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DISSERTATION

**IMPACTS OF SEXED SEMEN UTILIZATION ON COMMERCIAL BEEF
PRODUCTION**

Submitted by

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Department of Animal Sciences

In partial fulfillment of the requirements

for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2000

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COLORADO STATE UNIVERSITY

August 25, 2000

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY STEPHEN PATRICK DOYLE ENTITLED IMPACTS OF SEXED SEMEN UTILIZATION ON COMMERCIAL BEEF PRODUCTION BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION
IMPACTS OF SEXED SEMEN UTILIZATION ON COMMERCIAL BEEF
PRODUCTION

The objectives of this study were to: 1) determine if use of sexed semen adversely affects fertility and embryo viability, and if current sexing technology indeed alters the sex ratio in beef cattle; 2) evaluate the impacts of sexed semen utilization on the biological efficiency of commercial beef production when calves are sold at weaning versus retained through stocker and feedlot phases of production; and 3) determine the economic value of a sexed semen inseminate in commercial beef production when calves are sold at weaning.

The first phase of the project involved field trials performed to evaluate the effects of sexed semen use on fertility and embryo viability as well as the efficacy of sexing in skewing the sex ratio. During the 1997 through 1999 breeding seasons, 118, 82, and 123 heifers were bred to control semen, sorted 5° C or 18° C semen, and frozen, sorted semen, respectively. In 1998 and 1999, 121 cows were bred to control semen, 56 cows were bred to sexed 18° C semen, and 140 cows were bred to frozen, sorted semen. Semen from ten Angus bulls of unknown fertility was collected by artificial vagina, processed, stained with the DNA-binding dye Hoechst 33342, and sorted with a 150 mW UV argon laser on a MoFlo® flow cytometer/cell sorter modified for sperm sorting operating at 50 psi using 2.9% Na citrate as sheath fluid in the first two years and a tris

buffer in the third. Control semen ranged from 20 to 40 x10⁶ sperm/dose, sorted 5° C or 18° C semen ranged from 3 to 5x10⁵ sperm/dose, and frozen, sorted treatments ranged from 1 to 3 x 10⁶ sperm/dose. Pregnancy rates for sexed semen in yearling heifers were 40 to 80% of those associated with conventional frozen semen controls in the first two years and as good or better numerically in 1999 as frozen, unsorted semen, but with only 1% to 15% as many sperm per dose. Cow pregnancy rates for sexed semen were less than half to 77% of those for frozen, unsorted semen in cows, but with only 5% to 15% as many sperm per dose. Fertility of sorted sperm was higher for certain bulls: practical application of current technology may require identification of bulls whose sperm tolerate the stress of sorting and cryopreservation, particularly when low numbers of sperm are inseminated. We significantly altered the sex ratio toward 90% the desired sex of calf in primiparous and multiparous beef females. There was little embryonic death loss between 30 days and 60 days of gestation or abortion between 60 days of gestation and calving in the sexed treatments: no more losses were observed than in the controls. Calves resulting from sexed semen appear morphologically normal.

In the second phase of the project, the Colorado Beef Cattle Production Model (a deterministic and stochastic simulation model) was used to examine the effects of sexed semen technology on the biological efficiency of commercial beef production when calves were sold at weaning versus when retained through harvest. Sex ratios examined included 50% with natural service, 50% with artificial insemination involving conventional, unsexed inseminate, and 60, 70, 80 and 90% with sexed semen. Production scenarios included straightbred, straightbred X terminal and rotation-terminal mating systems using either artificial insemination followed by natural service (AI+) or artificial

insemination alone (AI-). The direction in which the sex ratio was skewed was determined by the type of mating. If maternal, the sex ratio was skewed toward female calves, and if terminal, toward male calves. Five products were simulated and included live weight at weaning (LWW), live weight at harvest (LW), carcass weight (CW), empty body weight at harvest (EBW) and fat free weight at harvest (FFW). Compared to natural breeding scenarios, the number of cows required to produce female replacements decreased as much as 33% as the sex ratio increased from 50 to 90%. Biological efficiency (kcal metabolizable energy per kg of beef product) for LWW increased 2.5 to 4.6% when artificial insemination was used followed by exposure to natural service cleanup. When using artificial insemination as the sole method of breeding, efficiency increased as much as 6.8%. The largest increases were observed in the straightbred mating system and at sex control of 80%. For LW, biological efficiency increased 3.3 to 4.5% and 6.7 to 7.5% when using AI+ and AI-, respectively. The largest increases were observed in the straightbred mating system at 70% sex control (AI+) and rotation-terminal mating system at 90% sex control (AI-). Similar increases in efficiency were observed for CW, EBW and FFW. Sexed semen technology added value to artificial insemination. Results suggest that sex control is beneficial at varying levels of efficacy and that sexing does not have to be perfect in order to take advantage of increases in biological efficiency.

Simulated production from the Colorado Beef Cattle Production Model and budget data representing cow-calf production in Colorado were used to evaluate the economic value of sexed semen on commercial beef production at weaning. Five sex ratios (50, 60, 70, 80 and 90%), three mating systems (straightbred, straightbred by

terminal, and rotation-terminal), and three methods of breeding (natural service, one period of artificial insemination followed by exposure to natural service, and artificial insemination only) were evaluated. Weaning rates included 80, 85 and 90%. The base scenario within each mating system included natural service breeding, an 85% weaning rate, and 15% replacement rate. Within each mating system, heifers and young cows were bred to produce female herd replacements while the remaining older cows were bred to produce male market offspring. As the ability to determine the sex of offspring increased from 50 to 90%, the number of cows needed to produce the required number of female herd replacements decreased 34.3 to 44.4%, allowing a larger number of cows to be transferred to the terminal breeding group to produce male market offspring. Compared to the natural breeding scenarios within each mating system, average weaning weight per cow increased, resulting in increases of gross revenue from calf sales as much as 11.8, 9.1 and 9.8% for the straightbred, straightbred by terminal and rotation-terminal mating systems, respectively. Given average market prices, an inseminate of sexed sperm targeting 90% sex ratio in favor of the preferred sex of offspring was worth \$9.24 to \$10.57 in a straightbred mating system using AI- and AI+, respectively. These values range from \$1.01 to \$3.93 and \$3.30 to \$5.72 for the straightbred by terminal and rotation-terminal mating systems using AI+ and AI-, respectively. Besides cost and efficacy of the sexing technology, this value is dependent upon several factors, such as weaning rate (i.e. pregnancy rates and calf survival), mating system, artificial insemination program, and market conditions. Based on the assumptions of this study, the cost of sexed semen needs to be relatively close to that of unsexed semen when used in a straightbred production system; however, sexed semen appears to be economically infeasible in those systems

applying crossbreeding. Furthermore, artificial insemination with conventional, unsorted semen did not appear economically feasible under the simulated conditions of this study; however, sexing added value to artificial insemination.

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DEDICATION

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CHAPTER 1

INTRODUCTION

Intervention to alter the male:female sex ratio at birth is an age-old concept (Windsor et al., 1993). Controlling the sex ratio in beef and dairy production could have considerable economic value. Sexed semen would allow cattlemen to produce the optimum proportion of males and females to take advantage of phenotypic and genetic differences in sex-influenced, sex-limited, and sex-linked traits, and would provide an opportunity to increase selection pressure and optimize genetic gain (Foote and Miller, 1971).

In the dairy industry, commercial producers would be able to produce replacement females out of cows high in merit for dairy production traits while breeding the remaining cows to beef bulls to increase the value of slaughter calves. Commercial beef producers would be able to make use of superior growth and carcass genetics through breeding cows to produce male slaughter progeny. If one's goal is producing replacements, the herd's high merit cows for maternal ability would be bred to produce replacement heifers while the remainder of the herd would be bred for male slaughter progeny as above. Seedstock dairy and beef producers would be able to produce and prove potential sires with fewer cows and half the time, reducing the overhead costs associated with progeny testing. An obvious application for both industries would be to breed virgin heifers to produce female

calves, resulting in lower calving difficulty because heifer calves typically are lighter at birth than male calves.

