterozygous and the effects of many of these problems are lessened. Raimondi (1965) reported that when Italian dairy producers bred cows to Piedmontese bulls (a breed with a high frequency of double muscling), for slaughter calf production, a 20 % larger profit was realized over Friesian and Brown Swiss calves of the same age.

Blasi et al. (1986) reported on a Colorado study which also used Piedmontese bulls, comparing them to Red Angus and Gelbvieh bulls, all mated to crossbred cows. Birth weights and calving difficulty of Piedmontese-sired calves were similar to those of the Gelbvieh-sired calves, but greater than the calves sired by Red Angus bulls. There were no differences between sire breeds in weaning weight, or in daily gain or feed efficiency during the growth period for steers. During the feedlot phase, Piedmontese and Red Angus-sired calves had similar daily gain, whereas Gelbvieh-sired calves grew faster. Thiessen and Rollins

(1982) found similar results when comparing normal and homozygous double muscled Angus bulls mated to Angus, Hereford and Shorthorn cows. They found no differences in birth, weaning or yearling weight between the normal and heterozygous double muscled calves, although the heterozygous calves did have a tendency to grow faster. There was no difference between the two groups in feed intake, but in one trial the heterozygous calves had a 5.6 % advantage in feed efficiency. Bibe et al. (1977) reported slightly different results when comparing double muscled and normal bulls mated to dairy cows. In this study double muscled sired calves had higher birth weights and slower preweaning growth rates. While in the feedlot the heterozygous double muscled calves had a faster growth rate, lower feed intake and better feed efficiency.

Most studies reported heterozygous double muscled calves had higher dressing percents (Bibe et al., 1977; Menissier, 1982; Thiessen and Rollins, 1982), which Carroll et al. (1978) suggested was due to the lower offal weights. These cattle also had less fat (West et al., 1973; Bibe et al., 1977; Bouton et al., 1978; Menissier, 1982; Thiessen and Rollins, 1982), although in one case the difference was not significant (Carroll et al., 1978). Bibe et al. (1977) and Menissier (1982) reported a larger muscle percentage, while West et al. (1973), Bouton et al. (1978) and Thiessen and Rollins (1982) indicated larger ribeye areas for calves sired by double muscled bulls. Results of Gronewald et al. (1986) from the Colorado study are in agreement, as the Piedmontese-sired calves were leaner and more muscular. Marbling scores and quality grades varied among studies. West et al. (1973) reported no difference in quality grade, as did Carroll et al. (1978) in bullocks whereas normal heifers had more marbling and a higher quality grade than heterozygous double muscled heifers. Thiessen and Rollins (1982) found the heterozygous calves had lower quality grades, but there was no difference in quality detected by a taste panel. Normal heifers in the study conducted by Carroll et al. (1978) tended to have meat which was more tender and juicy than the heterozygous double muscled heifers, whereas the bullocks sired by double muscled bulls tended to be more tender than the normal bullocks. There were minor differences in flavor and overall acceptability.

West et al. (1973) reported lower Warner-Bratzler shear force values, higher juiciness scores and higher connective tissue softness in longissimus muscles from heterozygous double muscled steers. Heterozygous steers also had lower Warner-Bratzler shear force values, higher average taste panel scores and lower percent fat than normal steers in the semitendinosus muscles. Also working with the semitendinosus muscle, Bouton et al. (1978) found Warner-Bratzler shear forces and adhesion values, measured with an Instron machine, were lower for double muscled animals, thus suggesting greater tenderness. No differences were found in sarcomere lengths or cooking losses between the double muscled-sired and normal-sired groups.

Results of these studies indicate double muscled bulls would be useful as terminal sires. Although birth weights may be slightly increased, little additional calving difficulty should be experienced, especially when mated to older cows, and the heterozygous double muscled calves do not appear to be less viable than normal calves (Thiessen and Rollins, 1982). Growth should be similar to calves with normal muscling, but lower feed intake and better feed efficiency would result in more economical gains. The greatest advantage occurs at slaughter, as the increased dressing percent and muscularity coupled with decreased fat should result in premiums, since a lean, yet palatable product is provided to the consumer. If carcasses have too little fat for industry acceptance, animals can be fed to heavier weights while retaining acceptable quality and cutability characteristics (Bouton et al., 1978). Although this practice will increase carcass weights, if smaller framed cows are utilized in the terminal herd, carcass size should not be excessive. The increased age associated with longer feeding should not adversely affect tenderness, due to low connective tissue content and initially lower Warner-Bratzler shear force values characteristic of meat from heterozygous double muscled animals. Bouton et al. (1978) have also shown heterozygous double muscled animals are probably not any more susceptible to stress than normal animals, so an increase in dark cutters should not be expected.

While a terminal sire breeding program minimizes many of the problems associated with double muscled cattle, those problems will still exist in those herds which produce the double muscled bulls. However, implementing some of the management practices presently available may help alleviate some of these problems. Embryo transfer could be practiced so double muscled cows wouldn't have to experience the calving problems they are so well known for, which should also decrease the calf mortality rate (Bibe et al., 1977). This would also produce more calves per cow, thus allowing increased selection pressure for performance, and would disregard the poor milk production of double muscled cows. Eliminating the problems with dystocia should help alleviate some reproductive problems double muscled cows experience. Days to puberty may be decreased to some extent through use of proper selection practices, but this trait may be a problem breeders of double muscled cattle will have to accept, especially in heifers because of their need for a certain amount of fat in order to initiate and maintain an estrous cycle. Although Thiessen and Rollins (1982) report homozygous bulls do have satisfactory libido and semen quality, use of the test described by Blockey (1981) would be an appropriate method to ensure only bulls capable and willing to breed cows are utilized in a natural service breeding program. Due to their increased incidence of leg problems and susceptibility to stress, double muscled bulls should probably be expected to travel less and breed fewer cows, thus requiring an increase in the number of bulls needed.

While the problems associated with double muscled animals are many, these cattle may offer some characteristics useful in today's cattle industry. A terminal sire breeding program can best utilize the efficient production of lean meat possible with cattle carrying the double muscled gene. The ideas previously outlined provide a basis for producing and utilizing those animals, and warrants the need for further research.

Characterization and Comparison of Limousin and Gelbvieh Breeds

Since the mid 1960's there has been a vast increase in the number of cattle breeds available to producers in the United States. Mason (1971) and Longrigg (1976) give brief descriptions of these breeds and their characteristics.

The Limousin breed is from the old province of Limousin, located in the west central part of France, where the breed was selected for work and meat production (French et al., 1966; Frahm and Belcher, 1978). Calves generally weigh 35-40 kg at birth and mature to adult weights of 950-1150 kg for males and 600-800 kg for females (French et al., 1966; Mason, 1971). The breed is known for high dressing percent, outstanding ribeye area and lean:bone ratio (Longrigg, 1976). For a further description of the breed see Frahm and Belcher (1978).

