Life cycle evaluation of five biological types of beef cattle in a range production system
by Kathleen Jeanne Christensen Davis

A thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Animal Science
Montana State University

Abstract:
Data collected on five dam breedtypes, Hereford (HH) , 50% Angus-50% Hereford (AH), 25% Simmental-75% Hereford (1S3H), 50% Simmental-50% Hereford (SH), and 75% Simmental-25% Hereford (3S1H), were used to develop a life-cycle, stochastic model of cattle production. Yearlings were bred to a single Red Poll sire with subsequent matings to either Charolais or Tarentaise sires. Model inputs were cow weights at four times during the production year, calf birth and weaning weights, and pregnancy, dystocia and calf survival rates. Expenses included feed costs (supplementation, pasture rent and hay costs) , and non-feed costs (replacements, bulls, veterinary costs, labor, marketing and interest). Returns were based on the sale of calves and cull cows. Five replications were simulated for each dam breedtype x sire breed combination, with 60 heifers started for each system. Measures of system performance included number of matings, calves weaned per cow exposed, calf weight weaned per cow exposed, DM and Meal of ME consumed per kg of calf weight and total weight sold, input cost per kg of steer equivalent weight sold, cost of production, and net returns. Data were analyzed using two-way analysis of variance. Sire breed effects and the interaction were not generally significant while dam breedtype effects were highly significant for traits. Economic efficiency and net returns were closely related to the number and weight of calves sold, but not to measures of energetic efficiency or productivity defined as total weight sold per cow exposed when comparing dam breedtypes. The SH and AH dams were consistently more profitable, though they were least energetically efficient. The dam breedtype comparisons were not sensitive to changes in prices paid for feed or the price received for the calf crop. The two backcross groups were generally intermediate, and showed net profits, suggesting a rotational crossbreeding system may be feasible. Reproductive performance in young dams was important, though some loss of reproduction could be tolerated if weaned calves had higher weaning weights. Utilizing heterosis appeared to be important. The crossbred groups all performed better than the straightbred group. For a northern range cow/calf production system, dams with maximum heterosis or the more intermediate types realized greater economic returns. (KEY WORDS: Simulation, Beef Cattle, Efficiency)

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Kathleen Jeanne Christensen Davis

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ABSTRACT

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CHAPTER 1

INTRODUCTION

Beef cattle producers need information that will help them increase efficiency and profit for their operations. The research community has devoted considerable effort to find ways to enable producers to meet these needs. Systematic crossing of cattle breeds to take advantage of direct and maternal heterosis and complimentarity among breeds has contributed to increased and/or more efficient production in the commercial sector. It has been well documented that many crossbreds have shown increased growth rates, increased milk production, and earlier sexual maturity compared to parental straightbreds. Opportunities also exist to develop breeds or mating systems for specific management schemes. Recent emphasis has been on designing mating systems for specific production schemes and environments.

Limitations to producing crosses and testing traits of interest include the time and money involved in developing and maintaining herds of cattle. With more than 275 breeds of cattle worldwide and over 75 breeds recognized in the United States (Turner, 1988), the need for specialized reporting of types best suited to existing resources becomes clear. It is in this area that the computer is being utilized for simulation of different production schemes. Bourdon and

Brinks (1987) and Notter (1979) published results for biological and economic efficiency of cattle by simulation modeling. However, simulation model development depends on data collected, analyzed and reported for different breeds and management schemes. The researcher can then build a model that best represents those aspects of production which have meaningful relationships within the system.

The objective of the research reported here was to evaluate lifetime economic efficiency of five biological types of beef cattle in a northern range cow/calf production system. A computer simulation model, developed for data collected at the Northern Agricultural Research Center near Havre, Montana, was utilized to achieve this objective.

CHAPTER 2

LITERATURE REVIEW

The research community's main objective should be discovering and delivering useable information to livestock producers. This literature review illustrates the many diverse studies on systematic crossing of cattle breeds, the understanding of relationships among these studies required to make intelligent decisions for production systems, and how computer simulation may be of help in assisting producers in this decision making process.

Crossbreeding Studies

While not wishing to make a review of crossbreeding studies the main focus of this discussion, some time must be devoted to this area of research. A brief review of the literature (Armstrong et al., 1990; Belcher and Frahm, 1979; Chenette and Frahm, 1981; Dickerson, 1969; Fredeen et al., 1987; Neville et al., 1984; Rahnefeld, 1989; Rohrer et al., 1988; Sacco et al., 1989; Setshwaelo et al., 1990; Williams et al., 1990) shows the diversity of animal types and traits of interest available for study.

Subjects reported in these eleven studies included cow and calf weights, body condition scores, growth patterns, feed intake, calving ease, milk production, reproduction, 2-yr-old and older dam performance, heterosis, productivity defined in different terms, and net returns. There were eighteen cattle breeds used in several different mating strategies at eight locations in the United States and Canada.

Weight of cows and calves are easily obtained measurements that have been used as the basis for explanation of many different inputs and outputs in a production system. For the cow, mature weight helps explain feed intake required for maintenance and growth. It gives some boundary for birth weight of calves over which dystocia will more likely occur. The size of the cow is used in determining both her biological and economic efficiency.

Calf birth and weaning weights are similarly used in trying to predict efficiencies within a system. Higher birth weight is proposed as the greatest single factor in increased dystocia. Weaning weight is used as a measure of maternal ability. It is also used to estimate the overall efficiency of a breed, mating program or production system.

The use of weight to make predictions for a production system may pose problems for the producer simply because of the wide variation in weights of cattle of differing types. Mean cow weights in the previously mentioned studies ranged from 416 to 511 kg for first calf heifers and 435 to 737 kg for mature cows. Calf birth weights ranged from 28 to 42 kg and weaning weights from 155 to 231 kg.

Nutrient Requirements and Intake

Armstrong et al. (1990) reported feed intakes based in part on the size of the cow. A large, rotational cross (694 kg) had the greatest intakes with straight Hereford (574 kg) ranking lowest. A 4-breed terminal cross (613 kg) and a small, rotational dual purpose cross (565 kg) ranked second and third, respectively. These rankings remained the same during lactation and dry periods. The intakes measured did not follow the weight rankings in that the small dual purpose cross had a higher intake than the Hereford group, possibly due to the crossbred animals being young dams with higher growth requirements. The authors also felt that because an effort was made to adjust diets to maintain an average backfat measurement, reported animal intakes were 18 to 33% lower than requirements estimated from NRC (1984).

Comparisons of various F_1 crosses of Hereford, Angus, and Shorthorn dams by Charolais, Limousin, and Simmental sires, plus a Hereford x Angus cross control were reported by Fredeen et al. (1987) which related crossbred cow productivity to winter feed inputs at two locations in Canada. Energy requirements were estimated based only on body weight according to NRC (1976) but proved inadequate in the less intense management system during the first year of the study. Energy inputs were adjusted to 20% over NRC (1976) in an attempt to increase the body condition of these animals. The cows failed to maintain condition and a subsequent high mortality rate for both cows and calves, and low conception the following year was the basis for yet another 20% increase in energy over NRC (1976) estimates and a change in management from pasture grazing to drylot feeding. Cattle at both locations were fed in excess of estimated requirements in order to attain or maintain a minimum condition score in all cattle at both locations.

Deviations from the Hereford-Angus controls in energy inputs were generally comparable to the deviations in mean initial weights though there were exceptions. In the more intensive management system, all Simmental crosses and a Limousin-Shorthorn cross required more feed than their body weights would indicate, while all Charolais crosses in the harsher environment required less feed relative to the control.

Rahnefeld (1989) reported different growth patterns for young crossbred dams of similar breeding in these same environments. As might be expected, more intensive management in a less restrictive environment resulted in heavier animals during several stages of early production. The less restrictive environment resulted in a 3/4 Simmental-1/4 Shorthorn cross being heaviest, while in the harsher environment the 3/4 Charolais-1/4 Shorthorn was heaviest.

Jenkins and Ferrell (1983) compared the nutrient requirements to maintain mature weight of four breedtypes (Hereford x Angus reciprocal crosses, and Charolais, Jersey and Simmental sires bred to Hereford and Angus dams). These breedtypes were chosen to represent differing mature size and milk production potentials based on their mature weights and milk production levels. Animals were fed at low, medium or high levels of energy in drylot.

The Charolais, Simmental and reciprocal cross dams did not differ in weight throughout the study, but were different from the Jersey crosses which were smallest. Reported dry matter intakes at the low level of feeding (90 kcal metabolizable energy/kg metabolic body weight/day) were consistent with the weight rankings. However, at the high level of feeding (ad libitum), the Charolais cross dams had significantly lower dry matter intakes than the Simmental crosses and the Hereford x Angus reciprocals and did not differ from the Jersey crosses. A conclusion was that factors other than weight affected energy utilization and intake.

Maintenance requirements and energetic efficiency of Angus, Brahman, Hereford, Holstein and Jersey and their reciprocal crosses were measured by Solis et al. (1988). Among the straightbred animals, the Angus and Brahman had lower body weight maintenance requirements than the Holstein and Jersey, and the Holstein and Hereford had lower requirements than the Jersey. Of the crossbred animals, the Holstein x Angus, Jersey and Hereford had higher requirements than those of the Brahman x Hereford and Holstein and Hereford X Angus and Jersey.

While cow weight is commonly used in estimating feed requirements, several authors caution that differences may occur due to milk production potential, lean tissue mass, site of fat deposition and differing basal metabolic rates between *Bos indicus* and *Bos taurus* breeds.

Milk Production

Belcher and Frahm (1979) found significant differences in milk production among 2-yr-old dams of various breed groups produced by mating Angus and Hereford dams with Angus, Hereford, Simmental, Brown Swiss and Jersey sires. Those dams sired by Brown Swiss produced the most milk, followed by crosses of Jersey and Simmental sires on Angus dams. Reciprocal cross Hereford and Angus (control) dams showed the lowest milk production levels. These milk production traits echoed calf pre-weaning average daily gain (ADG) and 205-d adjusted weaning weights.

Chenette and Frahm (1981) reported significant differences among crosses involving Hereford, Angus, Simmental, Brown Swiss, and Jersey for early milk production by 4-yr old dams. The differences had dissipated by late summer and early fall most likely due to drought conditions. While milk production showed little difference later in the year, those dams that were heavier producers early in lactation raised heavier calves at weaning. Higher milk production paralleled higher weaning weights, but areas potentially limiting to the production system, including the feed requirements and subsequent reproduction of these animals due to differing levels of milk production, were not discussed.

Casebolt (1984) reported on lactation curves and milk production potentials for cattle with varying degrees of crossbred influence. The breedtypes included straightbred Hereford, two F_1 crosses (Angus and Simmental crossed on Hereford dams), and 25% and 75% Simmental x Hereford crosses. There was no significant difference between the two F_1 crosses, nor was there a difference between the two backcross breed groups. The F_1 crosses produced significantly more milk than the backcross cows. All crossbred dams produced more milk than the straightbred Herefords. It was also noted that the crossbred dams had more persistent lactation than the straightbred animals.

A study by Setshwaelo et al. (1990) included Holstein and Jersey breeds to determine the effects of high milking ability in crossbred dams. They showed no differences for calf gains from 1/4 Jersey dams as compared to Hereford x Angus reciprocal crosses. It was thought this was due to decreased mammary development as a result of the Jersey cross dams being raised by high milking dams themselves. If the maternal grandsire was Brown Swiss or Gelbvieh, the preweaning growth of the calves showed a larger deviation from the Hereford x Angus reciprocal crosses because of the greater growth potential of these breeds. When cows were sired by Holstein or Brahman (high milk potential), they showed no adverse affects due to poor mammary development, and benefitted from both maternal ability and growth potential.

Measures of Productivity

Defining productive longevity as the age at which a cow dies or is culled because she is incapable of producing a live calf, Rohrer et al. (1988) compared longevity and reasons for removal of straightbred and crossbred beef and dairy cattle at College Station, TX, managed in a beef production scenario. Results showed dairy breeds and their crosses exhibited earlier sexual maturity, and weaned heavier calves during their productive life, but due to the stresses of high milk production, these animals were more prone to mineral imbalances and disease which resulted in death or early removal from the herd. Inability to maintain body condition was also thought to contribute to lower longevity in these breeds.

Brahman breedtypes remained in the herd for more years than any other dam breedtype despite having the highest rate of removal for reproductive failure and a high incidence of uterine and vaginal prolapse as older dams. The experimental design was very lenient on culling due to poor reproductive performance, requiring the birth of at least one live calf every two years.

While traditional British breeds (i.e. Angus and

Hereford) and their crosses were most often removed for structural unsoundness, they showed greater productive longevity as a result of lower removal rates as young dams.

Sacco et al. (1989) reported results in terms of lifetime productivity (the total weight of calves weaned) for this same group of cattle. Straight Angus dams produced the greatest number of calves after four years of age and produced the most weaning weight adjusted per year of herd life. All straightbred Jersey dams had left the herd by nine years of age and Jersey and Holstein dams produced the least amount of calf weight per year of herd life. Brahman dams remained in the herd longer than other dam types but lifetime productivity was low owing to poorer reproductive performance. This agrees with results reported by Williams et al. (1990).

Animals that die have no salvage value, but young dams culled on reproductive performance generally have high resale value in the sale ring. However, the cost of replacing young dams is also quite high. In trying to interpret these results, it should be taken into account that the experimental design for these studies was such that many producers might have trouble implementing it.

Fredeen et al. (1987) reported significant differences in weight change and backfat between two locations which were believed to contribute to differences noted in lifetime productivity. Estimates of winter feed requirements per unit of calf weight weaned averaged 47% higher for the harsher, more restrictive environment. The large location differences in the energy requirements was attributed to the location differences in average cow weight at the beginning of winter feeding. Energy provided during the first year of the study was not adequate to maintain condition in the cows in the harsher environment. Of the breedtypes themselves, Charolais and Simmental crosses recorded greater productivity at both locations, and Limousin crosses showed lower productivity than the Hereford-Angus controls.

While this study only considered relatively high cost winter feed inputs, they felt it was indicative of overall production costs. One consideration not addressed was stocking rate for fixed land resources. If the location limits the number of cattle and calves that can be produced, returns may not cover costs of production.

Armstrong et al. (1990) reported a large rotational cross showed the highest weaning weights and the greatest net returns when compared to purebred Herefords, a small, rotational dual purpose cross, and a 3-way rotational cross. The small rotational cross ranked third in weaning weight produced but second in net returns. Constraints to the system influenced net returns when comparing the straight Hereford to the terminal cross. Feed constraints gave the Hereford dams the advantage since more animals could be maintained on the same amount of feed and the higher weaning weights of the terminal cross calves did not offset the additional feed costs required. However, when herd size was the constraint, the terminal cross system showed higher profits due to increased output per cow. Final inferences stated neither body size nor feed intake alone were good indicators of net return.

Setshwaelo et al. (1990) reported no differences in conception rate among 3-breed cross females utilizing seventeen cattle breeds, possibly due the high (94%) overall conception rate making it difficult to detect any differences that may have been present. Heterosis of the crossbred dams and culling policy most likely combined to result in this high rate.

Calf weight weaned per cow exposed to breeding in this study (Setshwaelo et al., 1990) showed large and positive deviations only for Holstein (40 kg) and Brahman (21 kg) sired dams. Maternal grandsire effects were not included due to large sampling errors. Body condition scores were negative for all breeds but Brahman, Devon, Charolais and Simmental. The dairy breeds are believed to have lost condition as a result of their high milk production. Because feed requirements were not measured, the authors caution making any decisions based on these deviations. The results only suggest the direction of deviations in efficiency from the control group. Those animals with the most output were also larger and produced higher levels of milk indicating a need for greater input levels.

Belcher and Frahm (1979) also reported that milk production levels had an effect on dam body condition scores for 2-yr-old dams during the lactation period with Jersey and Brown Swiss crosses being thinnest and the control being average. Summer weight gain was not different among breed groups. Productivity, defined as total calf weight weaned per cow exposed, showed Simmental x Hereford crosses to be lower than the control group while Simmental x Angus crosses were higher. Jersey crosses and Brown Swiss x Angus dams were most productive.

Rebreeding performance was not closely related to milk production across breed groups. Brown Swiss crosses, with their high level of milk production, did show low reproductive levels while Jersey cross dams, also with relatively high milk production levels, had the highest reproductive performance. It was suggested some of this difference might be due to differences in maturing rates, and could change in mature cow analysis. While it might be expected that higher productivity, i.e. greater calf weight weaned per cow exposed, would translate to higher returns, no estimates of inputs to maintain the differing levels of milk production were presented.

Calf Birth Weight

Birth weight is most often related to calving difficulty and the subsequent affects on a production system. Setshwaelo et al. (1990) found all breed deviations for birth weight were positive except for Brahman and Jersey, and closely related to mature dam size except in the negative maternal effect of Brahman sired dams and a positive grand-maternal effect of the Red Poll breed. The Brahman crosses subsequently had lower calving difficulty scores due to small calf size compared to dam size. This study suggested those dams with 1/4 Hereford breeding had less calving difficulty than those with 1/4 Angus breeding.

Neville et al. (1984) reported results in an experiment involving straightbred, two-breed, and three-breed rotational crosses of Angus, Hereford and Santa Gertrudis in Georgia. Birth weights were highest for Santa Gertrudis followed by Hereford and Angus for each of three generations present. Birth weights increased as generations of rotational cross breeding advanced. In partitioning this trait into additive effects, the Angus crosses showed a negative deviation and the Santa Gertrudis crosses showed a positive deviation from the Hereford breed in all generations. For the maternal component, both crosses showed negative deviations.

Calf Weaning Weight

Weaning weight is considered an important trait because it is the main saleable product of the cow/calf system, and because of its correlation to yearling weight and growth for feedlot operations. Weaning weights are very often reported not only in terms of breed, but also in relationship to the milk production of their dams.

Armstrong et al. (1990) ranked calf weaning weight from a large rotational cross first, followed by a 4-breed terminal cross, a small rotational cross and straight Hereford, in that order.

Setshwaelo et. al. (1990) compared deviations for several three-breed cross dams from Hereford x Angus reciprocal crosses for sire and grandsire effects on cow and calf performance to weaning. Breed deviations for dam weight were positive and significant for all sires except Jersey, Red Poll, Limousin, and Angus. The mainly positive breed of sire and maternal grandsire effects were attributed to higher individual genetic potential for growth and mature size from the other sire breeds.