Refinements in artificial insemination procedures and new developments in flow cytometry and processing of sorted sperm appear to be paving the way for future application of sexed semen technology in both the beef and dairy industries: sexed semen will need to be similar to conventional artificial insemination in fertility and ease of use. Adoption, however, will depend upon the cost-benefit relationships unique to each production system.

The objectives of this study were to: 1) determine if use of sexed semen adversely affects fertility and embryo viability, and if current sexing technology indeed alters the sex ratio in beef cattle; 2) evaluate the impacts of sexed semen utilization on the biological efficiency of commercial beef production when calves are sold at weaning versus retained through stocker and feedlot phases of production; and 3) determine the economic value of a sexed semen inseminate in commercial beef production when calves are sold at weaning.

CHAPTER 2

LITERATURE REVIEW

Introduction

Intervention to alter the male:female sex ratio at birth is an age-old concept (Windsor et al., 1993). Controlling the sex ratio in beef and dairy production could have considerable economic value. Sexed semen would allow cattlemen to produce the optimum proportion of males and females to take advantage of phenotypic and genetic differences in sex-influenced, sex-limited, and sex-linked traits, and would provide an opportunity to increase selection pressure and optimize genetic gain (Foote and Miller, 1971). Refinements in artificial insemination procedures and new developments in flow cytometry and semen processing appear to be paving the way for future application of sexed semen technology in both the beef and dairy cattle industries.

Sexed Semen Technology

Many different technologies have laid claim to being able to sort spermatozoa on the basis of producing a desired sex of progeny (Kiddy and Hafs, 1971; Amann and Seidel, 1982; Amann, 1989). Proposed phenotypic differences between X- and Y-bearing sperm have included morphological differences, pH sensitivity, plasma membrane surface charge, sperm surface antigens, sperm swimming characteristics, and differences in cell density. Most of these technologies have been unable to produce repeatable results. Approximately eight patents on sexed semen exist in the United States, and of those, only

flow cytometry/cell sorting to measure differences in DNA content of sperm has been demonstrated to separate X- and Y-bearing sperm (Seidel, 1997).

Flow Cytometry/Cell Sorting

Currently, the most promising commercially viable sexed semen technology involves resolving differences in DNA content for X- and Y-bearing sperm using flow cytometer/cell sorter technology (Johnson et al., 1989; Seidel et al. 1999). This technology is based on the premise that one clear difference in gametes is the presence of either the X or Y chromosome. Bovine Y-chromosome bearing sperm contain approximately 4% less DNA than X-chromosome bearing sperm (Johnson et al., 1995).

Johnson et al. (1995) reviewed the process of sperm sorting via flow cytometry. A DNA-binding dye (Hoechst 33342) is placed into a solution containing sperm. Because X-chromosome bearing bovine sperm contain approximately 4% more DNA than Y-chromosome bearing sperm, they absorb more stain. After staining, the sperm pass through a flow cytometer/cell sorter equipped with a laser of a specific wavelength to excite the DNA-binding dye. Two optical detectors at 90° and 0° to the laser beam read the sperm's orientation and resulting fluorescence, respectively. Based on the sort window and amount of fluorescence detected, a computer categorizes the sperm into one of three categories: 1) probable X-chromosome bearing sperm; 2) probable Y-chromosome bearing sperm; or 3) indeterminable. The sort window is electronically set: the tighter the sort window, the slower the sort speed, but higher the purity. An excess of positive or negative charge is assigned to each droplet based on the above categories. Passing through an electrostatic field, each droplet is then directed into its respective sperm collection tube. Under normal sorting conditions, 100% purity of a sperm

population is infeasible; however, purity in the range of 90 to 95% has been achieved (Johnson, 1992; Seidel et al., 1997; Johnson et al., 1998)

Factors Limiting Adoption of Sexed Semen Technology

Currently, there are several factors limiting the application of sexed semen in the beef and dairy industries. Primary limitations include the degree by which the sex ratio is altered or accuracy of sorting, fertility, cost of the technology, and tradition in conjunction with ethical and moral considerations (Foote and Miller, 1971). Many of these limitations have been and/or are currently being addressed by research facilities such as Colorado State University's Animal Reproduction and Biotechnology Laboratory, Fort Collins, in conjunction with XY, Inc., Fort Collins, and USDA-ARS, Beltsville, Maryland.

One of the limitations of flow cytometry directly related to accuracy of sorting is the speed at which sperm sorting occurs. There is a delicate balance between the number of sperm sorted and the accuracy of sorting. In 1997, Seidel reported sorting speeds of up to 600 sperm per second of each sex with 90% purity. Conventional artificial insemination procedures often use 20×10^6 sperm per dose; however, such numbers would require large amounts of time to achieve with current sperm sexing procedures, making the procedure commercially impractical unless improvements are made in sort speed and/or insemination procedures (Seidel, 1997).

Johnson et al. (1998) have improved the production of X- and Y-bearing sperm per unit time through the use of high speed sorting and a newly developed orienting nozzle. Orientation of sperm head to the laser beam is a key factor in determining sorting speed. The broad surface of the sperm head should be perpendicular to the laser beam in

order to get an accurate measure of fluorescence, hence, the DNA content of each sperm. The new orienting nozzle allows for increased orientation efficiency and subsequently the number of sperm sorted per second. Johnson et al. (1997) reported increased numbers of correctly oriented sperm for sorting from 25 - 35% to 65 - 75% using the new orienting nozzle. Johnson et al. (1999) reported increased sorting speeds from .35 million/hour to 5 or 6 million sperm per hour for each population using a Cytomation MoFlo high speed cell sorter modified for sperm and adapted with the new orienting nozzle. This is a ten fold increase in sort rate over their previous studies. Reanalysis of sorted sperm DNA content for sort purity showed a 91.4% predicted skewed ratio in favor of female offspring. Scientists demonstrated that use of high speed sorting in combination with a newly developed orienting nozzle for separating X- and Y-chromosome bearing sperm can be used to produce adequate sperm numbers for use with conventional artificial insemination practices if the dose of sperm is lowered.

The use of low dose semen in artificial insemination of cattle is a potential means of overcoming the slower sort speeds associated with current sexing technology. Seidel et al. (1997) evaluated lowering the sperm concentration of insemination doses in 282 Holstein heifers. Unfrozen semen from three Holstein bulls was extended to concentrations of 1×10^5 or 2.5×10^5 sperm per .1 ml inseminate and 2.5×10^6 sperm per .21 ml inseminate as a control. The heifers were bred in the uterine horn ipsilateral to the ovary with the largest follicle as determined by ultrasound 12 hours post-estrus detection. Pregnancy examination via ultrasound occurred 42 to 45 days after estrus. Resulting pregnancy rates were 41, 50, and 61% for 1×10^5 , 2.5×10^5 , and 2.5×10^6 numbers of sperm, respectively. There were no significant differences in pregnancy rates

($P > .05$) among the heifers for the three AI technicians or the three bulls. A reduction in numbers of sperm per inseminate, achievement of acceptable pregnancy with such inseminate, and increased sorting speeds would increase the feasibility of commercially available sexed semen.

Two other limitations of great importance are cost and convenience of the technology. The current cost keeps sexed semen well beyond the reach of most cattlemen. Dr. Seidel of Colorado State University Animal Reproduction and Biotechnology Laboratory predicted an added cost of sexed semen to be approximately \$100 per sexed semen dose (Jordan, 1999); however, seven months later the initial premium was predicted to be \$50 per sexed semen dose (Johnson, 1999). There exists a target cost of sexed semen of \$10-\$20 above current semen prices (Seidel, 1997). Such a target is feasible given expected reductions in overhead costs as sexing procedures become more efficient.