Gelbvieh cattle, also known as German Yellow cattle, originated in Bavaria, which is located in southern Germany (Longrigg, 1976; Briggs and Briggs, 1980). The breed has been developed as a triple purpose breed for milk, meat and work (French, 1966), with emphasis placed on beef characteristics and carcass quality in recent years (Kraublich, 1976a; Phillipo, 1974). The breed has developed a reputation for producing very desirable carcasses (Briggs and Briggs, 1980), as it wins nearly half of Germany's carcass contests while comprising only 15 % of the cattle population, with Simmental being the most popular (Anon, 1974). In Germany a large portion of the breed's females are bred artificially, making the breed's performance testing and selection program especially effective (Phillipo, 1974; Kraublich, 1976a). In addition to carcass quality, the breed is known for its superior fertility, calving ease, mothering ability, growth rate of calves and feed efficiency (French, 1966; Briggs and Briggs, 1980). Birth weights range from 40-45 kg (French, 1966), with mature weights of 900-1000 kg for males and 500-700 kg for females (Mason, 1971).

Few studies have been conducted with Gelbvieh cattle (Schmitter et al., 1963, as reported by Mason, 1971; Kraublich, 1976b; Anon, 1981; Gotti, 1982; Gotti et al., 1985), with the primary one conducted at the US Meat Animal Research Center (MARC) at Clay Center, Nebraska in Cycle

II of their germplasm evaluation program (Gregory et al., 1978; Laster et al., 1979; Koch et al., 1979; Cundiff et al., 1981). Conversely, numerous studies have been conducted with the Limousin breed, in many instances as a terminal sire (Adams et al., 1973; Kraublich, 1976b; Berg et al., 1978; Anon, 1981; Fredeen et al., 1982a; Fredeen et al., 1982b; Rahnefeld et al., 1983; Dhuyvetter and Frahm, 1985), including Cycle I at MARC (Laster et al., 1976; Smith et al., 1976a; Smith et al., 1976b; Koch et al., 1976).

In a Georgia study (Gotti, 1982; Gotti et al., 1985) Gelbvieh, Angus and Santa Gertrudis bulls were used as terminal sires. Gelbvieh bulls sired calves similar in birth weight to Santa Gertrudis bulls, but heavier than the calves from Angus bulls. However there were no differences in calving difficulty or death rates (Gotti et al., 1985). Gelbvieh-sired calves had the highest preweaning daily gain, weaning weight and feedlot daily gain, although none were significantly different from Santa Gertrudis- or Angus-sired calves. Gelbvieh- and Santa Gertrudis-sired calves had an advantage over Angus-sired calves in weaning conformation score, slaughter weight, hot carcass weight and kidney, pelvic and heart fat percentage. Conversely, calves from Angus sires had higher quality grades than calves from Gelbvieh and Santa Gertrudis sires. Gelbvieh-sired carcasses had less fat over the ribeye, larger ribeyes and therefore lower yield grades than carcasses sired by Angus and Santa Gertrudis bulls (Gotti, 1982).

Vissac (1982) reported that in comparison to other Continental breeds, the Limousin breed has lower birth weight, less calving difficulty, especially on heifers, better feed efficiency and better carcass attributes of muscle:bone ratio and fat percentage. Canadian studies comparing Limousin, Simmental and Charolais bulls on Angus, Hereford and Shorthorn cows, and Limousin, Simmental, Charolais and Chianina bulls mated to F_1 cows gave similar results (Fredeen et al., 1982a; Fredeen et al., 1982b; Newman et al., 1985). In both studies, Limousin-sired calves had lower birth weights, less calving difficulty and lower preweaning mortality rates, but also the lowest preweaning daily gain and lightest 200-day weight. When the three breed cross calves were evaluated in the feedlot and slaughterhouse, Rahnefeld et al. (1983) reported Limousin-sired calves again had the slowest growth rate and lowest carcass weight per day of age. Conversely, calves from Limousin sires had the least amount of fat cover and the largest ribeyes per unit of carcass weight. Limousin- and Chianina-sired carcasses were similar in dressing percent, and greater than Simmental- and Charolais-sired carcasses. The Limousin-sired carcasses also had the highest lean:bone ratio, which agrees with results from Berg et al. (1978) when comparing Limousin, Simmental, Charolais, Danish Red and White, Romangnola, Hereford and Blond d'Aquitaine. When compared against crossbred carcasses sired by Simmental, Maine Anjou, Lincoln Red, Brown Swiss and Angus, Limousin-sired carcasses had larger ribeyes at a common carcass weight than all other breeds and higher cutability than Angus, Lincoln Red or Brown Swiss crosses (Adams et al., 1973). Dhuyvetter and Frahm (1985) reported similar results when comparing Limousin and Charolais sires mated to F_1 cows. Limousin-sired calves had lower birth weights, percent difficult calvings, preweaning mortality, preweaning daily gain and weaning weight. Charolais-sired calves had greater yearling weights, feedlot daily gain, slaughter weights, hot carcass weights, carcass weight per day of age and less external fat and kidney, pelvic and heart fat percentage, but also a lower dressing percent. Carcass cutability and quality grade were similar for the two sire breeds.

Limousin and Gelbvieh cattle may have common ancestors, as indicated by Rouse (1970, reported by Frahm and Belcher, 1978). If this is so, comparisons of these two breeds as they presently exist would show how the two breeds have changed as a result of different selection pressures. Some smaller studies have been conducted to compare the two breeds (Schmitter, 1963 as reported by Mason, 1971; Kraublich, 1976b; Anon, 1981), but the study involving the greatest number of animals was conducted at MARC in the germplasm evaluation program. Although the two breeds were evaluated at different times, Limousin in Cycle I and Gelbvieh in Cycle II, comparisons can be made through the comparable Hereford-Angus reciprocal crosses included in both cycles. As reported by Smith et al. (1976) in Cycle I Hereford and Angus cows were inseminated with semen from Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental bulls to produce calves in 1970, 1971 and 1972. Gregory et al. (1978) reported Cycle II consisted of sire breeds Hereford, Angus, Red Poll, Brown Swiss, Gelbvieh, Maine Anjou and Chianina mated to Hereford and Angus cows to produce calves in 1973 and 1974.

Limousin sired calves had heavier birth weights, greater dystocia and higher early mortality rates than Hereford-Angus cross calves. While Gelbvieh-sired calves had heavier birth weights than Hereford-Angus cross calves, there was not a significant difference in calving difficulty or percent perinatal mortality. Preweaning gain and 200-day weight for Limousin-sired calves were not significantly different from

Hereford-Angus crosses, whereas Gelbvieh-sired calves had higher daily gain and 200-day weights than Hereford-Angus crosses.

Heifers produced in Cycles I and II were not placed in the feedlot, but were evaluated for reproductive performance (Laster et al., 1976; Laster et al., 1979). The silage based ration fed resembles that of a growing ration utilized before animals are placed on a finishing ration. Therefore performance during this period could be equated to that of a stocker or grower program and warrants discussion when considering terminal sires. Limousin-sired heifers had more rapid gain from weaning to 400 days of age, but less rapid gain from 400 to 450 days of age. Consequently 400 and 550-day weights were similar to Hereford-Angus cross heifers. Gelbvieh cross heifers and Hereford-Angus cross heifers had similar daily gain during the AI period. Gelbvieh cross heifers were significantly heavier at 400 and 550 days of age due to their heavier weights at the beginning of the growing period.