Neville et al. (1984) reported that weaning weights in their rotational cross breeding experiment followed the same pattern as birth weight with weaning weight increasing as generations advanced. The Angus maternal effect was positive while the additive effect was negative when compared to the Hereford group. Santa Gertrudis showed positive effects for both maternal and additive effects. Neville et al. (1984) reported that when results were based on weight weaned per cow exposed, only in the first (straightbred) generation did the Santa Gertrudis outperform the Hereford and Angus dams. Weaning rate was similar during the first generation, but declined in the two- and three-breed rotations. Again, the second and third generations showed increases over parental types for this trait. Conclusions were that two- and three-breed rotational crossing was effective in increasing traits of interest though the three-breed rotation showed no significant advantage over the two-breed rotational system.

If a production system's success were dependent on only one of the traits discussed, selection of a breed or mating system to meet a single production goal such as heavy weaning weights or slaughter endpoint in the shortest period of time would not be overly difficult. Because of complicated interactions between various traits, however, it is far from easy to make decisions which will result in successful management of a system.

While all the above mentioned traits (and many more) are important aspects of cattle production, interpreting the results can become complicated and time consuming. Decision making for the producer would involve combining information from several different reports dealing with expected input and output parameters. Many producers may not have the time to sort through the myriad of information generated. It must also be remembered that what works in one part of a country in a certain production system may not necessarily transfer to a different area with any success.

Long (1980) published a review of experimental results from various crossbreeding studies, and concluded mating systems should be designed for specific production systems and environments. Utilizing data already reported, researchers have been able to construct computer models that combine several traits within different management schemes.

Computer Simulation Modeling

Modeling is simply another way of trying to equate biology into a system whereby inferences can be made about some aspect of production. Spedding (1987) defined modeling as

> "an abstraction and simplification of the real world, specified so as to capture the principal inter-action and behavior of the system under study and capable of experimental manipulation in order to project the consequences of changes in the determinants of the system's behavior".

Dent and Blackie (1979) define a model as a physical representation of a real object, such as toys, scaled mock-ups of buildings for later construction, or the chemists greatly magnified model of a molecule. In animal research for example, sheep, being smaller, less expensive to maintain, and easier to work with, might be used as models for cattle because they are both ruminant livestock species. They further define the computer simulation model as a symbolic representation of real life. The symbolic type of model is abstract, having no physical resemblance to the system it represents.

The computer model may be used because of the speed at which calculations can be made, its capability for handling many equations and concepts systematically, and its ability to re-evaluate these equations over many replications in relatively short periods of time. We can model many input variables such as culling strategies, herd size, diet compositions, and mating systems. Some variables that may be difficult to model precisely include individual animal variation, weather factors and current market structures (prices). These inputs may be accounted for by including wide ranges of values for the variable, or by assigning a random variation to them.

There are different construction methods for simulation models including empirical, deductive or mechanistic, deterministic, and stochastic. Each type has benefits and limitations associated with it.

Empirical Modeling

The empirical model is based on data obtained from actual experimental results, such as a feeding trial or mating system. Through statistical analysis of group comparisons, discriminant variables, or regression techniques, equations are developed to describe variables in the data set. These equations may help explain an actual biological relationship, or may only show a statistical relationship between variables that has very little biological meaning. They often show how descriptive variables are related, but not why they relate as they do.

In an early modeling experiment, Whittemore and Fawcett (1974) published their account of model development and results of simulation for responses of growing pigs to differing protein and energy inputs. Using various sources reported in the literature, they developed mathematical equations to describe deposition of lean and fat tissue in young, growing pigs under the hypothesis of first meeting maintenance requirements, secondly laying down lean tissue according to protein availability, and lastly using excess protein and energy for fat deposition. A sensitivity analysis was conducted to determine if any input variable might be excessively affecting the output. Validation was by comparison of simulation output to published results comparable to model parameters.

Though overestimation of lean tissue deposition and underestimation of fat deposition occurred, their results were in good agreement for direction and magnitude of change with the actual feeding trials they were compared to. The discussion of results stated errors would result if components of the model were not constant over ranges examined, if the equations used were inadequate to explain actual biological systems, or if the values chosen were invalid.

The main areas of suspicion related to using a single expression for maintenance cost, and in the estimation of efficiency of protein utilization. They felt the model demonstrated an ability to predict responses to dietary inputs, and would be useful in interpreting experimental results.

Jarrige et al. (1986) developed an entirely empirically based model for prediction of voluntary intake in ruminant animals. The goal was to assimilate information available into a system for dealing with intake on the same basis as energy and protein feeding, assign a single value for intake capacity of animals regardless of feed quality, and assign a single value to each forage regardless of animal status. The unit developed was the "fill unit".

Literature references provided voluntary dry matter intake values for 2331 different forages by Texel wethers. Data from 137 feeding trials were used to develop the voluntary intake of "standard" cattle. These values were assumed to represent the intake capacity of the animals. A substitution rate of concentrates for forages was also calculated. Digestibilities for forages were determined at several stages of development and a reference pasture grass was defined.

Some potential problems with the development of this model were small numbers of animals in feeding trials which may not account for the variability among animals within a species and whether the forages measured were collected over a long enough time frame to account for year to year variation. The model was not tested, or validated, on an independent data set since all available references were used in formulating the equations.

The authors caution that the system is based on intake restricted by fill, hence it cannot be used to formulate diets containing large amounts of concentrates. They also point out the data used to develop these equations were derived from experiments being conducted for other purposes. Individual feeding trials will not take into account social factors when animals are group or pasture fed. The relative value of findings derived from this program are inherent on the number and quality of the data base.

Many areas of research are quite specialized, dealing with only one aspect of a total entity. When conducting a nutritional study, diets are manipulated to reflect changes in a given set of constraints. There may be no attention paid to how one variable might affect a different area than the one under study. The empirical model has been useful in that it has enabled researchers to utilize published data to formulate equations which relate several different areas within a system. The major danger of these models lies in the fact that they are bound by the input which was derived from the data. If the numbers do not, in fact, explain the biological system, the empirical model will not reveal that fact but simply mimic the input parameters. Another type of modeling, termed deductive or mechanistic, attempts to overcome some of these restrictions.

Deductive Modeling

Deductive modeling has developed in an attempt to explain the causal relationships between components of a biological system. The modeler is not satisfied knowing how traits are related, but why. It may come about when a researcher's area of interest has no literary references available. Through personal knowledge and intuition, the scientist may develop a theory believed to explain the nature of a relationship. The deductive model is developed to test the hypothesis, then comparisons of output to a real life situation can be made.

An argument for development of mechanistic models was submitted by Sauvant (1987). Noting that most empirical models relating dry matter intake to milk production of dairy cattle cannot be applied outside their specific constraints (particularly the diet) without losing accuracy, he proposed inclusion of models which would account for biochemical conversions during digestion and metabolism. Development of these types of models will require intimate knowledge of the chemical reactions that occur between ingestion of feed and final milk output. Models for specific organs and metabolic pathways may be combined into the whole animal model and offer explanations and predictions for feeding the dairy cow to optimize production for different environments and systems.

Whittemore (1986) also proposed that deductive modeling should be developed in order to identify the questions which need to be asked. He stated that it was better to form an opinion of how biology works and then test the proposal than to measure traits and form regression equations believing they explain all that needs to be known. For example, he suggested that early growth in pigs may be much faster than data available from experimental results suggests. He proposed modeling growth independent of animal weight and age, rather defining circumstances in which the animal does not become fat. He also stated that construction of a well thought out, complete model will point to areas of research that are irrelevant, in conflict, or lacking. Finally, he proposed that once the model is built and working, it can be used to predict the responses of real life experiments, or even be used instead of the experiment. Whether an individual model can fully explain all aspects of a system well enough to be the experimental unit is a decision to be made by individual scientists.

Many times a combination of empirical and deductive methods will produce productive results.

Combining Modeling Techniques

A good example of a combination of modeling methods was presented by Bennett and Leymaster (1988). Noting that the description of litter size of swine as the product of ovulation rate and embryo survival failed to address an area of reproduction they believed to be important, they developed a model based on the hypothesis that uterine capacity also played an important role. They believed that if their theory was valid, it would be possible to determine a mean and variance for the trait, and also generate phenotypic and genetic variation.

Data available on estimates of ovulation rate and litter size at birth were incorporated into the model. Embryonic survival was divided into two phases. The first was defined as loss due to failure of fertilization of ova, abnormal development, genetic lethals, etc., and was estimated by summarization of reported values. The second phase was considered to be loss of viable embryos due to limited uterine capacity. Because no data were available as to when capacity would begin to limit litter size, a value was arbitrarily assigned and was not intended to reflect a known biological constant.

Two thousand simulations for each of 25 combinations of means for ovulation rate and uterine capacity were generated. Simulated statistics were then compared with reported experimental data for validation of the model. They were able to make a good argument for their hypothesis.

Marshall et al. (1985) also developed a model by using various sources of information from the literature and adjusting values to reflect their understanding of the system that was being modeled. Mathematical equations were developed to predict various trait responses affecting productivity and profit for a cow/calf/feedlot system. Different culling and selection strategies, also based on the modelers' views of important traits, were simulated for a 15 yr period. Their goal was to evaluate the long term effects of these different strategies.

Productivity was measured in terms of weaning weight and yearling weight produced, and the number of calves weaned per cow exposed to breeding. Profit involved cumulative profit to weaning and feedlot endpoints, and cumulative profit per cow per year for both production systems.

Findings from the study illustrated the effect of changes in independent variables on profit or measures of production. Management, selection, and changes to a production system will greatly affect subsequent outcome. Trade offs occurred between the more efficient use of feed by younger animals and the greater reproductive performance of older dams.

Use of available data and personal intuition in combination with modeling techniques may offer valuable insights for the further direction of experimental research. This requires well thought out use of available resources and an understanding of the many components within any type of system, and their effect on other components involved.

Any of the systems that have been discussed may be utilized within two other types of modeling techniques; deterministic and stochastic modeling procedures.

Deterministic Modeling

Deterministic modeling describes a model wherein the value associated with a trait or used in an equation does not vary; for example, individual animals versus the mean of a contemporary group. This approach to modeling does not, however, exclude variation due to time, age, or other factors. By incorporating data from several studies, mean values for traits of interest can be determined from different forms of analyses of the data. By inclusion of several values for the traits, mean response to change can be determined. Dent and Blackie (1979) have cautioned that deterministic models can only generate information on the mean response of the real system to a change in one of the variables.

Results from several examples of complex deterministic models have been reported in the literature (Notter et al., 1979; Tess et al., 1983; Bourdon and Brinks, 1987;). Complex systems were modeled in all cases.

Notter et al. (1979a) stated a primary goal of research is identification of genetic material and mating and management systems which, when combined, will minimize production costs for specific environments. This would require evaluation of all sources of costs and returns to the system. With all the types of cattle and management systems available, experimental evaluation of all combinations would be severely limited by the resources required. They proposed use of the simulation model to synthesize and extrapolate on information available from several sources for a cow/calf/feedlot enterprise in the midwestern area of the United States.

Simulations began with a modified version of the Texas A&M Cattle Production Systems Model (Sanders and Cartwright, 1979). Full details of model development, equations and systems were reported in a series of papers examining differing levels of milk production, cow size and mating systems. Three levels of maximum milk production (Notter et al., 1979a) were simulated for each of three mature weights (400, 500, and 600 kgs). Comparisons were made within cow size. The level of milk production affected reproduction, body condition, puberty, and weaning weight and rate. Biological efficiency was improved with increasing levels of milk production only if weaning rates were also improved. Economic efficiency suffered from increased milk production if it reduced weaning weight per cow exposed.

Effects of cow size were simulated for three weights (400, 600, and 800 kgs) each in two management systems for "ideal" and less favorable environmental conditions (Notter et al., 1979b). Mature size affected age at puberty, weaning, and slaughter. In their opinion, differences in economic efficiency were due to the interaction of mature size with management choices and prices paid for the products, and not inherently due to the biological effect of size.

Mating systems analyzed by Notter et al. (1979c) were purebred and two- and three-breed specific, and rotational crossing systems. Size of the sire was based on mature weights for females of the breed (500, 600,700, and 800 kgs). Two levels of milk production were also simulated. Biological and economic efficiencies were affected by incidence of dystocia due to the size of the sire, levels of heterosis within the mating system, milk production, growth rate, and the prices of feed relative to the system. Systems utilizing heterosis were more economically efficient, and systems which also used maternal heterosis were even more efficient.

Conclusions reported in all the papers were to be applied only to the management systems simulated, and offered guidelines rather than biological truths. If the environment or management was not extremely similar, further simulations and adjustments or assumptions would need to be made. Individual animals were not simulated, thus animal variation could not be included or measured.

Bourdon and Brinks (1987a,b,c) also published a series of papers reporting efficiency of production of beef cattle in a range environment using a modified version of the Texas A&M University Beef Cattle Production Model (Sanders and Cartwright, 1979). Again, growth rate, milk production, and reproductive traits were addressed along with different culling strategies and management options. The modified model was completely deterministic. Birth weight, yearling weight, mature weight and milk production levels were traits used in development of 12 genotypes. Genotypes simulated were not meant to represent any specific breed of cattle.

The importance of milk production for the beef cow in this model was dependent on the feed costs and production system (Bourdon and Brinks, 1987a). Efficiency increased with increased milk production if calves were marketed at weaning. When animals were retained to slaughter, high feedlot costs compared to low feed costs for the cow herd also favored increased milk production in the dams.

Production efficiency did not increase substantially with early puberty and associated increased fertility (Bourdon and Brinks, 1987b). The advantages of increased longevity were negated by the decreased efficiency of maintaining mature dams.

A bioeconomic model was constructed by Tess et al. (1983a) in an attempt to simulate effects of nutrition, genetic change, physiology, and economics in the life cycle of a pork production system. The model was a combination of empirical and deductive techniques. Simulation began with baseline levels of performance for crossbred hogs in a midwest production system.

The model addressed growth from birth through final disposition, and was divided into fat and lean body mass. Because very little research had been done on deposition of fat and lean during the early growth of pigs, equations for rate of fat and lean deposition were developed from serial slaughter experiments. Estimates for metabolizable energy (ME) were also adjusted to account for higher maintenance requirements for pigs with leaner carcasses.

Other traits modeled were age at puberty, conception rate, ME required for gestation and lactation, litter size and weight, survival rates, pre- and post-weaning growth of the pigs, body condition of the sows, management options, and economic input and the interactions of the traits with one another. Economic returns were based on average prices for market hogs and cull sows.

Validation is considered an important aspect of the modeling process. Incorporation of data not used in model construction is generally used to assess the accuracy of the model. Because no experimental results were available for the scope of the model developed by Tess et al. (1983a), validation was not possible. The authors gave alternate methods of evaluation of the design. Detailed descriptions of input parameters for several points in the life cycle of the production system offered some verification of the model. Because the model was constructed for these several points of production, comparison of simulated results with experimental results of the same type were also possible. The authors offered several comparisons of certain aspects of simulation with published reports for the same traits. They believed the model adequately represented the characteristics involved with growth and the production boundaries represented.

Selection for a specific trait or a combination of traits will be best accomplished if the traits chosen also account for changes which may occur in another area of the production system. Simulations generated by this model were used in an attempt to ascertain the relative value of genetic change for several measures of efficiency within a production system (Tess et al., 1983b).

Efficiency was described in terms of biological and economic measures, ME required and cost per 100 kg of empty body weight and carcass lean produced. The response to changes in the genetic level of a trait were simulated by increasing or decreasing the mean values from the base level used in construction and verification of the model. Because the response to independent changes would only describe the area being changed, attempts were made to quantify the interactions of the genetic components over the total range of the production system.

Some areas of discussion presented included indications that maternal traits might be more important than previously thought in increasing the economic efficiency of a system. The definition of value for the output is also extremely important in determining the traits used for selection. While no premium is as yet paid for lean carcasses, consumer demand for lean meat is not likely to disappear. The simulations showed significant differences relative to value between empty body weight and weight of carcass lean.

The goal of the research team was to provide guidelines in making selection decisions. The results would not be valid in specialized breeding systems. They also hoped to identify areas for further research and communication between the several disciplines within the animal science community.

The models discussed have attempted to address several areas of production systems and the biology of the animals which affects the results. In evaluating the use of deterministic models, Dent and Blackie (1979) point out there is no error term for use in computing F tests in analyses of variance or confidence limits. Data used to develop a model will always have error associated with variables not considered, imprecise measurements of biological or economic traits, lack of fit of statistical functions and biological variation. The results are restricted by the values used for construction. Some decision making may require more than the mean response due to a change in one variable. Incorporating randomness into the model is accomplished by including stochastic variables.

Stochastic Modeling

Dent and Blackie (1979) offer some good guidelines for use of stochastic variables in modeling. Historical data may not be available or be of a limited time frame. This type of data may also limit research in that effects of events not recorded or occurring in a different sequence might be omitted. The alternative to using historical data is to create the values as stochastic variables. These values are randomly generated from within a probability distribution derived from analysis of available data. Care needs to be taken that these values represent the variables within the real system under review.

Lamb and Tess (1989a) published results from stochastic modeling of crossbreeding systems within small beef herds (30 dams or less) using one sire per year. Small herds of cattle must deal with problems not inherent to larger production systems such as availability of replacement females due to the variation in sexes born each year. Use of complicated or multi-sire crossbreeding systems are also impractical. This study evaluated alternative crossbreeding systems specifically for the management of small herds of cattle utilizing a purebred, two- or three-breed rotations using natural service sires and artificial insemination breeding, and a four-breed composite. Inputs were assumed similar and comparisons were made based on differences in utilization of heterosis as it affected weight sold. Differences in natural breeding and artificial insemination would reflect loss of production due to incorrect matings.

The maximum age for culling dams proved to be 12 yr. When the maximum age was reduced, changes in the ratio of sexes resulted in too few animals to maintain herd size.

Heterosis increased when matings were correct and the number of breeds used increased, and measures of performance ranked the three-breed rotation and the composite higher than the two-breed rotation. However, the variation in calf weaning weights due to the differing breed composition from cows of several generations and the expression of heterosis showed no consistent deviations. There appeared to be no basis for recommending any of these crossbreeding systems over another in small herds.

A companion paper (Lamb and Tess, 1989b) reported results for herds of 50 cattle or more using two-sires per year. The nine production systems included the use of complimentarity among breeds through the incorporation of rotational-terminal systems. Artificial insemination was not meant to compare advantages due to selection of superior sires.