In its beginnings, sexed semen was available in only a cooled state rather than frozen; however, there appeared to be no major barriers to cryopreservation beyond finding the right recipe at the time (Seidel, 1997). The insemination procedure in 1997 included depositing half of the cooled, sexed inseminate into each uterine horn; this required a skilled technician. Both the cooled packaging and horn breeding presented convenience issues due to added handling and technician skill; however, advances in the sexed semen technology and post-sort handling in more recent years have made sexed semen packaging and insemination procedure similar to current conventional artificial insemination practices.

None of the advances matter unless the producer gets a live, normal calf on the ground. The breeding of large numbers of females under field conditions is needed to document that calves are morphologically normal and that embryonic death is not higher than normal (Seidel, 1997).

Although barriers exist, such as sorting speed, cost of the technology, and convenience, potential solutions exist and are currently being researched.

Altering the Sex Ratio via Flow Cytometry

As reviewed by Johnson et al. (1999), skewing the sex ratio in favor of the preferred sex has been demonstrated in rabbits (Johnson et al., 1989), swine (Johnson, 1991; Rath et al., 1997); sheep (Johnson, 1995; Catt et al., 1996; Cran et al., 1997); and humans (Johnson et al., 1993; Fugger et al., 1998). Alteration of the sex ratio in cattle from 50:50 has been demonstrated using flow cytometer/cell sorting technology in combination with IVF and embryo transfer, surgical insemination, and deep-uterine insemination. In 1993, Cran et al. carried out twin embryo transfers on nine heifers of which four became pregnant and carried pregnancies to term. Resulting offspring were three males and three females, all of the predicted sex. Cran et al. (1995) followed up earlier work with a field trial using only Y-chromosome bearing sperm and in vitro fertilization to produce embryos for transfer into recipient cows. Resulting offspring (41 calves) were 90 percent male. Early results involving in vitro fertilization and embryo transfer demonstrate the effectiveness of flow cytometer/cell sorting technology to skew the sex ratio from 50% male:50% female.

Seidel et al. (1997) combined low dose technology with artificial insemination of cattle with sorted sperm. Collected sperm was transported from Lancaster,

Pennsylvania to Beltsville, Maryland and sorted into X- and Y-bearing sperm populations using a flow cytometry/cell sorter operating at approximately 100 sperm/second of each sex at 90% purity. Once samples were sorted and stored at either ambient temperature or 5° C, samples were flown approximately 2600 km. Heifers were inseminated with either 1 to 2 X 10⁵ sorted X- or Y-bearing sperm in .1 ml within 9 to 29 hours post-sperm sorting. Heifers detected in estrus were inseminated deep into the uterine horn ipsilateral to the ovary with the largest follicle as determined by ultrasonography at the time of insemination or were inseminated with half of the inseminate deposited into each uterine horn. The ten females inseminated with semen stored at ambient temperatures failed to become pregnant. Of 155 heifers inseminated with sexed sperm cooled to 5° C, 22% (15/67) inseminated 9 to 13 hours post-sorting calved; however, only 3% (2/78) inseminated 17 to 29 hours post-sorting calved. Fourteen of the 17 calves (82%) were of the desired sex. Results suggest temperature at which the sorted dose is stored as well as time between sort and insemination appear to be significant sources of variation with cooled sperm, and a short lag between sort and insemination was more desirable.

With advancements in flow cytometer/cell sorter technology and improvements in sorted sperm handling practices, commercially viable sexed semen appears feasible in the near future.

Application of Sexed Semen

Controlling the sex ratio in the cattle industries both at the seedstock and commercial production levels has considerable biological and economic potential. Skewing the sex ratio would allow cattlemen to produce the optimum proportion of males and females to take advantage of phenotypic and genetic differences in sex-influenced.

sex-limited, and sex-linked traits and would provide an opportunity to increase selection pressure and optimize genetic gain (Foote and Miller, 1971). Altering the sex ratio can increase the efficiency of dairy and beef production through increasing the proportion of male animals raised for beef production, increasing the selection intensity within the female population through increased selection pressure on dams, and decreasing the number of cows required to produce replacement heifers, allowing more cows to be bred to specialized beef bulls (Cunningham, 1975; Doyle, 1998; Hohenboken, 1999).

Beef Cattle

Seedstock producers sell improved, superior genetics, either in the form of sires and(or) yearling replacements. Sexed semen would allow producers the opportunity to mate proven sires to top producing cows to produce male offspring as potential seedstock bulls for progeny testing. The producer would rank cows on the basis of merit for maternal ability and then breed the highest ranking cows to Y-chromosome bearing sperm of proven sires meeting production specifications. Sexed semen allows the number of cows needed to produce a specified number of bull calves to be progeny tested to be cut almost in half. Under natural sex ratios, twice as many cows must be mated as the number of progeny of the desired sex. The remaining cows and all yearling heifers would then be bred with X-chromosome bearing sperm of proven maternal sires to produce female herd replacements for his own herd as well as for his customers.

In commercial beef production, sexed semen will potentially allow producers to produce meat animals more efficiently. Research in animal breeding and genetics has revealed a number of genetic antagonisms between traits of economic importance (Koots et al., 1994). Traits such as early growth and desired carcass composition appear to be

genetically antagonistic with traits such as fertility and mothering ability (MacNeil et al., 1984; Splan et al., 1998). In order to handle such antagonisms, common practice has been to develop terminal lines and maternal lines of cattle. Commercial beef producers would be able to better utilize growth and carcass genetics in the production of male market offspring while capitalizing on maternal genetics and ability provided by the cow through the use of designated maternal lines. Such an application would eliminate the production of feeder females that often lead to inefficiencies in the feeding sector compared to their terminal male counterparts. Conversely, producers would have the opportunity to eliminate the production of excess males with maternal genetics that preclude them as inefficient producers of meat for the consumer market. Commercial cattlemen producing their own replacements would be able to breed their top cows based on maternal ability and yearling replacements to X-bearing sperm of proven maternal sires. The remainder of the herd would be bred with Y-bearing sperm of proven sires for growth and carcass genetics to produce feeder calves.

Specifically, sexed semen in combination with crossbreeding programs using terminal and maternal bred lines of cattle would allow producers to use breed complementarity for growth and carcass while at the same time take advantage of heterotic effects for traits related to female reproduction and mothering ability. In the case of the rota-terminal crossing system, a rotational system is maintained to provide replacement females with maternal ability while the terminal component is maintained to produce market offspring with the desired growth and carcass composition meeting market specifications. Traditionally, 40 to 50% of the cow herd (typically cows 2, 3, and 4 years of age) are dedicated to producing replacements. This is twice as many cows as

needed replacements. The remainder of the herd, including most cows 5 years of age and older, is bred to a terminal sire(s) (Gregory and Cundiff, 1980; BIF, 1996). Production inefficiencies occur in both the rotation as well as the terminal component. Under natural sex ratios, twice as many females are required to be bred as number of replacements needed; thus, 50% of the calf crop represents males with maternal genetic value that are not optimum for meat production in the feeding sector. Conversely, 50% of the calf crop on the terminal end represent females that are not as profitable in the production of beef compared to their male counterparts. Additionally, male market offspring typically bring more value than female offspring in most years (Cattle Fax, 1999). Using sexed semen in combination with a rota-terminal crossing system offers the opportunity for producers to use maternal lines to produce replacements with half as many cows as under natural sex ratios. On the terminal side, producers would be able to transfer more females to the terminal component; thus, increasing the number of male market offspring produced each year for the meat market.