Feedlot performance of steers was discussed by Smith et al. (1976) for Cycle I and Cundiff et al. (1981) for Cycle II. Limousin-sired steers were similar to Hereford-Angus cross steers in daily gain and weight at 405 days of age. Gelbvieh sired-steers were faster gaining and heavier at adjusted 424-day weights than Hereford-Angus cross steers. Feed efficiency was evaluated at a constant time, a constant weight and a constant marbling score in both cycles, and also at a constant percent fat trim in Cycle II. Limousin and Hereford-Angus cross steers were similar in feed efficiency on both a time constant (0 to 217 days on feed) and a weight constant (240 to 470 kg) basis. At a constant longissimus fat content of 5 %, which Koch et al. (1976) found to be equivalent to a marbling score of Small, Limousin-sired steers were less efficient than Hereford-Angus cross steers. This difference in efficiency can be attributed to the extended time needed for Limousin cross steers to reach the desired marbling score and thus the added days of maintenance. In Cycle II, Gelbvieh-sired steers were similar to Hereford-Angus cross steers at the time constant (0 to 248 days), marbling constant (0 days to 5 % longissimus fat) and fat trim constant (0 days to 18.9 % fat trim) intervals. At a weight constant (250 to 470 kg) interval Gelbvieh-sired steers were more efficient than Hereford-Angus cross steers, probably due to deposition of more lean and less fat by the Gelbvieh cross steers at this weight.

Carcass characteristics, presented by Koch et al. (1976) for Cycle I and Koch et al. (1979) for Cycle II, were also evaluated at various endpoints. Limousin-sired carcasses were heavier at a constant age and marbling score than Hereford-Angus cross carcasses, but did not differ in dressing percentage. Hereford-Angus cross carcasses had less kidney and pelvic fat percentage at all three endpoints, while Limousin-sired carcasses had a lower fat thickness and less longissimus fat at a constant age and at a constant hot carcass weight (288 kg). Ribeye area was larger and yield grades lower for carcasses of cattle sired by Limousin bulls at all endpoints. When evaluated at a constant age, Limousin sired carcasses had lower marbling scores and therefore lower quality grades, and higher Warner-Bratzler shear forces, indicating lower tenderness. Taste panel values were similar for juiciness and flavor, but confirmed the Limousin-sired carcasses were less tender, and therefore had lower overall acceptability scores. Gelbvieh-sired carcasses were heavier than Hereford-Angus cross carcasses at a constant age, fat trim (18.9 %) and marbling score (Small). Dressing percent was similar for the two breed groups. Gelbvieh-sired carcasses had higher kidney and pelvic fat percentages, less fat thickness and larger ribeyes than Hereford-Angus cross carcasses at all endpoints. Yield grades were lower for Gelbvieh-sired carcasses at a constant age, constant carcass weight and constant fat thickness (12.5 mm), and similar at a constant fat trim and marbling score. Hereford-Angus cross carcasses had higher marbling scores and therefore quality grades at a constant age and at a constant carcass weight, with no significant difference at a constant fat thickness or fat trim. When evaluated at a constant age of 473 days, Gelbvieh-sired steers had slightly higher Warner-Bratzler shear force values and lower taste panel tenderness scores, but were similar in juiciness and flavor scores to Hereford-Angus cross carcasses. As in Cycle I, all taste panel scores were in the very acceptable range.

Cundiff (1982) compiled a comparison of Cycles I, II and III of the germplasm evaluation program. All breed values are listed as deviations from the average of the Hereford-Angus reciprocal crosses for the three cycles, and direct comparisons between sire breeds are easier to make, however significant differences are not indicated. The results from the germplasm evaluation program are similar to direct comparisons between Gelbvieh and Limousin sires. When mated to Africander cows, Limousin-sired calves had a higher dressing percent (Anon, 1981). Schmitter et al. (1964, as reported by Mason, 1971) reported Gelbvieh bulls were significantly heavier at 140 and 420 days of age, whereas Limousin bulls had a significantly higher dressing percent and percent muscle and a significantly larger ribeye.

Summary

Crossbreeding is a proven management practice for increasing production efficiency. But with profit margins continuing to narrow, livestock producers must opt for better than any haphazard combination of breeds. Carefully designed breeding programs must be utilized to make the best use of available breeds and maximize production at the least cost. For this to be done, all breeds must be evaluated to determine how each can best be utilized.

Cattle exhibiting the double muscled condition are sold at a premium in some European countries, as the abundance of lean meat provided by such animals is in great demand. Livestock producers in those countries can therefore withstand some of the disadvantages of those cattle, such as poor reproduction and difficult calvings, because it is financially rewarding for them to do so. Market animals heterozygous for the double muscled condition may efficiently produce the lean, yet palatable meat demanded by today's consumer. Further research is certainly warranted to explore this possibility.

Meanwhile the breeds presently available must be further evaluated to determine how each can best be utilized to maximize production efficiency. In previous studies the Limousin and Gelbvieh breeds have shown desirable growth and carcass traits, but also possess the larger birth weights and greater calving difficulty associated with most larger, later maturing breeds. Continued evaluation is needed to further identify the breeds, lines within breeds and individual animals which can best be utilized to accomplish specific production objectives.

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CHAPTER III

COMPARISON OF GELBVIEH AND LIMOUSIN SIRES IN A TERMINAL CROSSBREEDING SYSTEM

Summary

The Gelbvieh and Limousin breeds were evaluated for use as terminal sires over a four year period (1982-1985). A total of 777 calves from 28 bulls (7 per year) of each breed were produced from eight various 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 and Jersey X Hereford). Calves were raised by their dams, without creep feed, on native and bermudagrass pastures until weaning at an average age of 205 days. Although calving difficulty was similar, Gelbvieh-sired calves were 1.1 kg heavier ($P<.05$) at birth and had 2.1 % higher ($P<.05$) preweaning mortality. Gelbvieh-sired calves gained an average of 57 g per day faster ($P<.05$) prior to weaning and therefore had a 12.3 kg advantage ($P<.05$) in weaning weight compared to Limousin-sired calves. The 1982 and 1984 calf crops (409 head) were placed in a feedlot and fed ad libitum a corn-based finishing ration. Animals were individually selected for slaughter when estimated to have attained a low Choice quality grade. Daily gain was similar for the two breeds, but due to a 13 kg advantage ($P<.05$) when placed on feed, the Gelbvieh-sired calves were in the feedlot 6.6 fewer days. Feed efficiency and slaughter weight were similar for calves from the two sire breeds. Limousin-sired calves had a .7 % advantage ($P<.05$) in dressing percentage, but had .13 cm more subcutaneous fat ($P<.05$). Hot carcass weight, carcass weight per day of age, estimated kidney, pelvic and heart fat percentage, longissimus area, cutability percentage and quality grade were similar for the two sire breeds, with overall least-squares means of 341.8 kg, 756 g, 2.74 %, 90.2 cm^2, 50.64 % and 9.56 (10=low Choice), respectively. Calves sired by both breeds performed well, indicating the Gelbvieh and Limousin breeds would both be useful as terminal sires.