The inclusion of the rotational-terminal systems did not provide sufficient increases to production to warrant their recommendation over rotational systems. The roto-terminal systems were sensitive to changes in the sex ratio of calf production. These results point to another area of management problems for the small herd producer. While no expenses were included to account for the additional labor required for artificial insemination, the results reported indicate any advantage to this breeding system would be through the increased genetic potential of the sires selected, not through increased heterosis.

The results of these studies indicate a two-breed rotational production system would yield satisfactory improvement over a purebred system owing to the random variation within the more complicated systems addressed.

Modeling has strengths and weaknesses as does any area of research. Organization of concepts into a framework for understanding is possible. We are able to study systems that do not exist or that may be too expensive to maintain and replicate. Long-term effects are within our boundary because the time-frame of the simulation is a controllable input.

However, the model may require simplification of a system because available data on or knowledge of important inputs is lacking. Using various data sources to estimate input parameters may not be an ideal situation from the researcher's point of view. Finally, validating, or "proving" what we have modeled is a true representation of real life is frequently impossible.

Construction of the model may point to areas where information is lacking, thus giving researchers new guidelines for future experimentation. If the researcher has used valid, unbiased results from the literature or has used a valid database, then the computer model is adequate if it answers the questions that were addressed.

Havre Research

Researchers at Montana State University initiated a long term study for comparison of cattle types differing in mature size, milk production potentials, and levels of crossbreeding. The data for this study, recorded at the Northern Agricultural Research Center near Havre, Montana, included milk production, body weights for cows and calves, pregnancy rates, occurrence of calving difficulty and survival rates for five biological types of dams raising terminal cross calves which could be integrated into a simulation model.

The first phase of the project involved development of the dam breedtypes. Lawlor et al. (1984) published results for the preweaning growth and survival of these cattle. They found the breed group of the calves was a significant source of variation for gestation length, birth weight, calving difficulty, late survival, percent of calves weaned per cow calving, 180-d weight, 180-d height and the weight:height ratio. Differences were due mainly to the 50% Simmental-50% Hereford calves having higher birth weights, experiencing more difficult births, having heavier weaning weights and being tallest at weaning. The 50% Angus-50% Hereford calves showed an advantage in net kilograms weaned per cow calving. The authors concluded that benefits obtained by higher growth potential could be reduced due to differences in survival rates.

Kress et al. (1984) also looked at the effect of these calves on their dams (straightbred Herefords). They found cattle raising crossbred calves gained less weight, had lower body condition at weaning, exhibited smaller gains in weight change per unit of height and experienced lower pregnancy rates than those dams raising straightbred Hereford calves. The calves sired by Simmental bulls had the greatest influence on the dams.

The next phase of the experiment involved the postweaning phase and heifer development to breeding. Steffan et al. (1985) reported on heifer postweaning growth traits and early reproductive performance. The 50% Simmental heifers showed the greatest ADG with 50% Angus and 25% Simmental heifers intermediate, and straightbred Hereford heifers exhibiting the slowest growth rate. The two F_1 crosses were heaviest at prebreeding and the straightbred heifers were lightest. All crossbred groups, on a percentage basis, reached puberty at an earlier age than the straightbred animals and subsequently had higher pregnancy rates at the end of the breeding season. The straightbred heifers apparently did not differ in their ability to conceive but pregnancy rates were different due to their not cycling by the end of the breeding season.

Kress et al. (1990 a,b) followed these studies with reports of maternal performance for calf production, milk production and reproductive traits for 2-yr-old and 3- to 8-yr-old dams raising terminal cross calves. A 75% Simmental-50% Hereford cross was included in these studies.

For 2-yr-old dams (Kress et al., 1990a), the 50% and 75% Simmental dams had calves with heavier birth and weaning weights, and greater body condition, than the 50% Angus and 25% Simmental dams. Straightbred Hereford dams had lighter calves with less condition throughout the preweaning period. These results were attributed to differences in the early milk production exhibited by the dams. Differences were also seen in proportion of cows calving and actual weight weaned per cow exposed to breeding. The F_1 crosses had higher calving and weaning rates and weaned the most kg of calf weight. All crossbred groups outperformed the straightbred group.

The same aspects of production appeared to be true in older dams (Kress et al., 1990b). The 75% Simmental showed improved production as older dams than as 2-yr-olds but the differences for calf weight weaned per cow exposed were significant only between the straightbred (least) and the 50% Simmental (greatest). Reproduction was influenced by dam age and year but breedtype was not a significant source of variation for proportion calved and weaned. When production was expressed as calf weight/cow exposed/cow weight, the F_1 dams proved most productive. The authors also reported a dam breedtype x calf sire interaction indicating that larger, higher milking dams should be matched with terminal sires with more growth potential.

The authors suggest the results from these studies should be taken into account when producers consider crossbreeding as a means of improvement for their production systems.

Hopefully, this literature review has pointed out the extent of literature available for study, the many traits that need to be appraised when making decisions, and how the computer may be effective in resolving some of the questions raised by researchers and producers.

CHAPTER 3

MATERIALS AND METHODS

Model Development

Model development began with a review of the original data collected during a 10-yr study conducted at the Northern Agricultural Research Center (NARC) near Havre, Montana. During the years 1976 through 1979 five dam breedtypes were developed utilizing Hereford, Angus, Simmental, and 50% Simmental-50% Hereford sires on Hereford or 50% Simmental-50% Hereford cows. The resulting dam breedtypes were straight Hereford (HH), 50% Angus-50% Hereford (AH), 25% Simmental-75% Hereford (1S3H), 50% Simmental-50% Hereford (SH), and 75% Simmental-25% Hereford (3S1H).

NARC is typical of a northern range production system, with spring calving and fall weaning. During the course of the experiment, breeding was by artificial insemination at naturally occurring estrus. For the first year of the experiment, 2-yr-old dams were exposed to a Tarentaise sire which resulted in a very high incidence of dystocia for all dam breedtypes. These matings and birth and weaning data were eliminated from the dataset. Data utilized were for yearlings bred to a single Red Poll sire during a 60-d breeding season to calve as 2-yr-olds. Subsequent matings were by random assignment to either Tarentaise or Charolais sires within breed group during a 45-d breeding season, with all females being managed similarly. Young dams in the first 3 yr of production were allowed to remain in the herd unless open 2 yr in a row. Dams 4 yr of age or older were culled if open. No further culling was practiced except in the case of severe physical injuries. If calves were not raised by their own dam, the data were excluded from analyses.

Supplemental feeding began the first part of January, turnout to spring pasture of crested wheatgrass was at the beginning of May, and summer and fall grazing continued from June through December on pastures dominated by fescue species.

The management system simulated was intended to mimic that at NARC with one major exception. Kress (1988) reported no advantage to maintaining open cattle, either as young animals or as older dams, hence the original data were edited to reflect a system whereby cows were culled at their first open season.

Movement through the simulated system began with yearling replacement heifers purchased on March 16 and fed a growing ration until turnout to spring pasture. Pasture grazing began May 1 and continued through the end of December. Because calf age at weaning was not different among dam breedtypes (P=.24), date of conception was set for the end of June and calving was set at April 15. Cows that lost a calf were given the opportunity to become pregnant during the next breeding season and were retained at least until the following fall. All cows that failed to conceive or that were 10 yr of age were culled at weaning (September 30). A 1% death rate, and 1% unsoundness cull rate for cows were included (M. W. Tess, personal communication). Calf survival was affected by incidence of dystocia.

The computer model was composed of a deterministic portion for the simulation of energy requirements, and a stochastic portion for the simulation of pregnancy rate, incidence of dystocia, calf survival, and cow and calf weights.

Inputs to the model were cow weights at four times during the production year for each dam breedtype x dam age subclass, calf birth and weaning weights for each dam breedtype x sire breed combination, age of dam, and sex of calf sub-class, and pregnancy rate, incidence of dystocia and calf survival rates. Input parameters were least squares means obtained from statistical analyses of the data (described later).

Deterministic Phase

The deterministic portion of the model included calculations of metabolizable energy (Mcal ME) requirements for maintenance and growth of calves and dams, plus gestation and lactation requirements. Equations were developed from NRC (1984), and were based on body weight and frame size. Estimates of energy requirements, feed intake and weight change were calculated daily.

Cow weights were available at weaning in the fall (September 30), prior to calving in the spring (March 15), and pre- and post-breeding during the summer (June 1 and July 16, respectively). For each dam breedtype, average daily weight change (ADWT) was calculated as:

ADWT = Weight Change/Number of Days

where

Weight Change = Cow Weight(i,j,n) - Cow Weight(i,j,n-1),

Cow Weight(i,j,n) = mean weight of cow in the nth period and jth age-group for the ith dam breedtype.

In order to more closely reflect maternal weight, the difference between the weaning and pre-calving weights were adjusted by subtracting the weight of the fetus, fluids, and membranes associated with pregnancy following the equation:

Cow Weight(i,j,n) - (Birth Weight(i,j,k,l)/.55)

where

k = sex of calf,

l = breed of sire of the calf.

The denominator was derived from Hafez (1987) and ARC (1980) who stated the fetus represents approximately 50%-60% of the products of conception in cattle at term.

Maintenance requirements were estimated using the following equation:

$$ME_m = b_m\ (Wt)^{.75}$$

where Wt was updated on a daily basis. Values for b_m were Mcal ME$*$kg$^{-.75}*$d^{-1} taken from work by Lamb (1991). Values used for AH, HH, 1S3H, SH and 3S1H were .1190, .1200, .1235, .1270 and .1305, respectively.

For animals 3-yr of age and less, metabolizable energy required for gain (ME_g) was calculated as (NRC, 1984):

$$ME_g = D1 * Wt^{.75} * ADWT^{1.119} / k_g$$

where

k_g = efficiency of ME use for gain based on diets with varying values for Mcal ME*kg DM.

Values for D1 were based on frame size and were .0686, .0686, .0667, .0647, and .0628 for AH, HH, 1S3H, SH, and 3S1H, respectively. For older dams:

$$ME_g = (6.2*ADWT) / k_g$$

from NRC (1984).

Casebolt (1984) developed lactation curves for each of the dam breedtypes using the algebraic model:

$$Y_n = an^b * e^{(-c*n)}$$

where Y_n is average daily milk yield for the nth day of lactation and a, b, and c are constants as described by Wood (1967). The constants for each dam breedtype are shown in Table 1.

Equations for lactation energy requirements were taken from NRC (1984) following the equation:

$$ME_l = (.1\ (\%\ fat) + .35) / k_m$$

where

k_m = efficiency of ME use for lactation based on diets with varying values for Mcal ME*kg DM,

and fat content of the milk was set at 4.5% (Gleddie and Berg, 1968; Cundiff et al., 1974). Because the lactation curves were based on 4-yr-old dams, an age adjustment of 80% and 90% was included for 2- and 3-yr-old dams, respectively (Lamb, 1991). Lactation was simulated for 180 days.

Adjustments were made for those animals that were losing weight at any period within the production system. During lactation, NRC (1989) states that milk production uses body energy stores more efficiently than ME from feed at an efficiency of 82%. In the model, if ADWT was less than zero during lactation, ME_g was calculated as follows:

$$ME_g = ADWT*6.2*.82 / k_g.$$

Table 1. Parameter means for model of lactation curves.

Breed	a	b	-c
AH	2.62	.2558	-.0108
HH	2.33	.3832	-.0101
1S3H	2.75	.2091	-.0074
SH	2.57	.3214	-.0093
3S1H	3.07	.1189	-.0054

During periods of non-lactation, loss of weight used the same equation without the 82% efficiency rate. This adjustment deducted energy needed from the intake estimates.

Gestation energy requirements (ME_{ge}) were estimated for each dam breedtype x sire breed combination by:

$$ME_{ge} = ((bwt(i,j,k,l)*(0.0149-0.0000407*t)* e^{0.0588t-0.0000804t2} / 1000.0) / k_m$$

where bwt(i,j,k,l) is the calf birth weight for each dam breedtype x sire breed combination (NRC, 1984). Length of gestation was set for 280 days (Hafez, 1987).

Calf energy requirements were divided between that obtained from milk and that from forage. Calf ADG was calculated by subtracting birth weight from weaning weight and dividing by 180 d (average age at weaning). Maintenance requirements were calculated by:

$$CME_m = (.077* Cwt^{.75}) / k_m$$

and energy for gain by:

$$CME_g = C1*(Cwt^{.75})*(ADG^{C2}) / k_g$$

where C1 = Mcal ME_g based on frame size and sex, C2 = 1.097 and 1.119 for steer and heifer calves, respectively, and k_m and k_g are efficiencies of utilization for maintenance and gain (NRC 1984). Daily calf need was the sum of energy required for maintenance and gain. Daily milk production of the dam was assigned an energy value of 1.32 Mcal ME/kg (NRC 1984). If the calf's energy requirements were greater than energy provided by the dam's milk, forage intake was simulated to meet the need.

Forage intake was estimated according to dam and calf requirements for energy and ME content of the feed. Mcal of ME per kg of dry matter (MEDM) of forages and feeds were estimated from NRC (1984), Kronberg (1983), and Vallentine (1990). Values for MEDM were set at 1.95, 2.17, 2.17, 2.71, 2.55 and 2.30 for the fall grazing, pre- and post-calving winter feeding, spring grazing, and early and late summer grazing, respectively. Intake was assessed for all producing dams, those dams that lost a calf, those dams that died during the year, all open animals carried through the summer grazing season and all calves.

Stochastic Phase

The stochastic portion of the model determined pregnancy rate, incidence of dystocia, and calf survival by random generation of values from within a probability distribution derived from analyses of the data reported. The uniform pseudorandom number generator (RAN) produced numbers that were uniformly distributed between zero and one. If, for example, the pregnancy rate of a 2-yr-old dam breedtype was 70%, any number greater than .70 indicated an open cow while any number less than or equal to .70 signified pregnancy. Calf sex was assigned by numbers from 0 to .5 being males and numbers greater than .5 being females.

The original experiment assigned dystocia as 1 = no difficulty, 2 = slight difficulty, 3 = difficult birth (mechanical pull), 4 = severe difficulty (caesarean), and 5 = malpresentation. The original data were reassigned as 0 = no assistance and 1 = any form of calving difficulty encountered. Calving difficulty was determined from within the probability distribution for dam breedtype, sire breed, sex of calf, and dam age. After dystocia was assigned, calf survival was determined based on whether or not dystocia occurred. The numbers generated were unique for each instance of use.

Culling for unsoundness and death loss of dams were included at 1%. Maximum age of dam was set at 10 yr. Those animals found to be open, aged or unsound had a market weight computed, and were sold. Those animals determined to be pregnant had sex of calf, probability of dystocia and calf survival rates assigned by RAN.

Cow and calf weights were determined by the pseudorandom number generator UNSK. Numbers generated had a normal, independent distribution with a mean and variance of 0 and 1, respectively. Cow weights were input as:

Cow weight = LSM(i,j,n) + UNSK*RSD

where

LSM(i,j,n) = the least squares mean for weight of the cow the nth period and jth age group for the ith dam breedtype,

UNSK = random normal deviate,

RSD = residual standard deviation for cow weight.

Calf weaning weight was calculated by:

Calf weight = LSM(i,j,k,l) + DAM + UNSK*RSD

where

LSM(i,j,k,l) = the least squares mean for the lth sex of calf in the nth period for the jth age group and ith dam breedtype,

DAM = dams's permanent contribution to weaning weight (repeatability = 40%),

RSD = residual standard deviation for weaning weight after accounting for the dam's permanent contribution to weaning weight.

Economic Parameters

Expense inputs included cost of the growing ration for replacement heifers at $0.22 per kg DM based on diets recorded during the original experiment, pasture rent at $10.00 per AUM (Don Anderson, personal communication), and hay at either $55.00 or $83.00 per metric ton. Cost of replacement females was $800.00 and bull costs were allocated per cow at $18.50 based on 25 matings per bull. Veterinary costs included herd health and sick pen treatments (see Table 2). Costs used were $15.54 for replacements, $3.84 for steer calves, $2.94 for heifer calves, and $10.45 for older dams, plus $25.50 for each incidence of dystocia (Dr. Bruce Sorensen, DVM, personal communication). Labor was assigned at $15.00 per cow exposed, and interest costs were input at 12% (M.W. Tess, personal communication).

Marketing depended on number and weight of calves and culls sold. A beef check off fee of $1.00 and an inspection fee of $0.35 per head was charged to reflect costs associated with animals being sold through auction. Trucking costs were based on 18,144 kg of weight trucked for 25 miles at

$2.00/mile (Bozeman Livestock Sales Co., Inc., personal communication).

Table 2. Costs assumed for herd health and sick pen treatments.

Service/Supply	Cost/head
Caesarean Section	$ 105.00 x .10 x dystocia
Labor/Dystocia	$ 15.00 x all dystocia
Pregnancy Test	$ 1.25 x all cows
IBR/BVD	$ 1.00 x all cows
Vibrio/Lepto	$ 0.75 x all cows
E-Coli	$ 0.90
Clostridial	$ 0.25 x animals < 2-yr
Warbex	$ 0.70 x all cows
Wormer - Ivormec	$ 6.00 x all yearlings
Wormer - others	$ 2.50 x all cows
Bangs	$ 2.00 x all yearlings
Trich Diagnosis	$ 28.00 x all bulls
Breeding Soundness Exam	$ 20.00 x all bulls
Fly Tags	$ 2.00 x all animals
Pinkeye	$ 3.00 x all animals x .03
Scours	$ 5.00 x all calves x .1
Pneumonia	$ 5.00 x all calves x .02
Implants	$ 0.90 x all steers

Returns were based on sale of calves and cull cows. Cattle prices were from a 2-yr average for prices during September, October, and November as reported by Cattle Fax (1990 and 1991). Calf prices were based on 181 kg weights at $2.24 and $2.16/kg for steer and heifer calves, respectively. Because replacement heifers were purchased, all calves were marketed with no females being retained as replacements. Calf prices included a sliding scale for lighter or heavier calves following the equations:

Steer = 2.24 - .00126*(average steer wt - 181.4)

Heifer = 2.16 - .00152*(average heifer wt - 181.4).

Prices for yearling, 2-yr-old, and older cows were $1.44, $1.26 and $1.13 per kg, respectively.

Simulated Output

Outputs generated by the model included steer, heifer and cull weights for each age of dam subclass, number of calves born and weaned, counts for dead, open and unsound cows, incidence of dystocia for 2-yr-old and older dams, number of matings, calves weaned per cow exposed, calf weight sold per cow exposed, DM and ME consumption, total AUMS and hay required, DM, ME, feed, non-feed and total costs per calf weight sold, cow weight sold, total weight sold, calf weaned and cow exposed.