Researchers at Washington State University used a deterministic model to examine effects of altering sex ratios on a straightbred mating system, a 2-breed rotational system crossed with a terminal sire, and a three-breed terminal system (Haaland-Holmes et al., 1982). Each system maintained a maternal line of cows where female calves were preferred for replacements with the remainder of the herd bred to produce male offspring for market. Sex ratios examined included 60:40, 70:30, 80:20, and 90:10. Production efficiency for all three breeding systems increased as the number of the preferred sex increased from 50% to 90%. The number of cows required to produce replacement females decreased by 44 to 46% as the proportion of the preferred sex of calf increased

from 50% to 90%. Along those same lines, the number of cows bred to produce male offspring increased; thus, the number of male offspring marketed increased, leading to an increase in average weaning weight sold and total revenue in all mating systems. As the number and proportion of male offspring increased, the 3-breed terminal system had the largest increase in weaning weight per cow bred (5.4%) followed by the rota-terminal system (2.7%) and the straightbred system (2.4%). The 3-breed terminal system also had the largest increase in revenue from calves sold (9.3%) followed by the rota-terminal system (7.1%) and straightbred system (6.3%); the systems ranked similarly in highest gross margin. It appears that sexing semen offers potential economic gains in mating systems where maternal and terminal lines are used.

Using the Colorado Beef Cattle Production Model (CBCPM) to simulate a rota-terminal crossing system using Angus-Hereford crossbred dams and Charolais terminal sires at five levels of sex control (50%, 60%, 75%, 87.5%, and 100%), researchers at Colorado State University examined the effects of sex control on herd structure in a rota-terminal crossing system (Hyde and Bourdon, 1998). As the level of sex control increased in favor of the preferred sex of offspring, a greater number of producing females were transferred to the terminal part of the system. The number of terminally bred cows increased 51% overall compared to a 39.5% decrease in maternally bred cows overall. At levels of sex control including and beyond 75%, females were transferred to the terminal part of the mating system one year earlier allowing them to produce one more market calf during their lifetime. This suggests that the sexing technology not be absolutely 100% in order for it to be biologically and economically feasible.

Using partial budgeting, scientists examined the economic effects of various success rates of sexed semen on a 100 head beef cow herd (Wise and Bobst, 1993). Three economic conditions were simulated and included a "base" which represented median calf prices and weaning weights, a "best" situation, and a "pessimistic" situation. The "best" situation reflected increases in calf price along with decreases in costs of production, increases in conception rates associated with sexed semen, and increases in weaning weight due to the use of superior bulls. Conversely, the "pessimistic" situation represented decreases in calf price and increases in costs of production, decreases in semen success rates, and lowered calf weaning weights. Success rates in changing the sex ratio in favor of the preferred sex included 70%, 80%, 90%, 95%, and 98%. As would be expected, the number of steers sold increased as the success rate of sexed semen increased, leading to increases in the weighted average of marketable calf weights. Because of the increase in variable costs due to sexed semen, only the "best" situation reflected increases in net income due to the use of sexed semen; however, the "best" situation reflects not only increases in selling price but also increases in weaning weights due to the use of superior bulls. For example, with a 90% success rate, the increase in average marketable weaning weight for the "best" situation increased approximately 8.3% compared to the "base". Net income for the "best" situation at a 90% success rate was \$111 per cow compared to \$12.48 per cow for "base" conditions. A second analysis was undertaken to examine the value of sexed semen. In the first analysis of the study, scientists assumed a cost of sexed semen of \$30; however, here the value of sexed semen was determined by its contribution to net income over the "base" situation. All costs, except semen, were subtracted from the gross margin with the residual value being

representative of sexed semen value. Only “best” conditions were assumed because previous analyses showed sexed semen did not add to net income for other situations above base conditions. The value of sexed semen increased as the success rate of sexed semen increased with a low of \$31 per cow at 70% and a high of \$44 per cow at a 98% success rate. Researchers concluded that the use of sexed semen would not be economically feasible unless its use increased selling weights and prices received were higher than “base” conditions.

One concern for many has been the effects that sexed semen will have on beef supply and price. Best (1995) used a non-linear dynamic modeling approach to analyze the effects that biotechnologies such as sexed semen have on the U.S. beef industry. A primary consideration here was the adoption rate of such a technology. Adoption rates of 12.5, 25, and 50% were evaluated to show price effects as the ratio of steers to heifers placed on feed increased. Theoretically, increases in the number of steers would decrease steer prices while the decreases in heifer numbers would increase heifer prices. However, in practice, a feedlot buyer is not going to buy a feeder heifer at a higher price when steers are available at lower prices, especially when considering the advantage steers possess in terms of gain efficiency. One thing to remember is that although steer numbers increase and heifer numbers decrease, the total supply or number of animals placed on feed remains unchanged. With an adoption rate of 12.5% by U.S. cattle producers, there would be little effect on the real fed cattle and real fed beef prices. The effect of 25% of producers adopting sexed semen was larger than the previous rate; however, it was only by a factor of two. It was not until the adoption rate reached 50% that any real effect on fed cattle and fed beef prices was seen. Here, a decrease of \$.80 to \$.90 per cwt for real

fed cattle (more than double the previous adoption rate) was seen while real fed beef prices dropped \$2.90. It appears that as the adoption rate increases so does the price movement. Best goes on to point out that the minimal impact found here might have been greater in the past due to a larger differential between steer and heifer slaughter weights; however, that differential is much less now with the effect being not as much of a change in total fed beef.

More recently, Steel (1998) evaluated the impacts associated with the adoption of sexed semen on a small, medium and large commercial cow-calf operation using the Farm Level Income and Policy Simulator (FLIPSIM). An 80:20 male to female sex ratio was simulated for those operations implementing sexed semen. Success rates associated with artificial insemination with sexed semen were assumed similar to those achieved with the use of conventional artificial insemination. Only cash costs were used in the determination of breakeven values for each operation. Scientists found that the cost of sexed semen would need to be similar to current costs associated with conventional artificial insemination. With no increase in production costs, the implementation of sexed semen decreased profitability. Production scenarios implementing sexed semen in conjunction with the realization of added sale weight at weaning due to genetic improvement were more profitable and had lower breakeven prices than those systems implementing sexed semen but not incurring the added benefit of increased sale weight due to genetic improvement in weaning weight.

Another potential application of sexed semen in the beef cattle industry is in single-sex systems. These systems may include one where all cows are bred to Y-chromosome bearing sperm with replacements being bought outside the herd or a system

where a heifer is bred to X-chromosome bearing sperm, calves producing her own replacement, and then is slaughtered. The latter works on the premise that the more offspring a dam has, the less efficient the system becomes because cull cow meat is produced less efficiently the later the cow is slaughtered (Taylor, 1977; Taylor, 1982). More expense is allocated to growth rather than maintenance when the cow is slaughtered after first calving.

Taylor et al. (1985) investigated four systems of beef production; two were based on current technology, and two, on the assumption that the sex ratio could be controlled. The systems were a traditional system, a single-sex bred heifer system, a system in which all slaughter progeny were male, and a traditional system with bred heifers. Researchers were interested in the overall efficiency of feed utilization of the four beef production systems where the production unit was defined as a dam and her slaughter progeny. Overall efficiency was measured as the ratio of lean tissue output to feed input. Scientists concluded that in a purebred beef production system and in all but the most efficient crossbreeding systems, overall efficiency declines as the number of calvings per dam increases. Thus, the quicker a replacement female can be slaughtered, the more efficient the beef production system. In all but the single-sex bred heifer system, efficiency of feed utilization increases as the maintenance requirements of the dam decreases. In the single-sex bred heifer system, the inefficiencies associated with maintenance were virtually eliminated. The single-sex bred heifer system deserves consideration due to the high levels of overall efficiency attainable given high technological efficiency and the ability to produce animals that breed early and meet desired carcass specifications. The all male slaughter progeny system is desirable if larger crossbred progeny counteract the decline in

efficiency as the number of calvings per dam increases. The feasibility of sex-controlled systems depends highly on technological advances. If technological efficiency is not high, the single-sex bred heifer and the all male slaughter progeny systems should be avoided.