(Key Words: Beef Cattle, Crossbreeding, Gelbvieh, Limousin, Terminal Sires)

Introduction

Crossbreeding has been widely accepted by commercial producers as a method of increasing production efficiency, as indicated by the 70 % of the cattle now marketed in the United States which are crossbreds (Koch and Algeo, 1983). The advantages from crossbreeding can be maximized with a well designed breeding program which matches breeds to utilize complementarity in the cow herd and their progeny. Dickerson (1969) stated that near maximum performance can be attained by using two-breed cross dams and selected sire lines. Numerous simulation models (Cartwright et al., 1975; Wilton and Morris, 1976; Notter et al., 1979; Clarke, 1984) indicate production efficiency was greatest when a terminal system was used. Matings of large sires and small dams also maximizes complementarity (Fitzhugh, 1975). Breeds useful as terminal sires show superior growth and carcass characteristics, but also tend to increase calving difficulty (Cundiff, 1974). Smith (1976) reported the advantage in growth, lean carcass composition and feed efficiency from large sires offset the additional costs per calf associated with more difficult births and preweaning mortality.

The Limousin breed has often been recommended (Smith, 1976; Frahm and Belcher, 1978; Vissac, 1982) and utilized (Adams et al., 1973; Berg et al., 1978; Fredeen et al., 1982a; Fredeen et al., 1982b; Rahnefeld et al., 1983) as a terminal sire due to its adequate growth rate, feed efficiency and ability to produce lean, meaty carcasses. Limousin-sired calves also have lower birth weights and less calving difficulty than the other Continental breeds (Vissac, 1982). Conversely, little information is available on the Gelbvieh breed for use as a terminal sire, although results of studies at the Meat Animal Research Center (Gregory et al., 1978; Koch et al., 1979; Cundiff et al., 1981) and Georgia (Gotti, 1982; Gotti et al., 1985) suggest the breed may be useful in such a role. The purpose of this study, part of a long term evaluation of various two-breed cross cows, was to compare the Gelbvieh and Limousin breeds for use as terminal cross sire breeds.

Materials and Methods

The Gelbvieh and Limousin bulls used in this study were selected by the American Gelbvieh Association and the North American Limousin Foundation, respectively. Semen from 28 different bulls (seven per year) of each the Gelbvieh and Limousin breeds was donated by owners of the bulls for use in the 1981 through 1984 breeding seasons. Cows of eight different two-breed combinations (Hereford X Angus, Angus X Hereford, Simmental X Angus, Simmental X Hereford, Brown Swiss X Angus, Brown Swiss X Hereford, Jersey X Angus and Jersey X Hereford) were randomly assigned to bulls, so each bull received approximately the same number of cows from each crossbred cow group and age. Cows ranged from 7 to 9 years of age when the first calves in the study were born in 1982, and from 10 to 12 years in 1985 when the last calves were born. For a more complete description of the cow herd and its development see Belcher and Frahm (1979). Cows were artificially inseminated each year during a 75-day breeding season starting approximately May 1.

Calves were born primarily in February and March at the North Lake Carl Blackwell Research Range west of Stillwater and were assigned a calving difficulty score of 1 to 6 (scoring system presented in Table II) by the herdsman. All calves were weighed, tagged, dehorned and the bulls castrated within 24 hours of birth. Calves were raised by their dams, without creep feed, on native and bermudagrass pastures until weaning at an average age of 205 days. Weaning weights were recorded and calves were scored for conformation (primarily muscling) and condition (fatness) by a panel of three people. Two of the panel members were the same for all 4 years of the study.

Following weaning, the 1982 and 1984 calf crops were transferred to a feedlot at the Southwestern Livestock and Forage Research Station at El Reno, Oklahoma. Calves were grouped by sire breed, crossbred dam group and sex and randomly assigned to pens in two barns, one for steers and one for heifers. Calves from the Hereford-Angus reciprocal cross cows were treated as one breed group and penned together. Both barns consisted of 14 concrete floored pens measuring 11.0 x 14.3 m, with 6.4 m covered by a pole barn open to the south. Self feeders were located in the barns and automatic waterers were present outside. The 1982 calves were placed on test the day following weaning, with actual weaning weights used as on-test weights. The 1984 calves were given a brief period to adapt to the surroundings and ration before shrunk weights were recorded when the test period began. All cattle received implants (Synovex-H for heifers and Synovex-S for steers) when placed in the feedlot and again midway through the feedlot period. The ration presented in Table I was weighed as it was dispensed into the self feeders from the feed cart. Excess feed was weighed at the end of the feedlot period.

Cattle were weighed approximately every 30 days, with a shrunk weight recorded when the average age was 365 days. As cattle neared slaughter condition they were weighed, evaluated and individually selected for slaughter every two weeks. Cattle were selected when estimated to have attained a low Choice quality grade. Shrunk weights were obtained before the cattle were transferred to a commercial slaughter facility where the cattle were slaughtered on either the day of, or the day following arrival.

Cold carcass weights were recorded and converted to a hot carcass weight basis (divided by .973) on the 1982 cattle, whereas actual hot carcass weights were obtained on the 1984 cattle. Carcasses were chilled a minimum of 48 hours before evaluation by Oklahoma State University Meat Science personnel. Carcass maturity, marbling score and estimated percent KPH fat were recorded at the plant. Longissimus muscle area and subcutaneous fat thickness tracings were measured with a compensating polar planimeter and fat depth probe, respectively. Fat thickness was measured at three places (1/4, 1/2 and 3/4 length) along the longissimus muscle edge and averaged. Cutability percentage was determined for each carcass using the USDA cutability equation.

All traits except feed efficiency were analyzed with Harvey's least squares analysis of variance procedures. The model included fixed effects of sire breed, crossbred dam group, age of dam, parity of dam, sex of calf and all two-way interactions. Three-way interactions were assumed to be nonsignificant. Since the number of parities in the data set ranged from three to 11, parity was subdivided into two classes: five or less and six or more. Random effects included in the model were years nested within sire breed and sires nested within year and sire breed. Sire breed and years within sire breed were tested with the mean square of sires within year and sire breed as the denominator. All other effects were tested with the residual mean square. Linear contrasts were used to test for specific interactions when the sire breed x crossbred cow group interaction was significant. The Hereford-Angus reciprocal cross cows were omitted when comparing Angus cross vs Hereford cross cows with such a linear contrast. When analyzing birth weight and calving difficulty score, calves born as twins were not included. Likewise, all calves presented abnormally at birth (calving difficulty score=6) were omitted when analyzing calving difficulty score. Subcutaneous fat thickness was analyzed as the average of three measures and also as a single measure (3/4 length of the longissimus muscle).

Age at weaning was included as a covariate when analyzing all weaning traits and on-test weight was included as a covariate for feedlot daily gain. Slaughter weight and all carcass traits except marbling score and quality grade were analyzed with marbling score included as a covariate. Nonsignificant sources of variation, including covariates, were omitted from the model and least-squares means obtained from the reduced model.