Input costs per steer equivalent weight sold were computed for high and low calf prices. Steer equivalent price was calculated as (kg each class of cattle sold * price received for each class)/steer price, and represents a break even steer price for the production system.

Experimentation

Two management systems were simulated. The first approach assumed no limit on land or feed resources, and results were on a "per cow" basis. The second assumed a fixed land resource of 2700 animal unit months (AUMS) with many costs proportional to the ranch rather than the cow herd. Herd size for the second simulation was determined by dividing the fixed land resource (2700 AUMS) by the AUMS needed for each dam breedtype simulated in the first approach. Simulations were run with low and high hay prices ($55.00 and $83.00 per metric ton) and with low and high calf prices where the high price was estimated from a 2-yr average for fall prices from Cattle Fax (1990 and 1991) for the northern plains region and low prices were set at 80% of the high calf price.

Pregnancy rates for many of the ages of dam were low, possibly due to the short AI breeding season. For a separate set of analyses, the program was modified by increasing pregnancy rates by 10% in order to reflect a longer breeding season utilizing natural service. Weaning age was also extended from 180 to 210 days which we believe to be more in line with standard practices in the cattle industry in Montana.

Statistical Analyses

Havre Data

The original experimental design allowed dams in their first three production years to remain in the herd unless they were open 2 yr in a row. Kress (1988) reported no advantage to carrying open cows, either as young animals, or as older dams. In the simulated system cows were culled following their first open season.

Traits analyzed from original data were cow and calf weights and pregnancy, dystocia and calf survival rates. Dystocia scores in the original data were based on a score of 1 to 5 with 1 being no assistance, 2 being slight assistance, 3 being a mechanical pull, 4 a caesarean section and 5 malpresentation. Scores were reassigned as 0 being no assistance and 1 being any form of assistance for calving difficulty. Pregnancy status was recorded as 0 being pregnant and 1 being open. Weaning viability was assigned 0 for a live calf and 1 for dead.

Data for cow and calf weights were analyzed by least squares procedures using the GLM Procedure of SAS (1985). The original model for cow weight at each period included the effects of year, dam breed, sire within dam breed, dam age and all two-way interactions. Three-yr-old and older dams were randomly assigned to either Tarentaise or Charolais sires within dam breedtype and age. The original model for birth and weaning weight included year, dam breed, sire within dam breed, dam age, sire breed, sire within sirebreed, sex of calf and all two-way interactions.

Because all 2-yr-old dams were bred to a single Red Poll sire, calf weights from 2-yr-olds were analyzed separately from older cows. The model for birth and weaning weight included year, dam breed, sire within dam breed, sex of calf, and two-way interactions.

In all cases for dam and calf weights, non-significant main effects, with the exception of year, dam breedtype and dam age, were deleted and reduced models fit to the data. Comparisons among least squares means were made using single degree of freedom contrasts. Table 3 shows the number of animals for each breedtype for the four weight periods and five age groups. Table 4 shows calf numbers.

Table 3. Cow numbers for weigh periods and ages.

	Pre-breed	Post-breed	Fall weaning	Pre-calving
Breed				
AH	170	170	190	146
HH	150	150	182	122
1S3H	182	178	220	168
SH	145	143	177	136
3S1H	137	134	169	115
Age				
1	195	195	270	
2	209	201	210	210
3	146	146	146	147
4	101	100	116	117
5	133	133	196	213
Total	784	775	938	687

Due to the binomial nature of the data for pregnancy, dystocia and survival, the categorical modeling procedure of SAS (CATMOD, 1985) was used to fit linear models to functions of response frequencies by maximum-likelihood estimation using a logit transformation. For each sample i, the probability of the jth response was estimated by the sample proportion, $p_{ij} = n_{ij}/n_{i\cdot}$. All models included the effects of year, dam breed, dam age, sire breed, and sex of calf at side with non-significant main effects deleted with the exception of year, dam breedtype and dam age.

Simulation Data

Two-way analysis of variance was used for analyses of the outputs from the simulation using the ANOVA procedure of SAS (1985). The model included dam breedtype, sire breed and the interaction. If the interaction was not significant, it was deleted from the model. Replication was the error term. Mean comparisons were performed by Duncan's multiple range test. Traits analyzed included number of matings, calves weaned per cow exposed to breeding, calf weight weaned per cow exposed, dry matter and ME consumed per kilogram of calf weight and total weight sold, steer equivalent prices for the standard and reduced calf prices, total costs per cow exposed, net profit per cow exposed for high and low calf prices and high and low hay prices, and number of matings and total cash expenses per ranch simulation.

Table 4. Calf numbers for birth and weaning weights.

Cow Breed	Sire Breed		
Birth Weight	Red Poll	Tarentaise	Charolais
AH	41	49	44
HH	28	41	38
1S3H	29	57	58
SH	24	48	45
3S1H	20	34	36
Total	142	229	221
Weaning Weight			
AH	40	49	41
HH	28	38	35
1S3H	27	52	55
SH	21	46	42
3S1H	19	34	34
Total	135	219	207

CHAPTER 4

RESULTS AND DISCUSSION

Statistical Analyses

Cow and Calf Weights

Analyses of variance for cow weights for the four weight periods are presented in Table 5. All main effects were highly significant (P<.001). Interactions were not significant. Least squares means for dam breedtype and age of dam are presented in Table 6.

In general, the HH dams were lightest, AH and 1S3H intermediate, and SH and 3S1H dams heaviest for all weigh periods of the production year. Weight increased on average 44 kg between age groups with more rapid growth occurring as yearlings and 2-yr-old dams.

Weights at fall weaning showed no difference between HH and 1S3H dams which were different than other dam breedtypes. Differences between AH and SH dams approached significance (P<.08) and 3S1H dams were heaviest.

Pre-calving weights showed the SH and 3S1H dams being heaviest and not different, AH and 1S3H dams intermediate and the HH group were the lightest but not different than 1S3H (P<.08). Using data collected during the original experiment, analysis of pre-calving weights showed similar trends with the exception of the 3S1H dams being heaviest and significantly different from the SH dams (see Tables 34 and 35).

The HH dams were lightest and different from all other dam breedtypes at pre-breeding. AH and 1S3H dams were intermediate and not different with no differences between SH and 3S1H dams which were heaviest.

Analyses of data collected during the original experiment (not edited to reflect culling at first open season) showed no difference between HH and 1S3H dams for pre-breeding weights while there were significant differences among the remaining three dam breedtypes.

Post-breeding weights showed no differences between the HH and 1S3H dams. Differences between AH and 1S3H dams approached significance (P<.07) with SH and 3S1H dams being heaviest and not different. Original data showed the same trends. However there was a significant difference between the AH, SH and 3S1H dams.

Wagner (1984) reported similar summer weights for mature dams that were a sub-sample of the same experimental herd. Reported summer weights from Lathrop (1984) and Funston (1987) on a sub-sample of cows were higher than those estimated in this study.

All dam breedtypes showed weight gains from pre-breeding to weaning in the fall. Fall weaning to pre-calving weights showed slight increases, but also reflected weight associated with fetal gains. When the weight of the fetus and conceptus

Table 5. Least squares analyses of variance for cow weights.

Source	df	Mean Squares
At weaning (N=938)		
Year	7	8604.36^{**}
Breed	4	24405.81^{**}
Sire(Breed)	63	7697.30^{**}
Age	4	137137.87^{**}
Error	859	1247.25
Pre-calving (N=687)		
Year	6	19029.02^{**}
Breed	4	18423.03^{**}
Sire(Breed)	60	6031.43^{**}
Age	3	115841.76^{**}
Error	613	1150.83
Pre-breed (N=784)		
Year	5	35762.18^{**}
Breed	4	28074.57^{**}
Sire(Breed)	61	5346.87^{**}
Age	4	261000.65^{**}
Error	709	1101.18
Post-breed (N=775)		
Year	5	6055.01^{**}
Breed	4	26087.36^{**}
Sire(Breed)	61	5827.94^{**}
Age	4	209976.70^{**}
Error	700	1145.15

** $P<.0001$

was deducted in the simulation, all dam breedtypes lost weight. Kress et al. (1986) reported considerable variation in cow weights from year to year reflecting changes in the forage resource. While it seemed the cattle were maintaining

Table 6. Least squares means and standard errors for cow weights by dam breedtype and dam age.

Effect	Calving[a]	Pre-breeding	Post-breeding	Weaning
Overall Mean	498.62	434.89	463.97	477.40
Breed				
HH	485.50[c] (3.69)[b]	432.49[c] (3.09)	461.55[c] (3.15)	477.79[c] (2.96)
AH	495.87[d] (3.92)	449.51[d] (3.29)	476.64[d] (3.36)	491.32[d] (3.45)
1S3H	493.88[cd] (3.06)	442.74[d] (2.86)	468.55[cd] (3.00)	474.66[c] (4.38)
SH	517.13[e] (3.58)	466.32[e] (3.23)	493.23[e] (3.30)	499.41[d] (3.21)
3S1H	518.97[e] (4.39)	473.51[e] (3.98)	500.96[e] (4.23)	513.02[e] (3.81)
Cowage[f]				
1		334.94 (4.14)	373.77 (4.25)	409.71 (4.09)
2	439.18 (3.71)	420.07 (3.25)	451.09 (3.37)	454.29 (3.52)
3	495.31 (3.44)	469.96 (3.16)	494.89 (3.24)	498.19 (3.53)
4	522.82 (3.71)	503.40 (3.94)	527.07 (4.05)	536.40 (4.04)
5	551.77 (4.27)	536.19 (4.77)	554.09 (4.87)	557.61 (4.74)

[a] Calving = Pre-calving weight (April 15), pre-breeding weight (June 1), post-breeding weight (July 15), weaning = fall weight (October 1).

[b] Standard errors in parentheses.

[c,d,e] Means within columns with different superscripts differ ($P<.05$).

[f] Significant differences among all weight periods for all age subclasses ($P<.0001$).

weight through the winter, they point out the weight of the products of conception were not deducted from pre-calving weights and also noted significant weight losses during the winter.

Analyses of variance for calf birth and weaning weights for 2-yr-old dams are shown in Table 7 and least squares means and standard errors are presented in Table 8. Data reported for 2-yr-old dams are from matings to a single Red Poll sire.

Table 7. Least squares analyses of variance for 2-yr-old dams calf birth and weaning weights.

Source	df	Mean Squares
Birth weight (N=142)		
Year	2	35.12*
Breed	4	54.01**
Sire(Breed)	51	17.62*
Sex	1	157.28**
Error	83	10.84
Weaning weight (N=135)		
Year	2	434.61
Breed	4	4620.94**
Sire(Breed)	51	871.37
Sex	1	3745.92*
Error	76	760.68

* P<.05
** P<.001

All main effects were significant for birth weight of Red Poll cross calves from 2-yr-old dams. Calf birth weight did not differ among the HH, AH or 1S3H breed groups. Differences between the 1S3H and 3S1H breed groups approached significance (P<.06) and the SH dams produced calves with the heaviest birth weights. Kress et al. (1990a) reported HH dams had the lightest birth weight calves, AH and 1S3H were intermediate and not different, and SH and 3S1H 2-yr-old dams had the heaviest calves at birth. Male calves were 2.65 kg heavier at birth than female calves.

Table 8. Least squares means and standard errors for calf birth and weaning weights for 2-yr-old dams.

Effect	Birth Weight	SE	Weaning Weight	SE
Overall Mean	34.55		210.20	
Breed				
AH	33.5^{a}	0.59	210.9^{b}	4.99
HH	33.5^{a}	0.68	181.9^{a}	5.74
1S3H	34.7^{ab}	0.81	208.4^{b}	6.93
SH	37.3^{c}	0.84	224.4^{b}	7.48
3S1H	36.7^{bc}	0.89	219.3^{b}	7.61
Sex				
Male	36.5^{a}	0.51	215.7^{a}	4.34
Female	33.8^{b}	0.52	202.3^{b}	4.51

[a,b,c] Means within columns with different superscripts differ (P<.05).

Straightbred 2-yr-old Hereford dams weaned the lightest calves. There were no significant differences among the remaining dam breedtypes although difference between the 1S3H and SH dams approached significance (P<.08). These results agree well with the weaning weights of 205, 191, 209, 228 and 228 for AH, HH, 1S3H, SH and 3S1H 2-yr-old dams, respectively, reported by Kress et al. (1990a) for the original experiment. There was an average difference of approximately 13 kg in weaning weight between steer and heifer calves.

Analyses of variance for calf birth and weaning weights from 3- to 8-yr-olds dams is presented in Table 9 and least squares means and standard errors are summarized in Table 10. Animals were grouped as 3-yr, 4-yr, and 5-yr-old or older dams. Breeding was by random assignment within breedtype and age group to either Tarentaise (8 sires) or Charolais (23 sires) bulls.

For calf birth weight, significant sources of variation included year, dam breedtype, sire(dam breedtype), sire breed, sire(sire breed), sex and an interaction of sire breed x sex. The same model was valid for weaning weight with the exception of sire breed (P=.85). Cow age was not a significant source of variation for calf birth or weaning weight from 3-yr-old and older dams.

There were no differences in birth weight of calves among the HH, AH, and 1S3H dams. The SH dams had calves with the heaviest birth weights with no difference between SH and 3S1H dams. Differences in birth weight between AH and SH dams approached significance (P<.07). There was an average 5 kg difference in birth weight between the sire groups for heifer calves with the Charolais sired females being the heaviest.

Charolais sired bull calves averaged 2.5 kg heavier birth weights than Tarentaise sired bull calves.

No significant differences were found between the HH and AH dams for calf weaning weight (207 kg and 215 kg, respectively). The remaining dam breedtypes were not different with 229, 239, and 233 kg weaning weights for the 1S3H, SH and 3S1H dams, respectively. Charolais sired females averaged 10 kg heavier at weaning than Tarentaise females while Tarentaise sired males averaged 8 kg heavier than the Charolais sired group. No differences were found due to age of dam.

Birth weights reported by Kress et al. (1990b) of 44.6, 43.5, 44.8, 46.0 and 46.0 for AH, HH, 1S3H, SH and 3S1H, respectively, agreed well with those being reported here. Weaning weights reported were 223, 211, 227, 237 and 243 for AH, HH, 1S3H, SH and 3S1H, respectively. There was no significant variation due to dam age. Significant interactions reported by Kress et al. (1990b) were sire breed x sex, dam breedtype x sire breed, and dam breedtype x dam age.

The difference between Tarentaise and Charolais sired calves for weaning weight was significant for heifer calves with the Charolais sired heifers being heavier, but no difference between sire groups for steer calves (Kress et al, 1990b). This interaction was consistent for other growth traits as well. Differences between sire breeds in the dam

Table 9. Analyses of variance for birth and weaning weights from 3-8 yr old dams.

Source	df	Mean Squares
Birth weight (N=450)		
Year	5	131.94^{****}
Breed	4	61.06^{*}
Sire(Breed)	54	37.41^{**}
Cow age	2	12.92
Sire breed	1	852.35^{****}
Sire(Sire breed)	30	65.37^{****}
Sex	1	1017.05^{****}
Sire breed*sex	1	172.07^{**}
Error	351	23.83
Weaning weight (N=426)		
Year	5	4485.10^{***}
Breed	4	7658.83^{****}
Sire(Breed)	54	1690.35^{**}
Cow age	2	948.45
Sire breed	1	38.22
Sire(Sire breed)	30	1634.36^{*}
Sex	1	9883.48^{**}
Sire breed*sex	1	6297.53^{*}
Error	327	

* P<.05 ** P<.01 *** P<.001 **** P<.0001

Table 10. Least squares means and standard errors for birth and weaning weights from 3-8 yr old dams.

Effect	Birth Weight	SE	Weaning Weight	SE
Overall mean	44.28		224.44	
Breed				
AH	43.68^{b}	0.69	215.16^{b}	4.67
HH	42.81^{bc}	0.72	207.54^{b}	5.10
1S3H	44.05^{bcd}	0.63	228.74^{c}	4.34
SH	45.66^{d}	0.76	239.04^{c}	5.19
3S1H	44.98^{cd}	0.86	232.76^{c}	5.80
Cowage				
3	43.69^{b}	0.68	226.70^{b}	4.70
4	44.41^{b}	0.66	227.94^{b}	4.53
5	44.61^{b}	0.70	219.30^{b}	4.80
Sirebrd*sex[a]				
Tar x m	44.58^{c}	0.63	234.11^{c}	4.35
Tar x f	39.77^{b}	0.60	214.30^{b}	4.08
Char x m	47.26^{d}	0.65	226.03^{c}	4.39
Char x f	45.33^{c}	0.72	224.15^{bc}	4.97

[a] Male Tarentaise, female Tarentaise, male Charolais, female Charolais.

[b,c,d] Means within columns with different superscripts differ ($P<.05$).

breedtype x sire breed interaction were small between the HH and AH dams, but showed an advantage for the Charolais sires in dams with higher percentages of Simmental breeding.

Dam breedtype x dam age interactions were significant for traits involving dam reproduction (Kress et al., 1990b). The F_1 females showed high production (calf weight weaned per cow exposed to breeding) as 2-yr-olds, decreases as 3- or 4-yr-olds due to a smaller percentage of calves weaned, and maximum production as mature dams. The 3S1H dams had low production as young animals, due to poor reproduction, and high levels of production as mature dams. The 1S3H dams were the only group not showing the greatest production as mature dams.

Pregnancy Rates

Maximum likelihood analysis of variance for pregnancy rates for yearlings, 2-yr-old, and 3-yr-old and older dams are shown in Table 11. Pregnancy rates were analyzed for yearlings, 2-yr-olds and 3-yr-old and older dams. Least squares means were calculated using the equation:

$$P = \frac{1}{e^{-\text{model}} + 1}$$

where (-model) includes the parameter estimates for each main effect in the statistical model. For example, the (-model) for probability of pregnancy for 3-yr-old HH dams was calculated using the maximum-likelihood estimates for the effect of the intercept (overall mean for total model) + constant for the HH dams + constant for 3-yr-old dams.

Maximum-likelihood least squares means and standard errors for pregnancy rates are presented in Table 12.

Table 11. Maximum-likelihood analyses of variance for full models for pregnancy rate.