Using a modified version of the Texas A&M Beef Cattle Production Model, Bourdon and Brinks (1987) simulated the life-cycle biological and economic efficiencies of various culling strategies and non-traditional management systems involving sex control. Two sex-controlled systems were evaluated and included a system where strictly heifer calves were produced with cows being culled as young as possible (SS) and the same system with the addition of 2-year-old cows being fed in a feedlot (SS+). The sex-controlled system SS was more biologically efficient in the production of live weight at weaning and fat-free weight at slaughter compared to a conventional beef production system. This suggests that efficiency can be increased if animals are growing and at the same time reproducing. Biological efficiency for empty body weight at slaughter declined because of the large decrease in raw empty body weight produced. The sex-controlled system SS was not economically efficient in most cases compared to a conventional system. This was in part due to the fewer animals being finished in the feedlot, producing less value-adjusted total product to offset fixed costs. However, SS was economically efficient when concentrate costs were double and cull cows were relatively more valuable than fed animals. Comparatively, the sex-controlled system SS+ was less biologically efficient for fat-free weight at slaughter because the weight gains of cows on feed were primarily fat; however, SS+ was more biologically efficient for empty body weight at slaughter due to increased raw empty body weight produced. The sex-

controlled system SS+ was more economically efficient than SS but not considerably more than a conventional beef production system. The authors went on to suggest that sex-controlled systems may be more appropriate where emphasis is on lean product and concentrate feeding is less prevalent.

Herd et al. (1993) modeled 26 production systems for a representative farm in southern Australia. Among those were "all male" and "all female" systems. Sex control by means of sexed embryo implantation was the method considered for all sex-controlled systems. The "all male" system was implemented to take advantage of lean growth and premiums paid for male calves. Heifers from outside the system were purchased to replace culled breeding cows. Conversely, the "all female" system represents a single-sex bred heifer system where only heifer calves are produced. Similar to Taylor et al. (1985), the yearling heifer is bred, calves, and is then sold soon after she weans her calf. The "all male" system was less efficient in the production of lean because of increased costs associated with the purchase of heifer replacements and lower calving rate associated with sexing. The "all female" system was the third most efficient system of those evaluated in terms of lean meat production. However, the high cost of producing sexed calves made sex-controlled systems unprofitable. The gross margins for the sex-controlled systems were competitive with traditional systems only when costs and calving rates were similar to "normal" for traditional practices. For example, the sexing technology would have to be available at a cost similar to other reproductive practices currently implemented, and associated calving rates would have to approach normal ranges of traditional production systems.

Sexed semen would also allow the producers, both seedstock and commercial, to breed maternal cows (typically younger females, especially yearling heifers) with X-chromosome bearing sperm. This would promote less calving difficulty, shorter gestation lengths, and longer post-partum intervals prior to the beginning of the subsequent breeding season (Pace, 1994; Seidel et al., 1997). Female offspring tend to weigh about 2.3 kg less than male offspring at birth.

Dairy Cattle

As with beef seedstock producers, dairy seedstock producers are in the business of selling improved, superior genetics. Sexed semen would allow seedstock producers to increase selection pressure on the dams chosen to produce male progeny for proving young sires. This would lead to reduced costs associated with progeny testing due to the fewer number of matings needed to produce bull calves to test as well as reduced numbers of matings required to produce the necessary progeny data for proving young sires in making final bull selections for use in seedstock and commercial herds. Producers would rank cows based on their merit for dairy production traits and then choose the highest ranking cows to produce bulls for progeny testing. The remaining cows in the herd could be bred to X-chromosome bearing sperm in order to produce replacements.

Commercial dairymen produce milk, female calves, and male calves. Female calves are destined to become replacements for the herd while male calves are destined for the feeding sector to be fed for slaughter. Unfortunately, compared to beef calves, dairy calves carry little market value as feeder cattle and are often considered an undesirable by-product of dairy production. Sexed semen would allow production of

replacement females from genetically superior cows and proven sires. A sufficient number of high ranking cows for milk production and maternal ability would be inseminated with X-chromosome bearing sperm from superior, proven dairy sires to produce the needed herd replacements. Selecting only the best cows to produce replacements increases the selection pressure for dairy production traits in the herd. The remainder of the cows in the herd would then be bred to unsorted or sorted semen from beef bulls. Dairy and beef crossbred calves tend to be worth more in value than straightbred dairy calves. Dairy crosses by beef breeds can have a net income superior to dairy strains up to 12% (Andersson and Lindhe, 1973).

Cunningham (1975) evaluated the use of sexed semen on the efficiency of cattle breeding operations, in particular dual-purpose populations. First, a higher proportion of male calves for beef production can increase beef output of a dual-purpose population by up to 5% depending upon cow turnover rate and the superiority of male over female calves. The proportion of males a population can sustain is a function of the net reproductive rate and the average number of lactations per cow, and can be expressed as follows:

$$R_m = 1 - (1/S * L) \text{ where}$$

R_m is the proportion of male calves born; S is the net reproductive rate; and L is the average number of lactations per cow. The maximum proportions a population can sustain range from 61% with three lactations per cow to 80% with six lactations. Assuming a net economic value of 10% to 20% of males over females for beef production, the percent increase in beef output ranged from 1.69% for steer beef (10% value) with a fast turnover rate to 5.00% for intact males (20% value) and a slow cow

turnover rate. Second, sex control allows opportunity to increase selection intensity, especially dams of bulls and dams of daughters. Assuming absolute sex control, the total effect on improvement could be in the range of 10% in the rate of genetic change in the population. Third, sex control increases the opportunity for beef crossing on dairy or dual-purpose animals. The maximum amount of beef crossing that can be tolerated in a dairy or dual purpose population is a function of the number of lactations per cow (L), the net reproductive rate (S), the proportion of cows crossed with beef breed bulls (K), and the proportion of heifer calves born (R_f) and can be represented as follows:

$$K_{\max} = 1 - (L * R_f * S).$$

Depending upon the cow turnover rate and the strains of beef cattle used, the increase in beef output can be up to 4%. In summary, altering the sex ratio can increase the efficiency of dairy and beef production through increasing the proportion of male animals raised for beef production, increasing the selection intensity within a population through increased selection pressure on dams, and decreasing the number of cows required to produce replacement heifers, which also allows for more cows to be bred with specialized beef bulls.

Van Vleck and Everett (1976) evaluated the economic value of sexed semen to produce dairy heifers and determined the additional price that could be paid for sexed semen compared to regular semen. Sexed semen producing 80% females can result in an increased transmitting ability of cows selected to produce heifers of 93 kg of milk or genetic gain of 8 kg per year. With a discount rate of 10%, a ten year horizon, conception rate of 50% for both regular and sexed semen, an added value above feed costs of

\$.1005/kg, and semen cost of \$6 for regular semen, the cost per ampule of sexed semen could be no more than \$15.67 in order for it to be profitable.

Using milk prices of \$.05/lb, a .10 discount rate, and a 15-year period. VanVleck (1981) reported an increase of 15% (253 lb vs. 220 lb) in annual genetic gain per year for milk in favor of artificial insemination using sexed semen versus artificial insemination with unsorted semen. Net present values of mating to selected dams of future dams were \$14 and \$63 for regular semen and sexed semen, respectively. Researchers demonstrated the cost of sexing semen needed to be no more than \$19 to be profitable based on the following assumptions:

- 1) regular artificial insemination costs were \$7,
- 2) artificial insemination costs with sexed semen were \$10 plus the expense of the sorted semen dose,
- 3) it takes six services to produce a heifer that freshens in the herd, and
- 4) sexed semen allowed for half of the cows to be bred with the sexed semen to produce replacements with the remaining herd being bred to regular semen.

The \$19 maximum found here for the cost of sexed semen falls within the range targeted by scientists of producing sexed semen at \$10 to \$20 above the current cost of unsorted semen.