Feed efficiency was measured on a pen basis and analyzed by least-squares analysis of variance. Fixed effects included in the model were sire breed, dam crossbred group, sex of calf and all two-way interactions. On-test weight was included as a covariate. The residual mean square was used to test all effects. Least-squares means were obtained from a reduced model which had nonsignificant sources of variation omitted.

Results and Discussion

A total of 777 calves (360 heifers and 417 steers) were born during the four year period. Sire breed least-squares means for birth and weaning traits are presented in Table II. Gelbvieh-sired calves were 1.1 kg heavier ($P<.05$) at birth, but did not have an increased calving difficulty score. A sire breed x crossbred cow group interaction ($P<.05$) was observed for birth weight, with least-squares means for those subclasses listed in Table III. The only noticeable differences were between calves from Brown Swiss-Hereford cross cows and from Brown Swiss-Angus cross cows when mated to Gelbvieh bulls and between Limousin-sired calves from Simmental-Hereford cross vs Simmental-Angus cross cows. Although there was not a significant difference between sire breeds for calving difficulty score, interactions ($P<.05$) between sire breed and certain dam characteristics (age of dam and parity) were observed. Table IV contains least-squares means for the sire breed x age of dam subclasses. Limousin-sired calves exhibited greater dystocia scores in all subclasses except when from 8-

and 12-year-old cows, with Gelbvieh-sired calves experiencing more calving difficulty from cows of those ages. Least-squares means for sire breed x dam parity are given in Table V. Gelbvieh-sired calves had less calving difficulty when from cows with five or fewer parities than when from cows with six or more parities. Conversely, Limousin-sired calves had less calving difficulty when from cows with six or more parities. The two interactions were probably correlated since number of parities increases as cow age increases. These results are similar to those obtained at the Meat Animal Research Center (Smith et al., 1976a; Gregory et al., 1978), as both Gelbvieh and Limousin-sired calves were heavier at birth than Hereford-Angus reciprocal cross calves, with Gelbvieh cross calves .8 kg heavier than Limousin cross calves (3.3 vs 2.5 kg heavier than Hereford-Angus reciprocal cross calves, respectively). Limousin-sired calves had greater calving difficulty than Hereford-Angus reciprocal cross calves, whereas Gelbvieh-sired calves were similar to the Hereford-Angus reciprocal cross calves at MARC, compared to no difference between the two sire breeds in this study.

Limousin-sired calves had lower preweaning mortality (2.1 %, $P<.05$) and daily gain (57 g/d, $P<.05$) than Gelbvieh-sired calves. Heavier birth weight combined with faster growth rate for Gelbvieh-sired calves resulted in a 12.3 kg advantage ($P<.05$) at weaning time (205 days). Other reports (Fredeen et al., 1982a; Fredeen et al., 1982b; Newman et al., 1985) have documented lower preweaning mortality and daily gain for Limousin compared to other Continental breeds. Gregory et al. (1978) reported greater daily gain and heavier weaning weight for Gelbvieh-sired calves when compared to Hereford-Angus reciprocal crosses and Smith et al. (1976a) reported similar performance between Limousin-sired and Hereford-Angus reciprocal cross calves. Like weaning weight, weaning conformation and condition scores were adjusted to a standard age of 205 days. Limousin-sired calves had a slightly lower ($P<.05$) condition score (5.3 vs 5.5) but a slight advantage ($P<.05$) in conformation score (13.5 vs 13.4). The sire breed x crossbred cow group interaction for conformation score was significant, with least-squares means for those subclasses listed in Table III. Table VI contains least-squares means for specific cow cross x sire breed interactions. Calves from Simmental cross cows had higher conformation scores ($P<.05$) than calves from Brown Swiss cross cows when mated to Limousin bulls, whereas conformation scores of calves from the two crossbred cow groups were similar when sired by Gelbvieh bulls. Limousin-sired calves had higher conformation scores ($P<.10$) from Angus cross cows than from Hereford cross cows, with these rankings reversed when calves were sired by Gelbvieh bulls.

Feedlot and carcass traits were evaluated on the 409 calves (191 heifers and 218 steers) comprising the 1982 and 1984 calf crops. Table VII contains least-squares means of sire breed performance for feedlot traits. When adjusted to a constant on-test weight, daily gain was similar for the two sire breeds, but there were significant interactions between sire breed and crossbred cow group. Table III lists the least-squares subclass means for those traits exhibiting a sire breed x crossbred cow group interaction. This interaction can be further divided into sire breed x Angus cross vs sire breed x Hereford cross cows ($P<.01$) and sire breed x small frame (Jersey cross) vs sire breed x large frame (Simmental cross and Brown Swiss cross) cows ($P<.10$).

Differences between least-squares means for cow cross groups within sire breed are presented in Table VI. There was a reversal in ranking of Hereford cross and Angus cross cows by sire breed, as calves from Angus cross cows gained faster than calves from Hereford cross cows when sired by Gelbvieh bulls, but slower when sired by Limousin bulls. The interaction between sire breed and cow size consisted of the same ranking, as calves from large frame cows grew faster when sired by either breed, but the magnitude of the difference varied, being greater (138 vs 75 g) in Gelbvieh-sired calves. There was also a significant sire breed x dam parity interaction for feedlot daily gain. Least-squares means are shown in Table V for those subclasses. Once again the ranking was the same, as calves from cows with more parities grew faster, but the magnitude of the difference was greater for Gelbvieh-sired calves (2 vs 70 g).

Gelbvieh-sired calves were 13 kg heavier ($P<.05$) when placed in the feedlot and because of similar daily gains maintained a weight advantage ($P<.10$) at 365 days of age (447.0 vs 435.3 kg). Since slaughter weight was similar for the two sire breeds when a marbling score of Small was included as a covariate, this weight advantage allowed the Gelbvieh-sired calves to be slaughtered with 6.6 fewer days in the feedlot ($P<.05$). Significant sire breed x crossbred cow group interactions were present for days on feed and slaughter weight. Table III lists subclass least-squares means for those traits. The days on feed interaction can be further divided to sire breed x Angus cross vs sire breed x Hereford cross cows. Differences between least-squares means for cow cross groups are shown for those subclasses in Table VI. Gelbvieh-sired calves were in the feedlot 11.3 fewer days when from

Angus cross cows, but Limousin-sired calves from Angus cross cows spent 3.4 more days in the feedlot than calves from Hereford cross cows. The sire breed x crossbred cow group interaction ($P<.05$) for slaughter weight was not readily explainable.