Source	df	Chi-square	Probability
Yearlings			
Intercept	1	53.10	0.0000
Year	3	6.08	0.1078
Dam Breed	4	16.38	0.0026
Likelihood Ratio	8	13.04	0.1106
2-yr-olds			
Intercept	1	28.41	0.0000
Year	3	3.44	0.3292
Dam Breed	4	3.73	0.4435
Likelihood Ratio	8	12.36	0.1359
3-yr-olds +			
Intercept	1	111.91	0.0000
Year	5	10.02	0.0746
Dam Breed	4	2.32	0.6770
Dam Age	2	0.82	0.6651
Likelihood Ratio	39	39.81	0.4339

Main effects for the full model for yearling pregnancy included year and dam breedtype. Dam breedtype was a significant source of variation for pregnancy rate due to HH dams having low pregnancy rates (62%) and the F_1 crosses having high pregnancy rates (94% for AH and 86% for SH). Other dam breedtypes were intermediate (72% and 70% for 1S3H and 3S1H, respectively). The percentage of cows calving as 2-yr-olds (based on number of dams exposed to breeding) from Kress et al. (1990a) were 58%, 92%, 72%, 91%, and 79% for HH, AH, 1S3H, SH, and 3S1H, respectively. Steffan (1983) reported yearling pregnancy rates of 59%, 90%, 77%, and 86% for HH, AH, 1S3H and SH heifers from this same experimental group.

The 2-yr-old dam model for pregnancy included year, dam breedtype, calf sex and calving difficulty. No main effects explained significant differences in pregnancy rate for 2-yr-old dams. Using information reported by Kress et al. (1990b), the proportion of 3-yr-old dams calving, based on number exposed to breeding, would indicate pregnancy rates of .72, .76, .78, .80., and .70 for AH, HH, 1S3H, SH, and 3S1H for 2-yr-old dams, respectively. The differences seen between these estimates probably results from the original experiment allowing young dams in their first three years of production to remain in the herd unless open two years in a row. The estimates from Kress et al. (1990b) would include animals that did not conceive as yearlings, but were able to become pregnant the following year as a 2-yr-old. Editing the data to reflect culling at the first open season would eliminate these animals and reduce the number of dams remaining in the herd to be bred as 2-yr-olds.

The statistical model for 3-yr-old and older dams for pregnancy rate included year, dam breedtype, dam age, sire breed of calf at side, sex of calf at side, and calving difficulty experienced with calf at side. No main effects were significant sources of variation for pregnancy rate of dams three years of age or older. Pregnancy rates used as model inputs for 3-yr-old and older dams were .77, .78, .84, .82, and .85 for AH, HH, 1S3H, SH, and 3S1H, respectively. Overall least squares means for pregnancy rates for dams from Kress et al. (1990b) were .75, .80, .81, .83, and .73 for AH, HH, 1S3H, SH, and 3S1H, respectively.

Table 12. Maximum likelihood least squares means and standard errors for pregnancy rates.

Effect	Yearlings	2-yr-olds	3-yr-old +
Breed			
AH	.94 (.03)[a]	.75 (.06)	.77 (.04)
HH	.62 (.06)	.75 (.07)	.78 (.05)
1S3H	.72 (.06)	.80 (.06)	.84 (.03)
SH	.86 (.05)	.68 (.08)	.82 (.04)
3S1H	.70 (.06)	.56 (.08)	.86 (.04)

[a] Standard errors in parentheses.

Dystocia

Maximum likelihood analyses of variance for incidence of dystocia are shown in Table 13. Two-yr-old dams were analyzed separately. The full model included year, dam breedtype and sex of calf. No main effects were significant sources of variation for calving difficulty for 2-yr-old dams. Model inputs for percent calving difficulty were 68%, 86%, 69%, 75%, and 60% for AH, HH, 1S3H, SH, and 3S1H dams, respectively. Kress et al. (1990a) reported no dam breedtype differences for calving difficulty even though there were significant dam group differences in birth weight.

The model for calving difficulty in 3-yr-old and older dams included year, dam breedtype, dam age, sire breed of calf, and sex of calf. All main effects, with the exception of year, were significant sources of variation for incidence of dystocia. The AH and 3S1H dams had lower incidence of dystocia (13% and 17%, respectively), HH and 1S3H were intermediate (28% and 27%, respectively), and SH dams had more difficulty calving (33%).

Kress et al. (1990b) reported percentage of dams within breed experiencing calving difficulty (0 for no difficulty and 1 for any other level of difficulty) as 10%, 24%, 20%, 26%, and 19% for AH, HH, 1S3H, SH, and 3S1H, respectively. When dystocia was scored as 1 = no difficulty, 2 = some assistance, 3 = difficult birth, 4 = caesarean, and 5 = malpresentation, no difference in calving difficulty scores were found among the dam breedtypes.

Age of dam showed 32% of 3-yr-olds, 22% of 4-yr-olds, and 20% of 5-yr-old or older dams having difficulty calving. The same trend was reported by Kress et al. (1990b), though the percent calving difficulty was lower for older dams (32%, 15%, and 11% for 3, 4, and 5-yr-old or older dams).

Calf sex showed 19% of female calves and 29% of males calves experienced calving difficulty. Kress et al. (1990b) reported proportion of calving difficulty as 15% for females and 25% for males. Sire breed of calf showed Tarentaise sired calves experienced 17% difficulty and Charolais sired calves having 32% difficult births. Kress et al. (1990b) reported calving difficulty rates of 13% and 26% for Tarentaise and Charolais sired calves. Maximum-likelihood least squares means used as model inputs are summarized in Table 36.

Table 13. Maximum-likelihood analyses of variance for full models for incidence of dystocia.

Source	df	Chi-square	Probability
2-yr-olds			
Intercept	6	19.36	0.0000
Year	2	3.63	0.1630
Dam Breed	3	2.97	0.5623
Sex	1	1.87	0.1712
Likelihood Ratio	16	19.75	0.2315
3-yr-old +			
Intercept	1	101.40	0.0000
Dam Breed	4	14.73	0.0053
Dam Age	2	7.73	0.0210
Sire breed	1	13.44	0.0002
Sex	1	7.25	0.0071
Likelihood Ratio	51	59.79	0.1866

Calf Viability to Weaning

The maximum-likelihood analysis of variance for calf survival to weaning is shown in Table 14. The full model for percentage of calves weaned by 2-yr-old dams included year, dam breedtype, sex and calving difficulty. No main effects were significant sources of variation for calf survival to weaning for 2-yr-old dams.

Overall survival rate without calving difficulty was approximately 95%. When dystocia occurred, survival was approximately 93%. The SH dams had the lowest calf survival rates (89% with no dystocia and 87% survival with difficult births). The 1S3H and 3S1H dams had calf survival rates of 94% and 95%, and 93% and 94%, with and without dystocia. The HH and AH dams weaned 97% and 98% of calves not experiencing difficult births, and 96% and 97% when dystocia occurred. Differences in proportion calved and proportion weaned, reported by Kress et al. (1990a), showed calf survival to weaning as 97%, 95%, 85%, 89%, and 87% for HH, AH, 1S3H, SH, and 3S1H 2-yr-old dams, respectively.

The full model for calf survival to weaning for dams 3-yr of age or older included year, dam breedtype, dam age, sire breed of calf, difficult birth, and sex of calf. Whether the dam experienced difficulty giving birth or not was a significant source of variation for survival to weaning. No other main effects were significant. Input parameters for calf survival are summarized in Table 37.

Table 14. Maximum-likelihood analyses of variance for models for calf survival to weaning.

Source	df	Chi-Square	Probability
2-yr-olds			
Intercept	1	26.43	0.0000
Year	2	3.20	0.2021
Dam Breed	4	3.81	0.4323
3-yr-olds +			
Intercept	1	93.05	0.0000
Year	5	7.10	0.2131
Dam Breed	4	2.24	0.6923
Dam Age	2	2.10	0.3497
Difficulty	1	9.91	0.0016
Likelihood Ratio	237	132.08	1.0000

Overall survival rate was 96% when no calving difficulty was experienced, and 86% when dystocia occurred. Survival rates were 97%, 94%, 95%, 98%, and 97% for AH, HH, 1S3H, SH, and 3S1H, respectively, for dams not requiring assistance, and 88%, 79%, 83%, 90%, and 89% when assistance was required. Kress et al. (1990b) reported proportions calved and weaned which yield survival rates of 96%, 97%, and 94% for 3-, 4-, and 5-yr-old and older dams, and 96%, 93%, 96%, 95%, and 97% overall survival rates for AH, HH, 1S3H, SH, and 3S1H dams, respectively. No dam breedtype differences were significant for either proportion calved or proportion weaned. Older dams weaned a greater number of calves due to a higher percentage of animals calving (87% vs 75% and 73% for 5-yr-old +, 3-yr-old, and 4-yr-old dams, respectively) even though the survival rate was not as high for older dams. No results were reported with respect to survival due to calving difficulty (Kress et al., 1990b).

The younger animals in our analyses had much higher rates of calving difficulty than older dams, but this did not translate to lower survival rates. The differences in survival rates between young animals and mature dams may reflect the management practices at NARC. Younger animals, particularly 2-yr-olds and first calf heifers, are watched more closely for signs of dystocia, and consequently may have received assistance more promptly than the mature dams.

Summary

In summary, weights for the five dam breedtypes for the four weight periods were similar and in good agreement with earlier published reports using different culling procedures. The HH dams were lightest, AH and 1S3H were intermediate, and SH and 3S1H dams were heaviest. Calf birth and weaning weights for 2-yr-old dams were also in agreement with results from data collected during the 10 yr study at NARC. For 3-yr-old and older dams, birth weight showed similar rankings within the dam breedtypes, with slight variations among the AH, SH, and 3S1H groups. This was also true for weaning weight with the exception of no difference between AH and HH dams in this analysis in contrast to no difference between AH and 1S3H in the original experimental results.

The sire breed x sex interaction for birth weight was the result of larger differences between the female than the male calves for the two sire breed groups. Weaning weight showed the Charolais females had an advantage over the Tarentaise females, but this was reversed between the two sire groups for the male calves.

Pregnancy rates were highly variable among dam breedtypes and ages. Straightbred Hereford dams had low yearling pregnancy rates, with production increasing with age. The 3S1H dams had intermediate pregnancy rates as yearlings, a sharp decrease in pregnancy rate as 2-yr-olds and increased production thereafter. The remaining dam breedtypes did not show typical age of dam profiles for pregnancy, as did the HH dams. The two F_1 crosses showed high pregnancy rates as yearlings, decreases in pregnancy rate for the following two years, and increasing production as mature dams. The 1S3H dams had intermediate pregnancy rates as yearlings, increased rates as 2-yr-olds and slight decreases as mature dams.

Dystocia was affected by dam breedtype, sire breed and sex after the first calf. There were no differences detected in 2-yr-old, first calf heifers. Survival was affected by calving difficulty.

Model Simulation

Original Parameters

The simulation model was constructed based on the experimental data collected at NARC. Least squares means, discussed previously, were used as input parameters in order to estimate economic life-cycle production of the five dam breedtypes in a northern range, cow-calf production system.

Sixty yearling heifers were started for each of five replications, or runs through the simulation model, for each dam breedtype x sire breed combination resulting in 50 total observations. Culling was at the first open season with a 1% unsoundness culling rate, removal at 10 yr of age, and 1% death rate. No culling penalty was assessed on the dams due to the death of a calf.

Costs of production were calculated using two hay prices ($55.00 and $83.00 per metric ton) and cattle prices derived from a two year average fall price (discussed previously), plus a 20% reduction in prices received for calves. The base simulation assumed no restriction on land or feed resources and results are on a "per cow" basis.

Traits to be discussed include number of matings, number of calves weaned per cow exposed, calf weight weaned per cow exposed, DM and ME consumed per kilogram of calf weight weaned and total weight sold, steer equivalent weight for the two hay prices and the two calf prices received, and total production costs and net profit per cow exposed.

Measures of Production. Analyses of variance for measures of production, including number of matings, calves weaned per cow exposed, and calf weight weaned per cow exposed are presented in Table 15. Mean comparisons, by Duncan's multiple range test, and standard errors are presented in Table 16.

The number of matings is a reflection of longevity or average herd life. For this study, it is based on the dams' reproductive performance. Dam breedtype was a significant source of variation, but calf sire breed groups and the interaction had no significant influence. The AH and SH dams had an average number of matings of 254 and 256, respectively. The 1S3H dams were intermediate, but not different from the F_1 crosses with 239 matings. Due to the lower pregnancy rates as young dams, the HH and 3S1H dams had fewer lifetime matings (184 and 198, respectively) and, therefore, shorter average herd lives than the other dam breedtypes.

Rohrer et al. (1988) reported breedtype as a major source of variation for productive longevity among 15 breedtypes of cows. Straightbred dams had shorter average herd life than crossbred dams. Dairy breeds had the shortest average life span. They also referenced several studies indicating heterosis was important in increasing lifetime production (Dickinson and Touchberry, 1961; Spelbring et al., 1977; McClure et al., 1985; Nunez-Dominguez, 1985). The study of Rohrer et al. (1988) indicated that Angus-Hereford crosses had low initial removal rates, but the probability of removal at an older age increased rapidly. Removal for reproductive failure was not a major factor in this study due to a lenient culling policy.

A report on productivity of 2-yr-old dams by Belcher and Frahm (1979) showed a calving rate of 88% and a rebreeding rate of 73% for AH dams. The SH crosses in their study had the poorest reproductive performance as 2-yr-olds with only 58% calving and a 60% rebreeding rate. The Simmental x Angus cross showed 81% calving and 73% rebreeding. They reported this was not in agreement with a study reported by Fredeen et al. (1974) where no differences were found between Simmental sired crossbred dams for measures of reproduction as young dams. Dairy breed crosses, Brown Swiss and Jersey sires crossed on Angus and Hereford dams, exhibited high percentages for number calving and rebreeding with the exception of the Brown Swiss x Hereford cross which showed 78% and 44% for percent calving and rebreeding, respectively.

Average pregnancy rates for cows produced at Guelph, Ontario, Canada, reported by Fiss and Wilton (1989), were not significantly different among straightbred Herefords, straightbred Simmentals, a large, rotational beef cross, a small, dual purpose rotational cross, and a small, rotational beef cross. The authors did report a trend for the crossbreds to have higher pregnancy rates than the straightbred dams, and the smaller crossbreds having a higher reproductive rate than the larger crossbreds. This trend was also present in the straightbred systems.

Nunez-Dominguez et al. (1991) reported survival rates for straightbred and reciprocal crosses involving Hereford, Angus, and Shorthorn dams. Actual experimental procedure culled heifers that were open during the first breeding season, then only cows failing to conceive every other year were culled for reproductive failure until at least 10 yr of age. The authors also analyzed the data for a culling policy whereby all cattle were culled at their first open season. Infertility was the main cause of removal from the herd for both straightbred and crossbred dams, followed by mortality. Survival for all ages was highest for the Hereford-Angus reciprocal crosses and

Table 15. Analyses of variance for measures of production (N=50)†.

Source	df	Mean Square
Number of Matings		
Dam Breed	4	10873.83****
Sire Breed	1	1085.78
Error	44	588.92
Calves Weaned/Cow Exposed		
Dam Breed	4	0.0232****
Sire Breed	1	0.0003
Error	44	0.0009
Calf Weight Weaned/Cow Exposed		
Dam Breed	4	3204.06****
Sire Breed	1	41.95
Error	44	46.96

**** (P<.0001)

† Five dam breedtypes x two sire breeds x five replications.

lowest for the straightbred Shorthorns. Angus cows survived longer than Herefords, with the exception of the first two parities, and all breeds survived better than Shorthorns (Nunez-Dominguez et al., 1991). Crossbreds had lower probabilities of being culled than straightbreds. The number of replacements required was also greater for the straightbred animals.

Bailey (1991) also reported on hypothetical culling at the first open season for Hereford and Red Poll, and their reciprocal crosses, and F_1 crosses utilizing Angus, Hereford, Charolais and Brahman cattle at Reno, NV. Number of mating seasons was lowest for the straightbred Herefords (3.25) and highest for the Angus x Charolais (5.42) and Brahman x Hereford (5.72). All crossbred animals exceeded the straightbred groups for number of matings with the exception of the Red Poll having more matings than the Hereford x Red Poll crossbred group (3.82 vs 3.76). The Red Poll x Hereford crossbreds had 4.25 matings, and the Angus x Hereford averaged 4.64 matings.

Number of calves weaned per cow exposed also reflects the dam's reproduction in addition to considering the incidence of dystocia and the resulting survival to weaning among the dam breedtypes. Dam breedtype in the present study for this trait was highly significant but sire breed of the calf and the interaction were not. The F_1 crosses weaned the most calves

Table 16. Mean comparisons and standard errors for measures of production.

Effect	Number of Matings	Calves Weaned/Cow Exposed	Calf Wt Weaned/Cow Exposed (kg)
Overall Mean (N=50)	226.26	0.6816	151.56
Dam Breed			
AH	253.60^b	0.7287^c	157.43^b
HH	184.30^a	0.6072^a	121.78^a
1S3H	238.80^b	0.6865^b	153.94^b
SH	256.30^b	0.7178^c	170.16^c
3S1H	198.30^a	0.6678^b	154.49^b
SEM	7.67	0.0096	2.17

[a] Means within columns with different superscripts differ (P<.05).

with .73 and .72 calves for AH and SH, respectively, the 1S3H and 3S1H dams were intermediate with .69 and .67 calves, respectively, and the HH dams were lowest with .61 calves.

Despite the SH dams having a high percentage of calving difficulty and low calf survival rates, their increased reproductive performance resulted in a high percentage of calves weaned per cow exposed to breeding. The 3S1H and HH dams had low frequencies of calving difficulty and high survival rates, but weaned fewer calves in their lifetime due to decreased reproduction.

Kress et al. (1990b) reported no difference in proportion of calves weaned/cow exposed among these five dam breedtypes for 3- to 8-yr-old cows. The AH, HH, 1S3H, SH, and 3S1H dams weaned .72, .74, .78, .79, and .71 calves, respectively. These values are averaged over all ages and do not show the significant dam breedtype x dam age interaction which was found in their study.

No differences were found in calving difficulty among 2-yr-old dams from these breedtypes (Kress et al., 1990a) with differences in number of calves weaned relating more closely to the pregnancy rates than the stresses of calving. No main effects, including dystocia, were found to have an influence on calf survival for the 2-yr-old dams in the present study. Gregory et al. (1991) found significant effects of breed group on dystocia and calf survival for groups of 4-breed composite populations of 2-yr-old dams. They found survival to weaning was 7.7% higher in calves that did not experience dystocia.