Taylor et al. (1988) defined net present value of an artificial insemination sire as the expected profit per semen unit due to genetic improvement for daughter lifetime milk production in determining the additional cost Australian dairy farmers could afford to pay for sexed semen. With sexed semen resulting in 100% female calves, producers could

afford nearly double the cost of regular semen; however, 100% sexing is unrealistic. Under low milk market conditions (\$.13/L), the added value of sexed semen increased from \$8.59 to \$11.37 as the survival rate increased from 64% to 80%. The survival rate is the product of embryo and heifer calf survival since the sex ratio is equal to one. In contrast, higher milk market conditions (\$.23/L) resulted in added values of sexed semen from \$25.05 to \$31.32 as the survival rate increased from 64% to 80%. The value of sexed semen is not only determined by its success rate in altering the sex ratio and calf survival rates but also market conditions.

Dematawewa and Berger (1998) compared genetic and economic gains for production systems using artificial insemination with regular semen versus a system using artificial insemination with sexed semen. The use of artificial insemination with sexed semen reduced the number of dams required to produce bulls and herd replacements. This resulted in an additional genetic gain for milk of 24 kg/yr. Annual genetic gains for artificial insemination with regular semen and sexed semen were 257 kg and 281 kg, respectively. The economic gains for each were \$28 and \$125 for regular and sexed semen use, respectively. Economic gains were calculated using net present value and a discount factor of 5.29 for a 15 year investment period under .04 discount rate with a net value of milk of \$.11/kg. With similar methods to VanVleck (1981) but differing assumptions to calculate the break-even cost of sexing semen, the cost of sexing to obtain a net return at least equal to regular AI should not be more than \$35.33.

Predicted costs of sex semen tend to fall within the current target of no more than \$10 to \$20 above the current cost of unsorted semen. Sexed semen in combination with

today's breeding systems in both the dairy and beef industries should improve the biological and economic efficiency of beef production.

Summary

Advancements and new developments surrounding flow cytometry and sorted sperm handling appear to be paving the way for future application of sexed semen technology in the beef and dairy industries. Although barriers exist, such as sorting speed, cost of the technology, and convenience, potential solutions exist and are being applied currently.

Adoption of sexed semen technology will depend on individual production systems. Those with current artificial insemination programs will be the first to benefit from the new technology (Pace, 1994). It is important to note here that it is estimated that only about 13.3 % of beef cattle operations (NAHMS, 1997) currently use artificial insemination and only about 5% of beef cattle are inseminated each year (Taylor and Field, 1999) while nearly 70% of dairy cows and 25% of dairy heifers are bred artificially each year (Taylor and Field, 1999). For those not currently using artificial insemination, the availability of sexed semen may provide the economic incentive as well as genetic gain for producers to consider adopting artificial insemination into their production systems.

The potential benefits of commercially available sexed semen include more efficient beef and dairy production and allocation of beef and dairy genetics. Sexed semen will allow cattlemen to produce the optimum proportion of males and females in order to eliminate current inefficiencies related to progeny testing, feeding cattle, and overall beef production. Sexed semen has the potential to assist in eliminating, or at least

providing potential solutions for, inconsistencies identified in the most current National Beef Quality Audit (NBQA, 1995). Increasing the efficiency of beef production, eliminating inconsistencies, and promoting the propagation of a value-added product that brings with it quality consumers desire will only help in making beef a more competitive product in the meat market.

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CHAPTER 3

ARTIFICIAL INSEMINATION OF ANGUS FEMALES WITH SEXED SEMEN

Abstract

The objectives of this study were to determine if use of sexed semen adversely affects fertility and embryo viability, and if current sexing technology using flow cytometry indeed alters the sex ratio. During the 1997 through 1999 breeding seasons, 118, 82, and 123 heifers were bred to control semen, sorted 5° C or 18° C semen, and frozen, sorted semen, respectively. In 1998 and 1999, 121 cows were bred to control semen, 56 cows were bred to sexed 18° C semen, and 140 cows were bred to frozen, sorted semen. Semen from 10 Angus bulls of unknown fertility was collected by artificial vagina, processed, stained with DNA-binding Hoechst 33342, and sorted with a 150 mW UV argon laser on a MoFlo® flow cytometer/cell sorter modified for sperm sorting operating at 50 psi using 2.9% Na citrate as sheath fluid in the first two years and tris buffer in the third. Control semen ranged in concentration from 20 to 40 $\times 10^6$ sperm/dose, sorted 5° C or 18° C semen ranged from 3 to 5 $\times 10^5$ sperm/dose, and frozen, sorted treatments ranged from 1 to 3 $\times 10^6$ sperm/dose. Pregnancy rates for sexed semen in yearling heifers were 40 to 80% of those associated with conventional frozen semen controls in the first two years and as good or better numerically in 1999 to frozen, unsorted semen, but with only 1% to 15% as many sperm per dose. Cow pregnancy rates for sexed semen were less than half to 77% of those for frozen, unsorted semen in cows,

but with only 5% to 15% as many sperm per dose. Fertility of sorted sperm was higher for certain bulls; practical application of current technology may require identification of bulls whose sperm tolerate the stress of sorting and cryopreservation, particularly when low numbers of sperm are inseminated. We significantly altered the sex ratio toward 90% of the desired sex of calves in primiparous and multiparous beef females. There was little embryonic death loss between 30 days and 60 days of gestation or abortion between 60 days of gestation and calving in the sexed treatments or controls. Calves resulting from sexed semen appear morphologically normal.

Key Words: Beef cattle, Sex control, Fertility

Introduction

Predetermining the sex of offspring to alter the male:female sex ratio at birth is an age-old concept (Windsor et al., 1993). Controlling the sex ratio in beef cattle production could have considerable economic value. Sexed semen would allow cattlemen to produce the optimum proportion of males and females to take advantage of phenotypic and genetic differences in sex-influenced, sex-limited, and sex-linked traits, and would provide an opportunity to increase selection pressure and optimize genetic gain (Foote and Miller, 1971).

Sperm sorting via flow cytometry is the only proven method for sexing viable sperm. Determining DNA content is the operative principle; bovine Y-bearing sperm have approximately 4% less DNA than X-bearing sperm (Johnson et al., 1995). Refinements in artificial insemination procedures and new developments in flow cytometry and the processing of sorted sperm appear to be paving the way for future application of sexed semen technology in the beef industry. The objectives of this study

were to determine if use of sexed semen in both yearling virgin beef heifers and lactating beef cows adversely affects fertility and embryo viability, and if current sexing technology using flow cytometry indeed alters the sex ratio.

Materials and Methods

The study encompassed the 1997 through 1999 breeding seasons at the John E. Rouse Colorado State University Beef Improvement Center, Saratoga, WY. In all three years, Angus heifers (N=102, N=109, and N=122 for 1997, 1998, and 1999, respectively) 13-15 months old and in good body condition were synchronized using the MGA/prostaglandin F-2-alpha protocol. Heifers were fed .5 mg/head/day of MGA for 14 days followed by 25 mg of prostaglandin F-2-alpha 16 or 18 days later in 1997 and 1998; however, in 1999, the 25 mg of prostaglandin F-2-alpha was given 19 days later. Heifers averaged a body condition score of six across all years. Heifers were observed three to four times daily and were inseminated evenings only over a four day period (three in 1999), 6 to 26 hours after observed estrus.

In 1998 and 1999, Angus cows (N=212 and N=105 for 1998 and 1999, respectively) 2 to 15 years old and in good body condition were synchronized using the Select Synch protocol. GnRH (100 µg) was injected followed by prostaglandin F-2-alpha (25 mg) 7 days later. Cows averaged a body condition score of five in both years. Cows were observed for standing estrus three to four times daily and were inseminated evenings only over a four day period, 6 to 26 hours after observed estrus.

Semen was collected by artificial vagina from three 14-26 month old Angus bulls in 1997, five 14-36 month old Angus bulls in 1998, and five 14-48 month old Angus bulls in 1999. In 1997, semen was incubated at 75×10^6 sperm/ml in TALP medium with

38 μM Hoechst 33342 to stain the DNA for one hour at 34° C. In 1998 and 1999, semen was incubated at 400×10^6 sperm/ml in TALP with 224 μM Hoechst 33342 for one hour at 34° C and then diluted to 100×10^6 sperm/ml for sorting. Sperm were sorted with a 150 mW UV argon laser on a MoFlo® flow cytometer/cell sorter modified for sperm sorting operating at 50 psi using 2.9% Na citrate as sheath fluid in the first two years and tris buffer in the third.