Sire breed x dam parity ($P<.10$) least-squares subclass means for slaughter weight are shown in Table V. Gelbvieh cross calves from cows with six or more parities were 10.5 kg heavier than calves from cows with five or fewer parities, whereas the ranking was reversed in Limousin-sired calves, as calves from cows with more parities weighed 12.4 kg less than calves from cows with five or fewer parities. There was a sire breed x calf sex interaction ($P<.05$) for days on feed. Table VIII contains least-squares means for those subclasses. Steers for the two sire breeds spent similar time in the feedlot, but Gelbvieh-sired heifers were on feed 12.8 fewer days than Limousin-sired heifers. Gelbvieh-sired calves had a slight non-significant advantage in feed efficiency. Smith et al. (1976b) and Cundiff et al. (1981) reported that Gelbvieh-sired steers gained faster than Limousin-sired steers, while there was no difference between Gelbvieh and Limousin-sired calves in this study. Feed efficiency was similar for Gelbvieh and Limousin-sired steers when evaluated on an age constant basis, whereas Gelbvieh cross steers had an advantage when compared on a weight constant basis.

Since a low Choice quality grade was the desired endpoint, a marbling score of Small was used as a covariate when evaluating hot carcass weight, dressing percent and estimated KPH fat percentage. The covariate was not a significant source of variation for other carcass traits and was therefore omitted from the reduced model for those traits. Sire breed least-squares means for carcass traits are given in

Table IX. Hot carcass weight and carcass weight per day of age were similar for calves from the two sire breeds, but Limousin-sired calves had an advantage ($P<.01$) in dressing percent (62.9 vs 62.2 %). The sire breed x sex of calf interaction for dressing percent was significant, with least-squares means of those subclasses presented in Table VIII. Rankings of sexes within sire breed were the same, as heifers had a higher dressing percent in both cases, but the difference between sexes was greater for Gelbvieh-sired calves. Subcutaneous fat thickness was .13 cm less ($P<.05$) for Gelbvieh cross calves when evaluated as a single measure (3/4 length of longissimus muscle) and .20 cm less ($P<.01$) when evaluated as an average of the three measures recorded. Estimated KPH fat percentage and longissimus area were similar for the two sire breeds, with a sire breed x crossbred cow group interaction ($P<.10$) existing for longissimus muscle area. Least-squares means for longissimus area are listed for those subclasses in Table III. Differences were not readily apparent, but the interaction may be due to the smaller longissimus muscle area of calves from Brown Swiss-Angus and Jersey-Angus cross cows when compared to the comparable Hereford cross cows mated to Gelbvieh sires, and when compared to calves from Limousin bulls and the same crossbred cow groups. Carcass cutability, as calculated by the USDA equation, was similar for the sire breeds, but a significant sire breed x sex of calf interaction was present. Table VIII contains least-squares means for the subclasses of that interaction. Rankings within sire breed were the same, but Limousin cross calves had a greater difference between steers and heifers. Differences between sire breeds for marbling score and quality grade were not significant, although there was a sire breed x dam parity interaction (P<.05) for quality grade. Table V contains the least-squares means for those subclasses. Calves from cows with five or fewer parities had higher quality grades if sired by a Gelbvieh bull rather than a Limousin bull, whereas calves from cows with six or more parities had similar quality grades regardless of sire breed. Koch et al. (1976) and Koch et al. (1979) report comparable carcass characteristics when carcasses from Gelbvieh and Limousin cross cattle were compared to those from Hereford-Angus reciprocal cross cattle. Gelbvieh and Limousin cross carcasses were heavier, had a larger longissimus muscle area and were leaner than Hereford-Angus cross carcasses, but also had lower marbling scores. The MARC study showed Gelbvieh-sired calves to have more, and Limousin-sired calves less KPH fat than the Hereford-Angus calves, whereas in this study the two sire breeds had a similar amount of internal fat.

When evaluated as terminal cross sires mated to various two-breed cross cows, both the Gelbvieh and Limousin breeds performed favorably. Calves sired by bulls of both breeds exhibited desirable growth rate and feed efficiency, and produced lean, muscular carcasses. The greater preweaning growth rate of the Gelbvieh-sired calves was partially offset by a higher preweaning death loss. Since this study involved only mature cows, the heavier birth weight of Gelbvieh-sired calves may result in greater calving difficulty with younger cows. This study illustrates both the Gelbvieh and Limousin breeds are useful in a terminal crossing system. When selecting terminal sires from these two breeds, emphasis should be based as much on the individual bulls available and the price for which they can be obtained as the breed of the sire.

TABLE I

FEEDLOT RATION

Ingredient	Percentage in ration
Corn	78
Alfalfa	8
Cottonseed hulls	4
Molasses	5
Supplemental Pellets[a]	5
Total	100

[a]Supplemental pellets consisted of 67.6% soybean meal (44% crude protein), 12% urea, 10% calcium carbonate, 8% salt plus Aurofac, vitamin A and Trace minerals.

TABLE II

LEAST-SQUARES MEANS AND STANDARD ERRORS FOR BIRTH AND WEANING TRAITS

Trait	Sire Breed: Gelbvieh(G)	Sire Breed: Limousin(L)	Difference (G-L)
Birth wt, kg	39.6 ± .5	38.5 ± .5	1.1**
Dystocia score[a]	1.09 ± .04	1.17 ± .04	-.08
Preweaning mortality, %	3.3 ± .8	1.2 ± .8	2.1**
Preweaning ADG, g/d	1041 ±8	984 ±8	57***
Weaning wt, kg	252.9 ±1.9	240.6 ±1.9	12.3***
Weaning conformation[b]	13.4 ± .04	13.5 ± .04	-.1**
Weaning condition[c]	5.5 ± .04	5.3 ± .04	.2***

[a]Calving difficulty: 1 = no difficulty, 2 = little difficulty, 3 = moderate difficulty, 4 = major difficulty and 5 = caesarean.
[b]Conformation score: 13 = average choice and 14 = high choice.
[c]Condition score: nine point scale with 1 = very thin, 5 = average and 9 = very fat.
**P <.05, ***P<.01

TABLE III

LEAST-SQUARES MEANS AND STANDARD ERRORS BY SUBCLASS FOR TRAITS WITH A SIGNIFICANT SIRE BREED X CROSSBRED COW GROUP INTERACTION