In a study reported by Marshall et al. (1990), comparisons of pregnancy, weaning rate, and calving difficulty were made among straightbred Herefords, F_1 Angus or Simmental and Hereford crosses, and crosses containing high or low percentages of Angus or Simmental and Hereford. Breed group was not a significant source of variation for these traits. Calving difficulty ranged from 4.2% for Simmental x Hereford with a low percentage Simmental to .02% for Angus x Hereford F_1 crosses. Pregnancy and weaning rates ranged from 84% and 81% (straightbred Herefords) to 97% and 97% (Angus x Hereford with a low percentage Hereford).

Kilograms of calf weight weaned per cow exposed to breeding is a measure of the dam's reproduction, calf survival, and calf weights. Dam breedtype was again highly significant as a source of variation while sire breed and the interaction were not. The AH dams ranked above the SH dams in number of calves weaned per cow exposed but the SH dams ranked higher in weight weaned per cow exposed due to the heavier weaning weights associated with their calves. The AH, 3S1H and 1S3H dams were intermediate, and the HH dams weaned the least amount of calf weight.

Kress et al. (1990a) reported actual weight weaned/cow exposed at 179, 105, 126, 182, and 154 kg for 2-yr-old AH, HH, 1S3H, SH, and 3S1H dams, respectively. There were no differences among the HH and the two backcross breed groups, and no difference between the two F_1 crosses. For 3- to 8-yr-old dams, weight weaned/cow exposed were 163, 157, 179, 189, and 169 kg for AH, HH, 1S3H, SH, and 3S1H dams, respectively. The HH weaned the least amount of calf weight and the SH weaned the greatest amount. All other breed groups were intermediate and not different.

Neville et al. (1984) published results of 205-d weight weaned/cow exposed for straightbred and 2- and 3-breed rotational crosses utilizing Angus, Polled Hereford and Santa Gertrudis cattle in Georgia. Straightbred Angus and Hereford dams produced the least amount of calf weight, followed by their 2-breed rotational crosses. The remaining rotational crosses produced the greatest amount of weight per cow exposed to breeding with the Santa Gertrudis being intermediate. These 205-d weights were similar to the 180-d weights of the present study.

Comparison of various combinations of Angus, Hereford, and Brahman cattle in Oklahoma for calf weight weaned per year were presented by McCarter et al. (1991). This trait was a combination of reproduction and mothering ability. Weight weaned per year increased with increasing Brahman influence for the spring calving production system.

Biological Efficiency. Because feed costs account for a large percentage of production costs, researchers have tried to define which types of cattle are most efficient. One measure of efficiency is a ratio of output (calf weight, calf weight/cow exposed, number of calves weaned) to input (DM or ME consumed) which is termed biological efficiency.

Analyses of variance for measures of biological, or energetic, efficiency for the present study are presented in Table 17. These measures include dry matter and metabolizable energy consumed per kilogram of calf weight weaned and total weight sold. Mean comparisons and standard errors are presented in Table 18.

The AH, 1S3H and SH dams had lower (i.e., more desirable) values for DM and ME consumed per kilogram of calf weight weaned, the 3S1H dams were intermediate, and the HH dams had the highest, or least desirable, values. These values indicate that the F_1 crosses and the 25% Simmental dams were more efficient when production efficiency was measured in terms of feed inputs per kg of calf weight produced for market. These dam breedtypes had longer average herd lives, produced a greater number of calves per cow exposed to breeding, and weaned more kilogram of calf weight per cow exposed than the other two dam breedtypes. The 3S1H dams had shorter herd lives and fewer numbers of calves weaned, but weaned larger calves. The HH dams weaned fewer calves with lighter weaning weights, and were therefore less efficient for this definition of productivity.

When we compare this to efficiency in terms of total weight sold, the inverse is true. The HH and 3S1H dams were most efficient, and the 1S3H, AH, and SH dams the least efficient. Selling a larger number of young dams, as happened with the HH and 3S1H groups due to poorer reproduction as young dams, will increase the biological efficiency since these young dams are akin to young, growing animals in a feedlot. Having a greater proportion of the herd as mature dams, as is the case with the F_1 crosses, will decrease this measure of efficiency.

Havstad et al. (1986) reported results from an intake study using dry and lactating HH and 3S1H for 3-yr periods. No significant differences were found between the breedtypes for non-lactating cows in any of the years. Estimated intake averaged 4.5, 6.8, and 9.1 kg/454 kg of body weight in 1981, 1982, and 1983, respectively. The differences in intake were due to differing digestibilities of the forages for each of the years (36%, 50%, and 65% in 1981, 1982, and1983, respectively). Total forage consimption (kg/d) did differ between the dam breedtypes due to the 3S1H dams' greater body weight.

Table 17. Analyses of variance for measures of biological efficiency (N=50)†.

Source	df	Mean Square
DM/kg calf weight		
Dam Breed	4	20.646****
Sire Breed	1	0.084
Error	44	0.299
ME/kg calf weight		
Dam Breed	4	112.882****
Sire Breed	1	0.347
Error	44	1.628
DM/kg total weight		
Dam Breed	4	2.697****
Sire Breed	1	0.245
Error	44	0.274
ME/kg total weight		
Dam Breed	4	13.812****
Sire Breed	1	1.409
Error	44	1.418

**** (P<.0001)

† Five dam breedtypes x two sire breeds x five replications.

Lactating animals (Havstad et al., 1986) consumed 53% more forage on average than non-lactating animals. Differences were found between the two dam breedtypes in 1982 and 1984, but not in 1983 when forage digestibility was 65%. In 1984, all five dam breedtypes were included in the study (all animals were lactating). The HH and 1S3H dams consumed the least amount of forage per 454 kg of body weight, the 3S1H and SH dams consumed the most, and the AH were intermediate and not different from the SH group. Differences in total intake were also different due to dam size and milk production levels. Estimated forage intake for a 90 d grazing period were 1205, 1102, 1061, 1306, and 1388 kg for AH, HH, 1S3H, SH, and 3S1H breed groups. Havstad et al. (1986) concluded intake was dependent on physiological status, milk production levels, environmental differences, and cow size. Factors affecting intake were numerous, complex and interrelated.

Biological efficiencies derived from the above mentioned studies were reported by Doornbos et al. (1986). Six ratios were calculated for measures of biological efficiency with higher ratios being more favorable (greater output compared to input). The 1S3H dams had higher ratios than the other dam breedtypes for all measures of efficiency due to having the lowest estimated forage intakes. The HH, AH and SH dams had similar ratios for calf weight weaned/cow exposed/kilogram forage consumed, while the 3S1H dams were the least efficient.

The ranking of dam breedtypes for measures of biological efficiency were very different from rankings based on production alone. All crossbred dams exceeded the HH for calf weight weaned/cow exposed with the SH being most productive. The two backcross dam groups and the AH dams were intermediate.

Ferrell and Jenkins (1985) found maintenance requirements of F_1 crossbred cattle varied more with milk production potential than with requirements per unit of weight, even when the animals were not lactating. Some differences in energy required for gestation and lactation existed among different breedtypes, but these requirements were relatively small when compared to the maintenance requirements. Regardless of cow type, 70 to 75% of the energy required was for animal maintenance.

A study on forage intake by lactating beef cattle with different milk production levels was initiated in Nebraska by Hatfield et al. (1989). They found forage dry matter intake increased with increasing milk production potential in both early and late lactation. Animals with high milk production levels consumed 1.4 kg more DM per day than animals with low levels of milk production in early lactation and 1.7 kg more per day during late lactation. However, the low producing cows were 22.5 and 27 kg heavier than the high producing animals.

Montano-Bermudez and Nielsen (1990) reported biological efficiencies for first-cross cattle with different potentials

Table 18. Means comparisons and standard errors for measures of biological efficiency.

Effect	DM/kg calf weight	ME/kg calf weight	DM/kg total weight	ME/kg total weight
Overall Mean (N=50)	20.29	46.77	10.92	25.18
Dam Breed				
AH	19.55^{a}	45.14^{a}	11.22^{b}	25.89^{b}
HH	22.74^{c}	52.48^{c}	10.30^{a}	23.77^{a}
1S3H	19.52^{a}	44.90^{a}	11.17^{b}	25.69^{b}
SH	19.23^{a}	44.27^{a}	11.49^{b}	26.44^{b}
3S1H	20.40^{b}	47.05^{b}	10.45^{a}	24.09^{a}
SEM	0.173	0.404	0.165	0.377

^{abc} Means within columns with different superscripts differ ($P<.05$).

averaged 4.5, 6.8, and 9.1 kg/454 kg of body weight in 1981, 1982, and 1983, respectively. The differences in intake were due to differing digestibilities of the forages for each of the years (36%, 50%, and 65% in 1981, 1982, and 1983, respectively). Total forage consumption (kg/d) did differ between the dam breedtypes due to the 3S1H dams' greater body weight.

Economic Efficiency. Measures of economic efficiency for the present study include steer equivalent prices and net profit per cow exposed for the lower hay price and standard calf prices, and total cost of production per cow exposed. Analyses of variance for the base measures of economic efficiency are presented in Table 19. Mean comparisons and standard errors are presented in Table 20. Discussion will focus on the base economic parameters, and any variation or re-ranking due to changes in either hay or calf prices.

The steer equivalent price reflects the price a producer would have to receive for his steer calves in order to breakeven by weighting all classes of sale animals relative to the value of the steer calves. The HH dams had the highest (i.e., least desirable) average breakeven price at $2.33/kg. The SH and AH had the lowest breakeven prices at $1.76 and $1.84/kg, respectively, and the 1S3H and 3S1H dams were intermediate and not different from the AH dams with prices of $1.90 and $1.93, respectively.

Total cost of production per cow exposed to breeding shows the 3S1H and HH dams had the highest cost of production at $463.51 and $480.37/cow exposed, and were different than the other dam breedtypes. No significant differences were found among the remaining dam breedtypes at $414.75, $410.35, and $404.43 for the 1S3H, SH, and AH dams, respectively.

Net profits per cow exposed to breeding with standard calf prices were highest for the SH and AH dams at $73.01 and $63.30, respectively. The 3S1H and 1S3H dams were intermediate with $38.01 and $44.81, respectively. The straightbred Hereford dams showed a net loss of -$33.00 for the prices assumed in this simulation. All crossbred dams exceeded the straightbred dams in economic efficiency and profit with differences of $100.00/cow exposed.

Sensitivity. A sensitivity analysis to price of feed or price received for the calves was included in the simulations. Rankings and groupings did not change among the dam breedtypes for steer equivalent price regardless of the combination of hay and calf prices for this portion of the simulation. Analyses of variance, means and standard errors for the base calf price and higher hay price ($83.00/metric ton) are summarized in Tables 38 and 39. Analyses of variance, means and standard errors for the reduced calf price with the two hay prices (20% reduction of calf price with $55.00 or $83.00 hay prices) are shown in Tables 40-43.

The price required for steer calves from the HH dam group averaged $0.37/kg higher than the 1S3H, which were the next highest group. Differences between SH and AH (the two lowest groups, respectively) averaged $0.07/kg. The variation in prices between the 1S3H and 3S1H dams was less than $0.02/kg.

This was also true of the production costs between the base and higher hay price, and net profit for all combinations of feed and calf prices. Production costs for the 3S1H and HH dams averaged from $60.00-$80.00/cow exposed higher than the other dam breedtypes. Net profit fluctuated accordingly and with similar degrees of magnitude among the various combinations of costs and money received.

This is not to say that prices paid or received had no influence on costs and profits. When calf prices were reduced by 20%, all dam breedtypes lost money, with the exception of the SH dams when hay price was low. With lower prices received for the calves, differences in net profit ranged from approximately $4.00 to -$100.00. The HH dams failed to show a profit for any of the scenarios simulated.

Kress et al. (1988) reported crossbreeding increased net returns by $19.00 to $75.00 per cow from results of a simulation model comparing straightbred, two- and three-breed rotational crosses, and a terminal 3-breed specific cross. The effect of using a terminal sire system increased economical efficiency by $56.00/cow.

Armstrong et al. (1990) found a large, rotational beef breeding system (four breeds) to be more profitable than a straightbred, a small, rotational dual purpose, or a three-way

Table 19. Analyses of variance for economic measures with base prices (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.489^{****}
Sire Breed	1	0.003
Error	44	0.010
Total production costs/cow exposed		
Dam Breed	4	12058.812^{****}
Sire Breed	1	623.029
Error	44	629.059
Net profit/cow exposed		
Dam Breed	4	17378.042^{****}
Sire Breed	1	509.124
Error	44	494.567

[****] ($P<.0001$).

[†] Five dam breedtypes x two sire breeds x five replications.

Table 20. Means and standard errors for measures of economic efficiency with base prices.

Source	Breakeven Price	Total Cost/Cow Exposed	Net Profit/Cow Exposed
Overall Mean (N=50)	\$1.95	\$434.68	\$37.23
AH	\$1.84^{ab}	\$404.43^{b}	\$63.30^{ab}
HH	\$2.33^{c}	\$480.37^{a}	-\$33.00^{d}
1S3H	\$1.90^{b}	\$414.75^{b}	\$44.81^{bc}
SH	\$1.76^{a}	\$410.35^{b}	\$73.01^{a}
3S1H	\$1.93^{b}	\$463.51^{a}	\$38.01^{c}
SEM	0.031	7.93	8.46

^{abc} Means within columns with different superscripts differ (P<.05).

rotational crossing system. This breeding system produced more output per cow which offset nonfeed expenses. The three-way rotation netted lower returns than all other types when the feed supply was the restraining factor, but the straight Hereford group was less profitable when herd size was constrained. More straightbred animals could be maintained on the same amount of feed, and the higher weaning weights from the three-way rotation did not offset the added feed costs.

Smith et al. (1987) showed that good reproduction with lighter weaning weights increased income more so than heavy weaning weights with poor reproductive performance.

Experimentation

Weaning of calves at NARC occurs approximately one month earlier than many producers throughout the state of Montana. The decision was made to extend the age at weaning by 30 d and a new set of simulations were run. The calf weaning weights were increased by addition of the previously estimated ADG for an additional 30 d in one day increments. Likewise, lactation curves of the dam breedtypes were extended to 210 days.

Breeding at NARC was by artificial insemination for a 45 day season. This policy resulted in fairly low overall pregnancy rates because many of the animals had only one chance to become pregnant during the breeding season. In addition to extending the weaning age, pregnancy rates for all ages of animals were increased by 10% with the exception of the AH yearlings which had a 93% pregnancy rate. The addition of 10% to the pregnancy rate would have been in excess of 100%, so the AH yearlings were increased to a 99% pregnancy rate. No estimates for the expected increase in pregnancy rates due to extending a breeding season by an additional two weeks were found in the literature, hence the 10% increase was deemed reasonable.

After these modifications were made, simulations were run as described previously, and analyses were conducted following the same models as used for the original parameters. Analyses of variance for measures of production from the modified model are presented in Table 21 and means comparisons and standard errors are presented in Table 22.

Increasing pregnancy rates by 10% for each dam age resulted in approximately 40% more lifetime matings overall. Re-ranking which occurred between the original parameters and the experimental results were that the 1S3H dams ranked first, the SH dams ranked second, and the AH dams ranked third, though there was no significant statistical difference among them for either simulation. The 1S3H dams did gain more advantage with a 42% increase whereas the SH and AH dams showed a 32% increase.

Dam breedtype was a significant source of variation in number of calves weaned per cow exposed, while sire breed and the interaction were not. The increased reproduction resulted in an 11% increase in number of calves weaned. The 3S1H dams moved up in ranking over the 1S3H dams, but were not different

Table 21. Analyses of variance for measures of production for modified simulations (N=50)†.

Source	df	Mean Square
Number of Matings		
Dam Breed	4	10203.1****
Sire Breed	1	37.0
Error	44	755.28
Calves Weaned		
Dam Breed	4	0.0082****
Sire Breed	1	0.0004
Error	44	0.0004
Calf Weight Weaned		
Dam Breed	4	2734.32****
Sire Breed	1	0.10
Error	44	41.71

**** (P<.0001)

† Five dam breedtypes x two sire breeds x five replications.

statistically.

Dam breedtype was the only significant source of variation in calf weight weaned per cow exposed. Calf weight weaned increased by an average of 40 kg over the original parameters. The SH dams again weaned the greatest amount of calf weight and the HH dams weaned the least amount. The 3S1H dams exceeded the AH dams by 3%. This was the result of increased weaning weight and the increase in number of calves weaned. Calves from 3S1H dams had higher calf ADG and heavier weaning weights than calves from AH dams. With the increase in pregnancy rates, the 3S1H dams gained an advantage. The AH and 1S3H dams were intermediate and not different.

Table 22. Means comparisons and standard errors for measures of production for modified simulations.

Effect	Number of Matings	Calves Weaned/ Cow Exposed	Calf Wt Weaned/ Cow Exposed
Overall Mean (N=50)	314.82	0.7551	191.41
Dam Breed			
AH	335.80^b	0.7888^c	193.04^b
HH	269.90^a	0.7107^a	163.98^a
1S3H	338.30^b	0.7528^b	192.85^b
SH	338.20^b	0.7684^c	208.05^d
3S1H	291.90^a	0.7546^b	199.13^c
SEM	8.69	0.0062	2.04

[abcd] Means within columns with different superscripts differ ($P<.05$).

Feed and energy consumed per kg of calf weight weaned was affected by dam breedtype for these measures of biological efficiency. Rankings did not change between the original and modified versions, but the mean comparison groupings for DM and ME consumption did. There were no differences between the SH and 1S3H dams, which were most efficient for feed consumed. The AH and 3S1H dams were intermediate with the AH dams not different from the 1S3H dams, and the HH dams consumed the most feed per kg calf weight weaned. Mcal ME showed the same trends as the original simulation runs except there was no difference between the 3S1H and AH dams which were different from the 1S3H and SH dams. The HH dams were least efficient.

Analyses of variance are shown in Table 23 and means and standard errors are summarized in Table 24.

When the ratio of input to output was based on total weight sold, the ranking of the dam breedtypes changed in that the AH dams were least efficient, followed by the 1S3H and SH dams, though there was no statistical difference among them. The HH and 3S1H dams were most efficient with the 3S1H not different than the first three breed groups. The difference between the original and modified simulation is due to an increase in breeding efficiency for the 1S3H and 3S1H dams.

Bourdon and Brinks (1987) used simulation modeling to increase probability of conception from 75% to 85% for cattle with mature weights of 525 kg and milk production potential of 12 kg/d. Replacement rate decreased, mean calving date was slightly later, and weaning rate remained basically the same. Because fewer replacements were required, herd size was increased under a weanling management system and less product resulted from cull cows. Biological efficiency decreased due to a larger portion of the herd being mature dams. They also reported a decrease in economic efficiency with increased fertility when prices paid for cull cows were high. The fed animals had to be very valuable compared to cull cows in order for economic efficiency to improve with improved pregnancy rates.