In 1997, semen treatments included a frozen, unsorted control (15.6×10^6 motile sperm/dose post-thaw) and two cooled treatments, unsorted (a second control) and sorted. For the sorted treatment (sorted 5° C), approximately 500 live, X-bearing sperm/sec were collected at >90% purity into Cornell Universal Extender, centrifuged, and then suspended at 1.63×10^6 live sperm/ml. The cooled, unsorted semen treatment (unsorted 5° C) was extended similarly to 1.63×10^6 motile sperm/ml. Both cooled treatments were loaded into .25-ml French straws to contain 3×10^5 motile sperm and then transported approximately 240 km in a temperature-controlled cooler at 3 to 5° C. Heifers were randomly assigned to one of three treatments balanced over three bulls and two inseminators at a ratio of 3:2:2 inseminations for sexed semen, liquid control, and frozen control. Insemination procedures for the cooled treatments included depositing 3×10^5 motile sperm, half into each uterine horn using side-opening IMV blue sheaths, within approximately 5 to 9 hours of sorting. Conventional artificial insemination procedures involving uterine body semen deposition were followed for the frozen, unsorted control sperm.

In 1998, three semen treatments were used in heifers and included a frozen, unsorted control (40×10^6 sperm/dose) and two sorted treatments, 18° C and frozen.

During sorting, approximately 900 live, X-bearing sperm/sec were collected in 2 ml egg yolk extender, centrifuged, and suspended to 1×10^7 live sperm/ml in Cornell Universal Extender for liquid semen or 20% egg yolk in 2.9% Na citrate extender for frozen semen. Sexed semen for the frozen treatment was cooled to 5° C and then loaded so that .25-ml straws contained 1×10^6 sperm/straw. After glycerolization straws were frozen on racks in liquid nitrogen vapor. The cooled, sorted treatment contained 5×10^5 sperm/straw and was transported 240 km at 18° C in a temperature-controlled cooler. Heifers were randomly assigned to one of three treatments and balanced over four bulls and two inseminators. Insemination procedures for both sexed semen treatments were the same as the cooled, unsorted treatment in 1997. Conventional artificial insemination procedures were followed for the frozen, unsorted (40×10^6 sperm/dose) treatment.

In 1998, sperm treatments for cows included unsorted, frozen control (40×10^6 sperm/dose); unsorted, frozen low dose control; sorted (1×10^6), frozen sperm (1×10^6) and sorted sperm cooled to 18° C (5×10^5). During sorting, approximately 900 live, X-bearing sperm/s (~80% purity as established by reanalysis of sorted sperm) were collected in 2 ml egg yolk extender, centrifuged, and suspended to 1×10^7 live sperm/ml in Cornell Universal Extender for the sorted, cooled sperm treatment or 20% egg yolk in 2.9% Na citrate extender for the unsorted, frozen low dose control and sorted, frozen sperm. The unsorted, frozen low dose semen and sorted, frozen semen were cooled to 5° C over a 90 min period, 7% glycerol was added in two steps at 15 min intervals, semen was equilibrated for an additional 3 ½ hr, and .25-ml straws were loaded at a concentration of 1×10^7 sperm/ml. Straws were frozen on racks in liquid nitrogen vapor. The sorted, cooled semen contained 5×10^5 sperm/straw and was transported 240 km at 18° C in a

temperature-controlled cooler. Cows were randomly assigned to one of four treatments balanced over four bulls and two inseminators. The insemination procedure for all treatments, except the unsorted, frozen control, was to deposit half of the inseminate into each uterine horn using side-opening IMV blue sheaths; unfrozen semen was used within 5 to 9 h of sorting. Conventional artificial insemination procedures involving uterine body semen deposition were used for the unsorted, frozen control.

In 1999, three semen treatments were used in heifers and included a frozen, unsorted control (20×10^6 sperm/dose) and two frozen sorted treatments, 1×10^6 and 3×10^6 sperm concentrations/dose. Semen processing was similar to procedures followed in 1998; however, sorted treatments were frozen in a Tris-based extender. Heifers were randomly assigned to one of three treatments and balanced over three bulls and two inseminators at a ratio of 3:3:2 inseminations for sorted treatments and frozen control. Conventional artificial insemination procedures involving uterine body semen deposition were followed for all three sperm treatments.

In 1999, cows were bred to one of three treatments: sexed semen at 3×10^6 sperm/dose and uterine horn bred (sexed:horn), sexed semen at 3×10^6 sperm/dose and uterine body bred (sexed:body), or frozen control at 20×10^6 sperm/AI dose. Semen processing was similar to procedures followed in 1998; however, sorted treatments were frozen in a Tris-based extender. Cows were randomly assigned to one of three treatments balanced over three bulls and two inseminators at a ratio of 2:2:1 for sexed treatments and frozen control.

Rectal ultrasonography was performed to determine pregnancy and sex of fetus at 31-34 days (1997 only) and 64-67 days after insemination. The technician was unaware of treatment at the time of diagnosis.

Pregnancy rate was analyzed using the chi-square procedure in the CATMOD procedure of SAS (1992); the fixed effects of treatment, AI sire, AI technician, body condition, time of heat, and day of insemination, and interactions with each other were included initially. Independent variables determined not to be significant ($P>.05$) were removed from the model using a backward elimination procedure. Sex ratio was analyzed similarly; however, only the fixed effect of treatment was included. Contrast statements were used within the CATMOD procedure to compare levels of fixed effects.

Results and Application

In 1997 (Table 3.1), the pregnancy rate of cooled liquid sexed semen was approximately 80% of that for the two controls; however, this difference was not significant ($P>.10$). There were no significant AI sire, technician, day of insemination, time of estrus, or body condition effects on pregnancy rates, and no significant interaction effects. An important finding was that pregnancy rates from insemination 6-14 hours after detection of estrus were very similar to those from inseminations 21 to 26 hours after detection of estrus. Thus, once a day breeding appears acceptable in yearling virgin beef heifers.

One case of early embryonic death was detected with the sexed semen treatment and one with the frozen control (Table 3.2). Due to the relatively low embryonic death loss associated with sexed semen, this was not pursued in following years. All

pregnancies detected at 64-67 d went to term. All calves resulting from the sexed semen treatment were born alive and were morphologically normal.

Sex ratios for sexed semen, liquid control, and frozen control were 95%, 53%, and 73% in favor of females, respectively (Table 3.1). The difference in pregnancy rates was significant between the sexed semen treatment and liquid control ($P=.0166$). We altered the sex ratio significantly using artificial insemination without significantly decreasing fertility and embryo/fetus viability.

Table 3.1. Heifer pregnancy and sex ratio results (1997).

Treatment	No. Heifers Bred	No. Pregnant d31-34	No. Pregnant d64-67	No. Female Calves Born
Sexed Semen	45	20 (44%)	19 (42%)	18 (95%) ^a
Liquid Control	28	15 (54%)	15 (54%)	8 (53%) ^b
Frozen Control	29	16 (55%)	15 (52%)	11 (73%) ^{a,b}

^{a,b}Sex ratios without common superscripts differ ($P<.02$).

Table 3.2. Embryonic and fetal death loss (1997).