		Trait					
Sire breed	Crossbred cow group	Birth wt,kg***	Weaning Conformation[a]**	Days on Feed**	Feedlot ave Daily gain,g/d*	Slaughter wt,kg**	Longissimus area,cm^2*
Gelbvieh	Hereford X Angus	40.4±.6	13.2±.06	236.8±2.6	1303±155	535.4±4.5	89.3±2.0
	Angus X Hereford	39.0±.8	13.4±.06	233.3±3.1	1290±181	552.4±5.3	91.2±2.3
	Simmental X Angus	40.6±.6	13.9±.06	243.4±2.8	1369±161	594.9±4.8	97.6±2.1
	Simmental X Hereford	40.9±.6	13.8±.06	243.9±2.9	1296±168	577.0±5.0	94.6±2.1
	Brown Swiss X Angus	40.1±.7	13.8±.06	220.9±2.9	1347±172	552.1±5.1	87.1±2.2
	Brown Swiss X Hereford	44.3±.6	13.9±.06	242.5±2.8	1288±166	572.4±4.9	94.0±2.1
	Jersey X Angus	35.6±.7	12.5±.06	210.0±2.8	1181±166	483.5±4.9	79.8±2.1
	Jersey X Hereford	35.6±.9	12.8±.05	222.0±2.8	1192±169	517.6±5.0	86.3±2.1
Limousin	Hereford X Angus	38.0±.6	13.4±.05	243.9±2.9	1270±162	540.7±5.0	89.5±2.0
	Angus X Hereford	38.9±.6	13.5±.06	227.5±2.7	1336±153	536.5±4.7	88.7±1.9
	Simmental X Angus	38.1±.6	14.0±.05	250.1±2.7	1270±152	565.9±4.7	92.5±1.9
	Simmental X Hereford	41.5±.6	14.0±.06	256.2±2.9	1352±161	589.2±4.9	96.6±2.1
	Brown Swiss X Angus	40.8±.6	13.9±.06	247.8±2.7	1317±150	572.5±4.6	91.6±1.9
	Brown Swiss X Hereford	40.5±.7	13.7±.07	238.4±3.1	1307±170	548.0±5.2	92.7±2.2
	Jersey X Angus	35.4±.8	12.9±.05	224.2±2.6	1193±148	502.8±4.7	84.2±1.9
	Jersey X Hereford	35.0±.8	12.7±.06	217.4±2.9	1280±166	515.0±5.1	86.9±2.1

[a]Conformation score: 13=average Choice and 14=high Choice.
*P<.10, **P<.05, ***P<.01

TABLE IV

LEAST-SQUARES MEANS AND STANDARD ERRORS BY SIRE BREED AND DAM AGE FOR DYSTOCIA SCORE[a]**

Sire breed	Age of dam					
	7	8	9	10	11	12
Gelbvieh	1.04±.10	1.17±.07	1.03±.07	1.09±.07	1.03±.09	1.17±.12
Limousin	1.18±.09	1.06±.07	1.27±.07	1.21±.07	1.25±.08	1.02±.12

[a]Calving difficulty: 1=no difficulty, 2=little difficulty, 3=moderate difficulty, 4=major difficulty, 5=caesarean.
**$P < .05$

TABLE V

LEAST-SQUARES MEANS AND STANDARD ERRORS BY SUBCLASS FOR TRAITS WITH A SIGNIFICANT SIRE BREED X DAM PARITY INTERACTION

		Traits			
Sire breed	Parity	Dystocia score[a]**	Feedlot avg daily gain, g/d*	Slaughter wt, kg*	Quality grade[b]**
Gelbvieh	≤5	1.02±.07	1248±162	542.9±7.3	9.92±.73
	≥6	1.16±.03	1318± 89	553.4±4.0	9.45±.44
Limousin	≤5	1.26±.07	1289±155	552.5±7.3	9.32±.74
	≥6	1.07±.03	1291± 85	540.1±3.9	9.56±.43

[a]Calving difficulty: 1=no difficulty, 2=little difficulty, 3=moderate difficulty, 4=major difficulty, 5=caesarean.
[b]Quality grade: 9=high Good and 10=low Choice
*P<.10, **P<.05

TABLE VI

DIFFERENCES BETWEEN SUBCLASS LEAST-SQUARES MEANS OF SPECIFIC DAM BREED CROSSES FOR TRAITS WITH A SIGNIFICANT SIRE BREED X DAM BREED CROSS INTERACTION

	Contrast					
	Simmental X vs Brown Swiss X		Hereford X vs Angus X		Jersey X vs Simmental X and Brown Swiss X	
Trait	Gelbvieh	Limousin	Gelbvieh	Limousin	Gelbvieh	Limousin
Weaning conformation[a]**	0	.3				
Weaning conformation[a]*			.1	-.1		
Days of feed,d**			11.3	-3.4		
Feedlot avg*** daily gain,g/d			-40	53		
Feedlot avg* daily gain,g/d					-138	-75

[a]Conformation Score: 13=average Choice and 14=high Choice
*P<.10, **P<.05, ***P<.01

TABLE VII

LEAST-SQUARES MEANS AND STANDARD ERRORS FOR FEEDLOT TRAITS

Trait	Sire Breed		Difference (G-L)
	Gelbvieh(G)	Limousin(L)	
Initial feedlot wt,kg	251.5 ± 2.7	238.5 ± 2.7	13.0***
Yearling wt, kg	447.0 ± 6.2	435.3 ± 6.3	11.7*
Days on feed	231.6 ± 3.0	238.2 ± 3.1	-6.6**
Feedlot daily gain g/d	1283 ± 101	1291 ± 99	-8
Feed efficiency, kg feed/kg gain	6.90 ± 0.08	7.08 ± 0.08	-.18
Slaughter wt, kg	548.1 ± 5.3	546.3 ± 5.3	1.8

*P<.10, **P<.05, ***P<.01

TABLE VIII

LEAST-SQUARES MEANS AND STANDARD ERRORS BY SUBCLASS FOR TRAITS WITH A SIGNIFICANT SIRE BREED X SEX OF CALF INTERACTION

		Trait		
Sire Breed	Sex of calf	Days on Feed**	Dressing Percentage**	Cutability, %*
Gelbvieh	heifer	220.1±3.1	62.9±.2	51.02±.20
	steer	243.1±2.9	61.4±.1	50.54±.19
Limousin	heifer	232.9±3.1	63.2±.2	51.03±.20
	steer	243.5±2.8	62.7±.1	49.99±.18

*$P<.10$, **$P<.05$

TABLE IX

LEAST-SQUARES MEANS AND STANDARD ERRORS FOR CARCASS TRAITS

Trait	Sire Breed		Difference
	Gelbvieh(G)	Limousin(L)	(G-L)
Carcass wt, kg	342.6 ±3.2	341.2 ±3.2	1.4
Carcass wt/d of age,g	763 ±8	750 ±8	13
Dressing percentage	62.2 ± .1	62.9 ± .1	.7***
Single fat thickness,cm	1.15± .06	1.28± .06	-.13**
Avg fat thickness,cm	1.58± .06	1.78± .06	-.20***
Kidney,heart and pelvic fat, %	2.77± .05	2.72± .05	.05
Longissimus area, cm^2	90.0 ±1.2	90.4 ±1.2	-.4
Cutability, %	50.78± .19	50.51± .19	.27
Marbling score[a]	4.78± .10	4.76± .10	.02
Quality grade[b]	9.68± .50	9.44± .50	.24

[a]Marbling score: 4=Slight and 5=Small.
[b]Carcass grade: 9=high Good and 10=low Choice.
**P<.05, ***P<.01

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APPENDIX

TABLE I

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

Source	Birth wt	Dystocia score	Mortality %	Daily gain	Weaning wt	Weaning Scores Conform	Cond
Calf 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 cow Group (C)	X	X	X	X	X	X	
Cow age (A)	X	X	X	X	X	X	X
Cow parity (P)	X	X		X	X		X
Calf sex (S)	X	X	X	X	X	X	X
BxC	X					X	
BxA		X					
BxP		X					
CxA			X				
CxP	X						
CxS					X		
AxS			X				
Age at weaning				X	X	X	X

[X]Source of variation was included in reduced model.