Armstrong et al. (1990) reported increasing calving rate from 80% to 90% resulted in improved economic efficiency for

Table 23. Analyses of variance for measures of biological efficiency for modified simulations (N=50)[†].

Source	df	Mean Square
DM/kg calf weight		
Dam Breed	4	6.628****
Sire Breed	1	0.000
Error	44	0.197
ME/kg calf weight		
Dam Breed	4	36.074****
Sire Breed	1	0.012
Error	44	1.066
DM/kg total weight		
Dam Breed	4	0.305*
Sire Breed	1	0.042
Error	44	0.090
ME/kg total weight		
Dam Breed	4	1.626*
Sire Breed	1	0.175
Error	44	0.473

**** (P<.0001)

* (P<.05)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 24. Means comparisons and standard errors for measures of biological efficiency for modified simulations.

Effect	DM/kg calf weight	ME/kg calf weight	DM/kg total weight	ME/kg total weight
Overall Mean (N=50)	18.29	42.31	12.26	28.35
Dam Breed				
AH	18.07^{bc}	41.86^{b}	12.40^{b}	28.73^{c}
HH	19.63^{d}	45.42^{c}	12.02^{a}	27.80^{a}
1S3H	17.70^{ab}	40.88^{a}	12.38^{b}	28.59^{bc}
SH	17.63^{a}	40.75^{a}	12.36^{b}	28.58^{bc}
3S1H	18.42^{c}	42.61^{b}	12.12^{ab}	28.04^{ab}
SEM	0.140	0.327	0.095	0.218

^{abc} Means within columns with different superscripts differ ($P<.05$).

all beef to feed price ratios, management systems and resource all beef to feed price ratios, management systems and resource constraints involved in their study.

Measures of economic efficiency and profit for the base prices for the modified simulations are summarized in Tables 25 and 26. Sire breed approached significance for steer equivalent prices for all calf and feed price combinations ($P<.10$). Analyses of variance and mean comparisons for the various price combinations are summarized in Tables 44-49. Dam breedtype was highly significant for all measures.

Steer equivalent price again showed SH and AH dams to be most economically efficient. The 1S3H and 3S1H dams were intermediate with the 1S3H dams not different from the F_1 dams, and the HH dams were least efficient economically. This was also true with the higher hay price and base calf price. When calf prices were reduced, the SH dams were most efficient and different from all other dam breedtypes. The AH, 1S3H, and 3S1H dams were intermediate and not different, and the HH dams were again least economically efficient. Rankings were similar for the original and modified simulations.

Ranking for total production costs for base prices were similar between the original and modified simulations. The HH and 3S1H dams had the highest total costs per cow exposed. The remaining dam breedtypes were not different from one another. The 1S3H dams proved to have the least costs associated with them for the modified simulations, followed by the AH and then the SH dams. The difference between the

Table 25. Analyses of variance of economic measures with base prices for modified simulations (N=50)[†].

Source	df	Mean Square
Steer equivalent		
Dam Breed	4	0.182****
Sire Breed	1	0.017*
Error	44	0.006
Total production costs/cow exposed		
Dam Breed	4	3209.300****
Sire Breed	1	232.463
Error	44	285.830
Net profit/cow exposed		
Dam Breed	4	7825.421****
Sire Breed	1	253.575
Error	44	306.247

**** (P<.0001)
* (P<.10)
[†] Five dam breedtypes x two sire breeds x five replications.

Table 26. Means comparisons and standard errors for measures of economic efficiency with base prices for modified simulations.

Source	Steer Equivalent	Total Cost/Cow Exposed	Net Profit
Overall Mean (N=50)	$1.56	$377.63	$112.76
AH	$\$1.52^{ab}$	$\$362.52^{b}$	$\$127.17^{a}$
HH	$\$1.80^{c}$	$\$399.60^{a}$	$\$\ 63.98^{b}$
1S3H	$\$1.52^{ab}$	$\$361.26^{b}$	$\$118.17^{a}$
SH	$\$1.45^{a}$	$\$370.98^{b}$	$\$134.11^{a}$
3S1H	$\$1.53^{b}$	$\$393.77^{a}$	$\$120.37^{a}$
SEM	0.024	5.35	5.53

[abc] Means within columns with different superscripts differ ($P<.05$).

highest and lowest production costs was approximately $40.00/cow exposed.

Ranking of the dam breedtypes for net profit/cow exposed to breeding remained the same for all feed prices, calf prices, and between the original and modified simulations. The SH dams proved most profitable, followed by the AH, 3S1H, 1S3H, and HH dams. The HH dams were different from all other dam breedtypes. Differences were smaller among and between groups of cattle in the modified simulations, and all dam breedtypes showed a profit with the exception of the HH dams when calf prices were reduced. Differences in net profit between the backcross groups were very small (< $2.00). In the original simulations, profit was realized only if the calf prices were high, again with the exception of the HH dams which did not show a profit for any simulation strategy.

Ranch Simulations

The preceding results assumed no restrictions to land and feed availability. The program was again modified to reflect a fixed land and feed resource as associated with a ranching enterprise. Ranch size was set at 2700 animal unit months (AUMS) based on 304 kg DM/AUM. The animal unit includes pasture and hayland for a cow and her calf. For the original parameters, 380 tons of hay were produced with any additional needs being purchased at one of the two hay prices previously mentioned. For the modified version of the model, 355 tons of hay were produced. The figures for hay production were input so that the minimum amount of hay would need to be purchased based on the requirements of the straightbred Herefords raising Tarentaise calves. Required purchase of hay was modeled so as to avoid negative amounts for feed costs in the simulations. Costs assigned to the ranch portion of the simulations are summarized in Table 27.

Simulations were again run for the two calf prices, the two hay prices, and with the original and modified input parameters. Results discussed will relate to costs on a "per ranch" rather than a "per cow" basis.

The number of matings for the ranch simulation reflect the average herd size rather than the average herd life of the dam breedtypes. Herd size includes the number of replacements required and the producing cow herd. Analysis of variance for number of matings for the original and modified parameters are shown in Table 28, means and standard errors are in Table 29.

Dam breedtype was a significant source of variation for the original parameters for this trait while sire breed and the interaction were not. All dam breedtypes were different from one another. The system utilizing the straightbred Hereford dams had the largest herd size at 445 animals, followed by 1S3H (415), AH (402), 3S1H (391) and SH dams (381). When the modified inputs were used, dam breedtype and sire breed were both significant sources of variation (P<.01). The dam breedtypes ranked in the same order with the exception of no difference between the SH and 3S1H dams. The

Table 27. Overhead costs for ranching simulation.

Source	Cost	Increment	Total Cost[a]
Vehicles	$ 9,000.00	1	$ 9,000.00
Insurance			
House	$ 50,000.00	0.0068[b]	$ 340.00
Facilities	$ 30,000.00	0.0068	$ 204.00
Barns	$ 60,000.00	0.0068	$ 408.00
Equipment	$ 10,000.00	0.0068	$ 68.00
Repairs			
Improvements[c]	$150,000.00	0.02[d]	$ 3,000.00
Fencing	$ 50,000.00	0.02	$ 1,000.00
Utilities	$ 1,800.00	1	$ 1,800.00
Supplies	$ 1,500.00	1	$ 1,500.00
Property Taxes[e]	$ 4,800.00	1	$ 4,800.00
Interest on Land	$450,000.00	0.05[f]	$ 22,500.00
Haying Expenses	$ 30.00	380.0	$ 11,400.00
Labor	$ 1,000.00	6.0	$ 6,000.00
		Total Costs	$ 62,000.00

[a] Total costs per year

[b] Premiums paid at $6.80 per $1000.00 stated value

[c] Improvements equal value of assets mentioned in insurance portion

[d] Repairs calculated at 2% of improvements and fencing costs

[e] For 300 AU ranch

[f] Interest on land purchase @ 5%

Table 28. Analyses of variance for number of matings for ranch simulations (N=50)†.

Source	df	Mean Squares
Original Parameters		
Dam Breed	4	6108.35****
Sire Breed	1	0.20
Error	44	65.70
Modified Parameters		
Dam Breed	4	3377.90****
Sire Breed	1	109.22**
Error	44	13.97

**** (P<.0001)
** (P<.01)
† Five dam breedtypes x two sire breeds x five replications.

systems utilizing Charolais sired calves had approximately 1% more animals than the system using Tarentaise sires.

Analyses of variance for economic efficiency, total cash outlay and net profit for the base scenario are summarized in Table 30 with means and standard errors shown in Table 31.

The base assumptions for economic measures were again the standard, or higher, calf price combined with the lower feed costs. The steer equivalent, or breakeven, prices for the original parameters resulted in the same rankings for the ranch simulations as were found in the "per cow" simulations for all combinations of feed and calf prices. Dam breedtype was highly significant while sire breed and the interaction were not.

Table 29. Means and standard errors for number of matings for ranch simulations (N=50).

Effect	Mean	Effect	Mean
Original Parameters		Modified Parameters	
Dam Breed		Dam Breed	
Overall Mean	407.4	Overall Mean	346.5
AH	402.3^c	AH	344.6^c
HH	445.0^a	HH	372.5^a
1S3H	415.1^b	1S3H	356.2^b
SH	381.4^e	SH	330.8^d
3S1H	390.9^d	3S1H	328.2^d
		Sire Breed	
		Tarentaise	345.0^b
		Charolais	347.9^a
		SEM	1.18

[abcde] Means within columns with different superscripts differ.

The HH dams required the highest steer equivalent prices and the F_1 crosses were again the most economically efficient. The 1S3H and 3S1H dams were intermediate and not different from the AH dams when calf prices were reduced by 20%. With the higher calf price, the SH and AH dams were most economically efficient, the 1S3H and 3S1H dams were intermediate with the 1S3H dams not different from the AH dams, and the HH were least efficient. Summaries of the analyses for the different price combinations are shown in Tables 50-55.

Analyses of variance for the modified simulations are presented in Table 32, and means and standard errors in Table

Table 30. Analyses of variance for economic measures using original parameters and base prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.376****
Sire Breed	1	0.002
Error	44	0.008
Total costs		
Dam Breed	4	4059676564****
Sire Breed	1	87456396
Error	44	168404583
Net profit		
Dam Breed	4	2154041825****
Sire Breed	1	73056028
Error	44	64570064

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 31. Means and standard errors for measures of economic efficiency / base prices original parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	$1.96	$178156.61	$13559.63
AH	$1.86[ab]	$164480.00[ab]	$23709.00[ab]
HH	$2.29[d]	$210371.00[d]	-$11201.00[d]
1S3H	$1.92[bc]	$173742.00[bc]	$17033.00[bc]
SH	$1.79[a]	$159266.00[a]	$25104.00[a]
3S1H	$1.94[c]	$182924.00[c]	$13153.00[c]
SEM	0.028	4103.71	2541.06

[abc] Means within columns with different superscripts differ (P<.05).

33. The various price combination analyses are summarized in Tables 56-61. When the modified simulations were run, dam breedtype was a significant source of variation for breakeven prices, and sire breed approached significance (P<.10). The HH dams were least efficient and the SH dams were most efficient with the other dam breedtypes intermediate. The differences between the two backcross groups were less than $0.01 for all price combinations, and the differences between the AH and 1S3H dam groups were negligible. Differences between the SH and AH dams averaged $0.05 for breakeven prices, while the HH dams required in excess of $0.20/kg more than the other dam breedtypes. Charolais sired calves were less efficient than Tarentaise sired calves.

Dam breedtype was a significant source of variation for total cash expenditures for the ranch simulations using both sets of parameters. Rankings did not change due to changes in feed prices, nor between the original or modified simulations, though the groupings for dam breedtype means did. The HH dams had the highest total costs and were different from all other breed groups for all systems simulated. Results from the original parameter simulations for all price combinations showed the SH and AH dams had the lowest production costs with the two backcross groups intermediate. The 1S3H dams were not different from the AH dams. When the modified simulations were run, the HH had the highest total costs with no difference among the remaining dam breedtypes.

Net profit was influenced by dam breedtype for both sets of input values, with sire breed and the interaction being non-significant. When the simulations were run using the original input parameters, The HH dams failed to show profit for any of the price combinations. When calf prices were high, the remaining dam breedtypes showed profits ranging from $12,000 to $25,000/yr. With reduced calf prices, no dam breed group showed a profit. Feed price showed less influence on profit or loss than the prices received for the calves.

When the modified simulations were run, all breedtypes realized a profit except the HH dams when calf prices were reduced. The HH dams were different from all other dam breedtypes with no statistical difference among the remaining dams. Again, price received for the calves was more important than the cost of feed. With the standard calf price, profits were in excess of $30,000/yr (with the exception of the HH dams at approximately $20,000/yr), but when calf prices were reduced, profits were in the range of $10,000/yr.

Though herd size was reduced with increased pregnancy rate and the extended weaning date, profit to the production system increased substantially. Fewer replacement animals were needed, and the greater portion of the cow herd as older dams increased production per cow and costs were more efficiently distributed.

Differences in net profit between the original and

Table 32. Analyses of variance for economic measures using modified parameters and base prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.143****
Sire Breed	1	0.015*
Error	44	0.005
Total costs		
Dam Breed	4	834024380****
Sire Breed	1	81735017
Error	44	46899557
Net profit		
Dam Breed	4	531545563****
Sire Breed	1	18341274
Error	44	28109130

**** (P<.0001)

* (P<.10)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 33. Means and standard errors for measures of economic efficiency / base prices modified parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	$1.62	$136005.15	$33599.50
AH	$1.58[ab]	$130316.00[a]	$38426.00[a]
HH	$1.83[c]	$151621.00[b]	$21058.00[b]
1S3H	$1.58[ab]	$134163.00[a]	$36596.00[a]
SH	$1.52[a]	$128698.00[a]	$38400.00[a]
3S1H	$1.60[b]	$135227.00[a]	$33518.00[a]
SEM	0.022	2165.63	1676.58

[abc] Means within columns with different superscripts differ (P<.05).

modified simulations were in excess of $20,000.00 for all dam breedtypes. All crossbred animals again outperformed the straightbred animals.

CHAPTER 5

SUMMARY

The SH and AH dams had longer average herd lives due to better reproductive performance, especially as young dams. The 1S3H dams were not different from the F_1dams in average number of matings, though their reproduction followed the more classical line of lower production as young dams with improved calving rates as older dams. The AH and SH dams weaned the most calves per cow exposed to breeding, with the backcross dam groups intermediate and the HH dams weaning the least number of calves. The SH dams weaned the greatest amount of calf weight per cow exposed, the AH, 1S3H and 3S1H dams were intermediate, and the HH dams weaned the least amount of calf weight. The poorer reproduction of the 3S1H dams became less important for this trait because their calves had heavier weaning weights than the other dam breedtypes. It appears some loss of reproductive efficiency could be tolerated if weaning weights are heavy enough.

Biological, or energetic efficiency was reduced when productivity was measured as energy consumed per kilogram of total weight sold due to the greater number of mature dams in the herd. When the measure of productivity was calf weight sold, biological efficiency increased.

Economic efficiency and net returns were closely related to the number and weight of calves sold for market but not to measures of energetic efficiency or productivity defined as total weight sold per cow exposed to breeding. The HH, 1S3H, and 3S1H dams were energetically more efficient ranking first, third, and second for Mcal ME/kg total weight sold, yet had higher steer breakeven prices, ranking fifth, fourth and third, respectively. The SH and AH dams were consistently more economically efficient and profitable, but ranked fourth and fifth in terms of energetic efficiency. These two dam breedtypes had ratios of calf weight to cow weight sold of over 1.5:1 while the HH and 3S1H dams had ratios of 1.1:1 and 1.3:1, respectively. These results confirm the conclusions of Dickerson (1978) and Tess (1986) who proposed that measures of biological efficiency were of limited value in measuring the performance of production systems.

The dam breed groups comparisons were not overly sensitive to changes in prices paid for feed (hay) or price received for the calf crop. The model was sensitive to changes in prices as reflected in the differing profit/loss ranges for the production systems simulated.

Increasing overall reproductive performance and extending the age at weaning from 180- to 210-d increased profit for all price combinations simulated. Because these two traits were combined, it is not certain which had more influence on the production system. It would appear, however, that increased reproduction was important since the dam breedtypes that performed the best were those with greater reproductive performance, especially as young dams. While this study agrees with Bourdon and Brinks (1987b) in terms of decreased biological efficiency with increased fertility, the importance of fertility to economic measures are not in accord. With the costs of production and price received for calves assumed in this study, the more fertile females were economically more efficient for all cost and price combinations. When pregnancy rates were increased, along with extending weaning age, the differences among dam breedtypes disappeared in the ranch simulations, with the exception of the HH dams.

Heterosis was also important to the production systems simulated. The crossbred animals consistently outperformed the straightbred dams for production and economic traits. The two F_1 dam groups, which exhibit maximum heterosis, were the most economically efficient and profitable. The backcross groups were intermediate with reranking occurring between them according to the system being simulated. It would appear a breeding system utilizing rotational crossbreeding would be feasible.

Choices among breeds and mating systems are important management decisions for commercial beef cattle producers. The results of this study indicate that, for northern range cow/calf production systems, breedtypes with greater reproductive performance as young dams will be more profitable. Size and milk production appeared to have an influence on profits. The 3S1H dams did not produce as well, probably due to a combination of high milk potential and greater growth potential as young dams. Although the AH and SH had high potential for milk production, maximizing heterosis appeared to offset the negative aspects of this increased production. Increasing numbers and weight of the calf crop had positive affects on the profits for the system.

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APPENDIX

Table 34. Least squares analyses of variance for cow weights for data not edited to reflect culling at first open season.

Source	df	Mean Squares
At weaning (N=1463)		
Year	8	17192.55**
Breed	4	72737.09**
Sire(Breed)	63	13044.55**
Age	4	339361.67**
Error	1383	1954.28
Pre-calving (N=1231)		
Year	7	16928.98**
Breed	4	64620.85**
Sire(Breed)	63	9168.77**
Age	3	376230.27**
Error	1153	1915.65
Pre-breed (N=1228)		
Year	6	48627.04**
Breed	4	67174.76**
Sire(Breed)	63	8267.63**
Age	4	506733.29**
Error	1150	1564.28
Post-breed (N=1191)		
Year	6	13765.06**
Breed	4	62746.01**
Sire(Breed)	63	8382.52**
Age	4	415878.57**
Error	1113	1800.32

** P<.0001

Table 35. Least squares means and standard errors for cow weights for data not edited to reflect culling at the first open season.

Effect	Calving[a]	Pre-breeding	Post-breeding	Weaning
Overall Mean	552.38	471.48	501.50	513.83
Breed				
HH	492.73[c]	447.22[c]	476.79[c]	495.99[c]
	(3.01)[b]	(2.75)	(3.01)	(2.76)
AH	505.73[d]	465.20[d]	493.99[d]	509.45[d]
	(3.92)	(3.40)	(3.65)	(3.56)
1S3H	500.93[cd]	453.48[c]	482.59[c]	493.42[c]
	(3.61)	(3.40)	(3.83)	(3.40)
SH	521.15[e]	477.25[e]	506.82[e]	514.18[d]
	(3.87)	(3.49)	(3.75)	(3.60)
3S1H	543.06[f]	497.27[f]	528.13[f]	540.84[e]
	(3.82)	(3.59)	(4.15)	(3.49)
Cowage[g]				
1		332.95	373.12	406.09
		(4.71)	(5.12)	(4.71)
2	426.46	426.39	459.68	469.22
	(4.26)	(3.65)	(4.04)	(3.88)
3	497.98	489.03	520.57	528.36
	(3.57)	(3.13)	(3.40)	(3.47)
4	543.95	532.79	555.48	567.60
	(3.46)	(3.42)	(3.75)	(3.61)
5	582.49	559.26	579.47	582.61
	(3.44)	(3.56)	(3.86)	(3.84)

[a] Calving = Pre-calving weight (April 15), pre-breeding weight (June 1), post-breeding weight (July 15), weaning = fall weight (October 1).

[b] Standard errors in parentheses.

[c,d,e,f] Means within columns with different superscripts differ ($P<.05$).

[g] Significant differences among all weight periods for all age subclasses ($P<.0001$).

Table 36. Input values for dystocia among dam breed, dam age, sire breed, sex.

Effect	AH	HH	1S3H	SH	3S1H
2-yr-old	.6829	.8571	.6897	.7500	.6000
3-yr-old					
Tarentaise					
male	.1454	.3350	.3879	.3231	.2077
female	.0825	.2102	.2509	.2014	.1217
Charolais					
male	.2882	.5452	.6013	.5318	.3843
female	.1763	.3878	.4435	.3751	.2480
4-yr-old					
Tarentaise					
male	.0882	.2226	.2649	.2134	.1297
female	.0486	.1314	.1599	.1254	.0730
Charolais					
male	.1872	.4053	.4616	.3924	.2619
female	.1085	.2648	.3118	.2544	.1579
5+-yr-old					
Tarentaise					
male	.0768	.1976	.2365	.1892	.1136
female	.0421	.1151	.1407	.1098	.0634
Charolais					
male	.1653	.3695	.4244	.3571	.2338
female	.0947	.2365	.2804	.2269	.1388

Table 37. Calf survival rates among dam breed, dam age, and calving difficulty.

Source	2-yr-old	3+-yr-old
No Dystocia		
AH	.9782	.9683
HH	.9689	.9406
1S3H	.9381	.9543
SH	.8880	.9752
3S1H	.9546	.9716
Dystocia		
AH	.9744	.8808
HH	.9635	.7930
1S3H	.9279	.8349
SH	.8707	.9048
3S1H	.9469	.8922

Table 38. Analyses of variance for economic measures with standard calf price and increased hay price (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.458****
Sire Breed	1	0.002
Error	44	0.009
Total production costs/cow exposed		
Dam Breed	4	10781.416****
Sire Breed	1	476.486
Error	44	570.593
Net profit/cow exposed		
Dam Breed	4	15334.045****
Sire Breed	1	377.520
Error	44	444.433

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 39. Means and standard errors for measures of economic efficiency with standard calf price and increased hay cost (N=50).

Source	Breakeven Price	Total Cost/Cow Exposed	Net Profit/Cow Exposed
Overall Mean	$2.07	$460.45	$11.46
AH	$\$1.96^{ab}$	$\$430.60^{b}$	$\$37.13^{ab}$
HH	$\$2.43^{c}$	$\$501.82^{a}$	$-\$54.45^{d}$
1S3H	$\$2.02^{b}$	$\$440.83^{b}$	$\$18.73^{bc}$
SH	$\$1.88^{a}$	$\$439.09^{b}$	$\$44.28^{a}$
3S1H	$\$2.04^{b}$	$\$489.92^{a}$	$\$11.61^{c}$
SEM	0.030	7.55	6.67

^{abc} Means within columns with different superscripts differ (P<.05).

Table 40. Analyses of variance for economic measures with reduced calf price and lower hay price (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.326****
Sire Breed	1	0.002
Error	44	0.006
Total production costs/cow exposed		
Dam Breed	4	12058.812****
Sire Breed	1	623.030
Error	44	629.059
Net profit/cow exposed		
Dam Breed	4	12459.222****
Sire Breed	1	410.125
Error	44	385.199

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 41. Means and standard errors for measures of economic efficiency with reduced calf price and lower hay cost (N=50).

Source	Breakeven Price	Total Cost/Cow Exposed	Net Profit/Cow Exposed
Overall Mean	$\$1.80$	$\$434.68$	$-\$25.65$
AH	$\$1.72^{ab}$	$\$404.43^{b}$	$-\$\ 2.72^{ab}$
HH	$\$2.11^{c}$	$\$480.37^{a}$	$-\$85.14^{d}$
1S3H	$\$1.76^{b}$	$\$414.75^{b}$	$-\$18.95^{bc}$
SH	$\$1.64^{a}$	$\$410.35^{b}$	$\$\ 3.91^{a}$
3S1H	$\$1.76^{b}$	$\$463.51^{a}$	$-\$25.33^{c}$
SEM	0.025	7.93	6.21

^{abc} Means within columns with different superscripts differ ($P<.05$).

Table 42. Analyses of variance for economic measures with reduced calf price and higher hay price (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.300****
Sire Breed	1	0.001
Error	44	0.005
Total production costs/cow exposed		
Dam Breed	4	10781.416****
Sire Breed	1	476.486
Error	44	570.593
Net profit/cow exposed		
Dam Breed	4	10749.425****
Sire Breed	1	293.256
Error	44	341.216

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 43. Means and standard errors for measures of economic efficiency with reduced calf price and higher hay cost (N=50).

Source	Breakeven Price	Total Cost/Cow Exposed	Net Profit/Cow Exposed
Overall Mean	\$1.91	\$460.45	-\$ 51.41
AH	$\$1.82^{ab}$	$\$430.60^{b}$	$-\$28.89^{ab}$
HH	$\$2.20^{c}$	$\$501.82^{a}$	$-\$106.59^{d}$
1S3H	$\$1.88^{b}$	$\$440.83^{b}$	$-\$45.03^{bc}$
SH	$\$1.76^{a}$	$\$439.09^{b}$	$-\$24.83^{a}$
3S1H	$\$1.86^{b}$	$\$489.92^{a}$	$-\$51.73^{c}$
SEM	0.023	7.55	5.84

^{abcd} Means within columns with different superscripts differ ($P<.05$).

Table 44. Analyses of variance for economic measures with low feed prices and reduced calf price for modified simulations (N=50)[†].

Source	df	Mean Square
Steer equivalent		
Dam Breed	4	0.137****
Sire Breed	1	0.014*
Error	44	0.004
Total production costs/cow exposed		
Dam Breed	4	3209.300****
Sire Breed	1	232.463
Error	44	285.830
Net profit/cow exposed		
Dam Breed	4	5314.762****
Sire Breed	1	220.206
Error	44	234.788

* (P<.10)
**** (P<.0001)
[†] Five dam breedtypes x two sire breeds x five replications.

Table 45. Means comparisons and standard errors for measures of economic efficiency with low feed prices and reduced calf price for modified simulations.

Source	Steer Equivalent	Total Cost/Cow Exposed	Net Profit
Overall Mean (N=50)	\$1.48	\$377.63	\$ 37.02
AH	\$1.44^{b}	\$362.52^{b}	\$ 49.59^{a}
HH	\$1.68^{c}	\$399.60^{a}	\$ -3.29^{b}
1S3H	\$1.44^{b}	\$361.26^{b}	\$ 42.17^{a}
SH	\$1.38^{a}	\$370.98^{b}	\$ 53.87^{a}
3S1H	\$1.44^{b}	\$393.77^{a}	\$ 42.77^{a}
SEM	0.02	5.35	4.85

^{abc} Means within columns with different superscripts differ ($P<.05$).

Table 46. Analyses of variance for economic measures with high feed prices and base calf price for modified simulations (N=50)[†].

Source	df	Mean Square
Steer equivalent		
Dam Breed	4	0.174[****]
Sire Breed	1	0.020[*]
Error	44	0.005
Total production costs/cow exposed		
Dam Breed	4	2912.790[****]
Sire Breed	1	287.240
Error	44	261.384
Net profit/cow exposed		
Dam Breed	4	6693.563[****]
Sire Breed	1	310.503
Error	44	281.986

[*] (P<.10)

[****] (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 47. Means comparisons and standard errors for measures of economic efficiency with high feed prices and base calf price for modified simulations.

Source	Steer Equivalent	Total Cost/Cow Exposed	Net Profit
Overall Mean (N=50)	$1.68	$406.63	$ 83.76
AH	$\$1.64^{ab}$	$\$391.31^{a}$	$\$\ 98.38^{a}$
HH	$\$1.91^{c}$	$\$424.92^{b}$	$\$\ 38.66^{b}$
1S3H	$\$1.64^{ab}$	$\$390.39^{a}$	$\$\ 89.06^{a}$
SH	$\$1.57^{a}$	$\$402.22^{a}$	$\$102.86^{a}$
3S1H	$\$1.65^{b}$	$\$424.31^{b}$	$\$\ 89.83^{a}$
SEM	0.023	5.11	5.31

^{abc} Means within columns with different superscripts differ (P<.05).

Table 48. Analyses of variance for economic measures with high feed prices and reduced calf price for modified simulations (N=50)†.

Source	df	Mean Square
Steer equivalent		
Dam Breed	4	0.129^{****}
Sire Breed	1	0.016^{**}
Error	44	0.004
Total production costs/cow exposed		
Dam Breed	4	2912.790^{****}
Sire Breed	1	287.240
Error	44	261.384
Net profit/cow exposed		
Dam Breed	4	4401.885^{****}
Sire Breed	1	273.546
Error	44	213.584

** (P<.05)

**** (P<.0001)

† Five dam breedtypes x two sire breeds x five replications.

Table 49. Means comparisons and standard errors for measures of economic efficiency with high feed prices and reduced calf price for modified simulations.

Source	Steer Equivalent	Total Cost/Cow Exposed	Net Profit
Overall Mean (N=50)	$\$1.59$	$\$406.63$	$\$\ 8.02$
AH	$\$1.55^{b}$	$\$391.31^{a}$	$\$\ 20.80^{a}$
HH	$\$1.79^{c}$	$\$424.92^{b}$	$\$-28.60^{b}$
1S3H	$\$1.56^{b}$	$\$390.39^{a}$	$\$\ 13.04^{a}$
SH	$\$1.49^{a}$	$\$402.22^{a}$	$\$\ 22.63^{a}$
3S1H	$\$1.55^{b}$	$\$424.31^{b}$	$\$\ 12.21^{a}$
SEM	0.019	5.11	4.62

[abc] Means within columns with different superscripts differ ($P<.05$).

Table 50. Analyses of variance for economic measures for original parameters, base calf prices, and high hay prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.367****
Sire Breed	1	0.001
Error	44	0.007
Total costs		
Dam Breed	4	3972057607****
Sire Breed	1	67388155
Error	44	164221141
Net profit		
Dam Breed	4	2094501331****
Sire Breed	1	54827538
Error	44	62162815

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 51. Means and standard errors for measures of economic efficiency / base calf prices, high hay price, original parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	\$1.97	\$178982.74	\$12733.51
AH	\$1.87^{ab}	\$165277.00^{ab}	\$22912.00^{ab}
HH	\$2.30^{d}	\$210876.00^{d}	-\$11707.00^{d}
1S3H	\$1.93^{bc}	\$174825.00^{bc}	\$15951.00^{bc}
SH	\$1.80^{a}	\$160391.00^{a}	\$23980.00^{a}
3S1H	\$1.95^{c}	\$183545.00^{c}	\$12533.00^{c}
SEM	0.027	4052.42	2493.25

[abc] Means within columns with different superscripts differ (P<.05).

Table 52. Analyses of variance for economic measures for original parameters, reduced calf prices, and low hay prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.242****
Sire Breed	1	0.001
Error	44	0.005
Total costs		
Dam Breed	4	4059676564****
Sire Breed	1	87456396
Error	44	168404583
Net profit		
Dam Breed	4	1768562481****
Sire Breed	1	56853581
Error	44	55206075

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 53. Means and standard errors for measures of economic efficiency / reduced calf prices, low hay price, original parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	$\$1.81$	$\$178156.61$	$-\$11892.75$
AH	$\$1.73^{ab}$	$\$164480.00^{ab}$	$-\$\ 2832.00^{ab}$
HH	$\$2.07^{c}$	$\$210371.00^{d}$	$-\$34380.00^{d}$
1S3H	$\$1.78^{b}$	$\$173742.00^{bc}$	$-\$\ 9425.00^{bc}$
SH	$\$1.67^{a}$	$\$159266.00^{a}$	$-\$\ 1241.00^{a}$
3S1H	$\$1.78^{b}$	$\$182924.00^{c}$	$-\$11586.00^{c}$
SEM	0.01	4103.71	2349.60

^{abc} Means within columns with different superscripts differ (P<.05).

Table 54. Analyses of variance for economic measures for original parameters, reduced calf prices, and high hay prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.2357****
Sire Breed	1	0.0004
Error	44	0.0046
Total costs		
Dam Breed	4	3972057607****
Sire Breed	1	67388155
Error	44	164221141
Net profit		
Dam Breed	4	1715859507****
Sire Breed	1	40926981
Error	44	52968062

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 55. Means and standard errors for measures of economic efficiency / reduced calf prices, high hay price, original parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	\$1.82	\$178982.74	-\$12718.88
AH	\$1.74^{ab}	\$165277.00^{ab}	-\$ 3629.00^{a}
HH	\$2.08^{c}	\$210876.00^{d}	-\$34886.00^{c}
1S3H	\$1.79^{b}	\$174825.00^{bc}	-\$10507.00^{b}
SH	\$1.68^{a}	\$160391.00^{a}	-\$ 2366.00^{a}
3S1H	\$1.79^{b}	\$183545.00^{c}	-\$12207.00^{b}
SEM	0.006	4052.42	2301.48

^{abc} Means within columns with different superscripts differ ($P<.05$).

Table 56. Analyses of variance for economic measures for modified parameters, base calf prices, and high hay prices for ranch simulations (N=50)†.

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.138****
Sire Breed	1	0.018*
Error	44	0.005
Total costs		
Dam Breed	4	805262036****
Sire Breed	1	99104615
Error	44	45661062
Net profit		
Dam Breed	4	507560991****
Sire Breed	1	27009339
Error	44	27270389

**** (P<.0001)
* (P<.10)
† Five dam breedtypes x two sire breeds x five replications.

Table 57. Means and standard errors for measures of economic efficiency / base calf prices, high hay price, modified parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	\$1.63	\$136706.09	\$32898.56
AH	$\$1.59^{ab}$	$\$130884.00^{a}$	$\$37858.00^{a}$
HH	$\$1.83^{c}$	$\$152032.00^{b}$	$\$20647.00^{b}$
1S3H	$\$1.59^{ab}$	$\$135140.00^{a}$	$\$35618.00^{a}$
SH	$\$1.53^{a}$	$\$129624.00^{a}$	$\$37474.00^{a}$
3S1H	$\$1.61^{b}$	$\$135850.00^{a}$	$\$32895.00^{a}$
SEM	0.021	2136.84	1651.37

^{abc} Means within columns with different superscripts differ ($P<.05$).

Table 58. Analyses of variance for economic measures for modified parameters, reduced calf prices, low hay prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.105****
Sire Breed	1	0.013*
Error	44	0.003
Total costs		
Dam Breed	4	834024380****
Sire Breed	1	81735017
Error	44	46899557
Net profit		
Dam Breed	4	432106817****
Sire Breed	1	21399929
Error	44	23033356

* (P<.10)

**** (P<.0001)

[†] Five dam breedtypes x two sire breeds x five replications.

Table 59. Means and standard errors for measures of economic efficiency / reduced calf prices, low hay price, modified parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	$1.53	$136005.15	$ 7429.60
AH	$\$1.50^{b}$	$\$130316.00^{a}$	$\$11696.00^{a}$
HH	$\$1.71^{c}$	$\$151621.00^{b}$	$-\$\ 3984.00^{b}$
1S3H	$\$1.50^{b}$	$\$134163.00^{a}$	$\$\ 9526.00^{a}$
SH	$\$1.45^{a}$	$\$128698.00^{a}$	$\$11857.00^{a}$
3S1H	$\$1.51^{b}$	$\$135227.00^{a}$	$\$\ 8053.00^{a}$
SEM	0.018	2165.63	1517.67

^{abc} Means within columns with different superscripts differ ($P<.05$).

Table 60. Analyses of variance for economic measures for modified parameters, reduced calf prices, and high hay prices for ranch simulations (N=50)[†].

Source	df	Mean Square
Breakeven steer price		
Dam Breed	4	0.1006****
Sire Breed	1	0.0151**
Error	44	0.0032
Total costs		
Dam Breed	4	805262036****
Sire Breed	1	99104615
Error	44	45661062
Net profit		
Dam Breed	4	411325681****
Sire Breed	1	30695916
Error	44	22265840

**** (P<.0001)
** (P<.05)
[†] Five dam breedtypes x two sire breeds x five replications.

Table 61. Means and standard errors for measures of economic efficiency / reduced calf prices, high hay price, modified parameters, ranch simulation (N=50).

Source	Breakeven Price	Total Cost	Net Profit
Overall Mean	$1.54	$136706.09	$ 6728.67
AH	$1.51[b]	$130884.00[a]	$11128.00[a]
HH	$1.72[c]	$152032.00[b]	-$ 4394.00[b]
1S3H	$1.51[b]	$135140.00[a]	$ 8549.00[a]
SH	$1.46[a]	$129624.00[a]	$10931.00[a]
3S1H	$1.51[b]	$135850.00[a]	$ 7430.00[a]
SEM	0.018	2136.84	1492.17

[abc] Means within columns with different superscripts differ (P<.05).