TABLE II

SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR FEEDLOT TRAITS

Source	Initial wt	Yearling wt	Days on feed	Daily gain	Feed Efficiency	Slaughter wt
Calf Sire Breed(B)	X	X	X	X	X	X
Year(Y)/B	X	X	X	X	X	X
Sire/Y/B	X	X	X	X		X
Crossbred cow Group (C)	X	X	X	X	X	X
Cow age (A)	X	X	X	X		X
Cow parity (P)	X	X	X	X		X
Calf sex (S)	X	X	X	X	X	X
BxC			X	X		X
BxP		X		X		X
BxS			X			
CxS						X
AxS			X			X
Initial wt.				X	X	
Marbling score						X

X Source of variation was included in reduced model.

TABLE III

SOURCES OF VARIATION INCLUDED IN REDUCED MODELS FOR CARCASS TRAITS

Source	Carcass wt	Carcass wt /day of age	Dressing %	Fat thickness single	Fat thickness average	KHP fat	Longissimus area	Cutability	Marbling score	Carcass grade
Calf sire breed(B)	X	X	X	X	X	X	X	X	X	X
Year(Y)/B	X	X	X	X	X	X	X	X	X	X
Sire/Y/B	X	X	X	X	X	X	X	X	X	X
Crossbred cow group(C)	X	X	X	X	X	X	X	X	X	X
Cow age(A)	X	X		X	X		X	X		
Cow parity(P)				X		X	X			X
Calf sex(S)	X	X	X	X	X	X	X	X	X	X
BxC	X						X			
BxP				X						X
BxS			X	X			X	X		X
CxA					X					
CxP						X				
CxS			X	X				X	X	
AxS	X			X			X	X		
PxS										
Marbling score	X		X			X				

X Source of variation was included in reduced model.

TABLE IV

MEAN SQUARES FROM REDUCED MODEL ANALYSES OF VARIANCE FOR BIRTH AND WEANING TRAITS

Source	df[a]	Calf birth wt,kg[2]	Calving diff score[2]	Prewean death loss,%	Avg daily gain,g[2]	Weaning wt,kg[2]	Weaning Scores[2]	
							Conformation	Condition
Calf sire breed(S)	1	193.6**	.46	.08**	599.1***	27880***	3.20**	3.96***
Year(Y)/B	6	104.8**	.26	.06**	178.0***	8045***	1.62***	4.86***
Sire/Y/B	48	39.0***	.19	.02	11.5**	602**	.47***	.29*
Crossbred cow group(C)	7	217.9***	.49	.05*	264.5***	14881***	25.18***	
Cow age	5	30.8	.04	.01	41.3***	2105***	1.29***	.87***
Cow parity	1	12.4	.03		16.9	740		.67*
Calf sex	1	1460.7***	1.69**	.02	305.1***	24687***	7.08***	6.10***
BxC	7	56.7***						
BxA	5		.67**				.66**	
BxP	1		1.76**					
CxA	35			.04**				
CxP	7	30.0						
CxS	7					607		
AxS	5			.09**				
Age at weaning	(1)				54.3***		17.24***	6.57***
Remainder	631(630)[b]	19.7	.29	.02	7.9	406	.29	.22

[a]Number in parenthesis represents df for models in which a covariate was included.
[b]Remainder df is increased by df of sources not included in the model.
*P<.10, **P<.05, ***P<.01

TABLE V

MEAN SQUARES FROM REDUCED MODEL ANALYSES OF VARIANCE FOR FEEDLOT TRAITS

Source	df[a]	Initial feedlot wt,kg^2	Yearling wt,kg^2	Avg. daily gain,g	Days on feed,d^2	Slaughter wt,kg^2
Calf sire breed(B)	1	17160***	9684*	3.6	4324**	227
Year(Y)/B	2	5985***	9510*	2.1	32102***	31538***
Sire/Y/B	24	719	3028***	49.5***	832	1876
Crossbred cow group(C)	7	5679***	18354***	120.5***	6593***	41278***
Cow age(A)	4	2231**	4731***	16.7	1090	2017
Cow parity(P)	1	4502**	128	53.1	68	37
Calf sex(S)	1	13454***	137020***	3154.6***	22372***	343899***
BxC	7			42.7**	1506**	4383**
BxP	1		2342	61.8*		6645*
BxS	1				3347**	
CxS	7					3940**
AxS	4				1989**	5079**
Inital feedlot wt	(1)			156.6***		
Marbling score	(1)					62288***
Remainder	347(346)[b]	836	1251	20.7	704	1763

[a]Number in parenthesis represents df for models in which a covariate was used.
[b]Remainder df is increased by df of sources not included in the model.
*P<.10, **P<.05, ***P<.01

TABLE VI

MEAN SQUARES FROM REDUCED MODEL ANALYSIS OF VARIANCE FOR FEED EFFICIENCY

Source	df	Feed Efficiency, $(kg/kg)^2$
Calf sire breed(B)	1	.33
Year/S	2	.14
Crossbred cow group	6	.26
Sex of calf	1	5.60***
Initial feedlot wt.	1	.85**
Remainder	44	.14

**$P<.05$, ***$P<.01$

TABLE VII

MEAN SQUARES FROM REDUCED MODEL ANALYSES
OF VARIANCE FOR CARCASS TRAITS

Source	df[a]	Hot carcass wt,kg^2	Carcass wt /d of age,g^2	Dress %	Fat thickness Avg, cm^2	Fat thickness Single,cm^2	KHP fat%	Longissimus Area, cm^4	Marble Score^2	Quality grade^2	Cutability %
Calf sire breed(S)	1	172.7	18.1	61.5***	3.87***	1.25**	.19	13.8	.09	4.26	7.23
Year(Y)/B	2	25776.4***	14.1	440.7***	3.37***	3.94***	40.15***	131.8	.99	.35	75.87***
Sire/Y/B	24	1251.0**	8.8**	3.9	.43***	.23**	.28	159.1***	1.40***	3.48***	4.01***
Crossbred cow group(C)	7	21636.9***	41.9***	5.5	.35**	.88***	.63**	964.4***	.79	1.47	3.79**
Cow age	4	1480.9	10.8**		.02	.04		20.4			.99
Cow parity	1					.03	.60	0.2		.70	
Calf sex	1	160811.2***	553.4***	87.7***	.39*	.03	2.70***	156.9	3.57***	.75	45.64***
BxC	7							136.4*			
BxP	1					.31				7.08***	
BxS	1			26.8**		.26		116.4		2.53	6.81*
CxA	28				.26***						
CxP	7						.76***				
CxS	7			10.7*		.20			.89*		3.52*
AxS	4	1457.0			.22	.36**		219.1**			4.62**
Marbling score	(1)	8363.1***		28.1**			.66				
Remainder	312(311)[b]	774.0	4.1	5.72	.14	.13	.27	67.7	.51	1.02	1.84

[a]Number in parenthesis represents df for models in which a covariate was included.
[b]Remainder df is increased by df of sources not included in the model.
*P<.10, **P<.05, ***P<.01

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