Treatment	No. Preg (30d)	No. Preg (60d)	Death Loss (60d-30d)	No. Calves Born	Death Loss (60d-calving)
Sexed Semen	20	19	1	19	0
Liquid Control	15	15	0	15	0
Frozen Control	16	15	1	15	0

In 1998, heifer pregnancy rates (Table 3.3) for the sexed 18° C and sexed frozen treatments were 41% ($P=.0002$) and 70% ($P=.0399$) of the frozen control, respectively. The pregnancy rate for sexed 18° C was 59% of the sexed frozen ($P=.0536$). In this particular study, day of insemination had an effect on heifer pregnancy rates (Table 3.4). There were, however, no significant AI sire, technician, time of estrus, or body condition effects on pregnancy rates. As in the 1997 heifer trial, pregnancy rates from insemination 6-14 hours after detection of estrus were very similar to those from inseminations 21 to 26 hours after detection of estrus. In addition, there were no

significant interaction effects. The sex ratios for the sexed 18° C and sexed frozen treatments were 91% and 78% female, respectively, and were significantly different from the frozen control treatment ($P<.02$). All pregnancies detected at 64-67 d went to term with the exception of one from the frozen control treatment. A second missing observation represents a cow culled from the herd on the basis of disposition and does not have a calving record. There appears to be a decrease in fertility associated with sexed frozen semen.

Table 3.3. Heifer pregnancy and sex ratio results (1998).

Treatment	No. Heifers Bred	No. Pregnant	No. Female Calves
Sexed 18° C	37	11 (30%) ^a	10 (91%) ^a
Sexed Frozen	35	18 (51%) ^a	14 (78%) ^b
Frozen Control	37	27 (73%) ^b	9 (36%) ^c

^{a,b,c}Values without common superscripts differ ($P\leq.05$).

Table 3.4. Effect of day of insemination on pregnancy rate (1998).

Day of Insemination	No. Heifers Bred	No. Pregnant
First	18	9(50) ^{a,b}
Second	40	24(60) ^a
Third	26	8(31) ^b
Fourth	25	15(60) ^a

^{a,b}Values without common superscripts differ ($P<.04$).

In 1998, cow pregnancy rates (Table 3.5) for the sexed treatments were significantly lower than the two controls ($P<.003$). It is important to note the frozen control had 40 to 80 times as many sperm as the sexed treatments. However, lowering the number of the low dose, frozen control sperm to 2.5% the sperm numbers of the standard control did not decrease pregnancy rates significantly. There were significant AI sire, technician, and treatment effects on pregnancy rates; however, there were no significant interaction effects.

There was a significant difference in pregnancy rates between Sire 2 and Sires 3 ($P=.0008$) and 4 ($P=.0137$; Table 3.6) as well as Sire 1 and Sire 3 ($P=.0277$). Although not as apparent in the heifers as in the cows, sperm from some bulls tolerated sorting better than others. just as some bulls are routinely observed to be more fertile than others. A method is necessary to identify those sires whose sperm tolerate sorting well.

The pregnancy rates for the two technicians breeding cows in 1998 were 49% and 31% ($P=.005$). It is unclear why one technician had such low pregnancy rates. The two technicians were similar in experience with uterine horn breeding in heifers; however, one technician was more experienced with conventional artificial insemination procedures.

As in previous studies involving yearling, virgin heifers, pregnancy rates from insemination 6-14 hours after detection of estrus were very similar to those from inseminations 21 to 26 hours after detection of estrus. Once a day breeding appears acceptable in lactating beef cows.

Table 3.5. Cow pregnancy and sex ratio results (1998).

Treatment	No. Cows Bred	No. Pregnant	No. Female Calves
Sexed 18° C	56	14 (25%) ^a	12(86%) ^c
Sexed Frozen	56	13 (23%) ^a	9(82%) ^{c,e}
Low Dose Control	51	25 (49%) ^b	12(50%) ^{d,e}
Frozen Control	49	33 (67%) ^b	12(36%) ^d

^{a,b} Pregnancy values without common superscripts differ ($P<.003$).

^{c,d,e} Sex ratios without common superscripts differ ($P<.04$).

Table 3.6. AI sire effects for 1998 cow pregnancy data.

Sires	Pregnancy Rate
SIRE 1	44% ^{a,c}
SIRE 2	56% ^a
SIRE 3	26% ^b
SIRE 4	34% ^{b,c}

^{a,b,c} Pregnancy values without common superscripts differ ($P<.03$)

The sex ratio for the sexed 18° C was 86% female and was significantly different from both the frozen control ($P=.0054$) and low dose control ($P=.0385$). In comparison, the sex ratio for the sexed semen treatment was significantly different from the frozen control ($P=.0166$) while the difference between it and the low dose control approached significance ($P=.0881$). Sex ratios for the sexed semen treatments were not significantly different from the target ratio of 90% females.

In 1999, heifer pregnancy rates (Table 3.7) for the two sexed semen treatments were approximately as good or better numerically than the frozen control; however, treatments were not significantly different than one another ($P>.10$). There were no significant AI sire, AI technician, time of estrus, or body condition effects on pregnancy rate and no significant interactions. The calving sex ratio for the sexed:1x10⁶ treatment was 100% female and was significantly different from both the sexed:3x10⁶ treatment ($P=.00$) and the control ($P=.00$).

Table 3.7. Heifer pregnancy and sex ratio results (1999).

Treatment	No. Heifers Bred	No. Pregnant	No. Female Calves*
Sexed:1x10 ⁶	44	26 (59%)	23(100%) ^a
Sexed:3x10 ⁶	44	24 (55%)	17(71%) ^b
Frozen Control	34	19 (56%)	10(53%) ^b

*All pregnancies went to term with the exception of three in the sexed:1x10⁶ treatment.

^{a,b}Sex ratio values without common superscripts differ ($P<.01$).

For cows in 1999, the pregnancy rate (Table 3.8) for the sexed semen treatment deposited in the uterine body (sexed:body) was not significantly different than both the frozen control and sexed semen treatment deposited half in each uterine horn (sexed:horn); however, there was a significant difference between the frozen control and sexed:horn ($P=.0466$). There were significant AI sire effects (Table 3.9; $P=.04$) and no significant interactions. Sire 1 ($P=.0156$) and 2 ($P=.0495$) were significantly different

than Sire 3. Sperm from some bulls tolerated sorting better than others, just as some bulls are routinely observed to be more fertile than others. As mentioned previously, a method is necessary to identify those sires whose sperm tolerate the sorting process and cryopreservation prior to inseminating large numbers of animals.

Table 3.8. Cow pregnancy and sex ratio results (1999).

Treatment	No. Cows Bred	No. Pregnant	No. Male Calves
Sexed:Horn	42	19(45%) ^b	18(91%) ^a
Sexed:Body	42	23(55%) ^{ab}	21(96%) ^a
Frozen Control	21	15(71%) ^a	5(33%) ^b

^{ab} Pregnancy values without common superscripts differ ($P < .05$).

Table 3.9. AI sire effects for 1999 cow pregnancy data.

Sires	Pregnancy Rate
SIRE 1	43% ^a
SIRE 2	49% ^a
SIRE 3	71% ^b

^{ab} Pregnancy values without common superscripts differ ($P < .05$)

Sex ratios at calving for both the sexed:body ($P = .0009$) and sexed:horn ($P = .0021$) treatments were significantly different from the frozen control.

This is the first report on the use of sexed semen in lactating beef cows; early studies included heifers and dry beef cows (Seidel et al., 1996). In these preliminary studies, pregnancy rates have varied greatly, in part due to the distance in which semen had to be shipped post-sorting prior to insemination. Of 155 heifers inseminated with sexed sperm cooled to 5° C, 22% (15/67) inseminated 9 to 13 hours post-sorting calved; however, approximately 3% (2/78) inseminated 17 to 29 hours post-sorting calved.

Alteration of the sex ratio from 50:50 to 90:10 in cattle had been achieved with sorted sperm in combination with in vitro fertilization and embryo transfer (Cran et al., 1993; Cran et al., 1995). Furthermore, in a study including heifers and dry cows where

semen deposition occurred in the uterine horn ipsilateral to the ovary with the largest follicle as determined by ultrasound, sex ratio of fetuses approximated predicted sex ratios from the reanalysis of sorted sperm for DNA (Seidel et al., 1996). Fourteen of 17 calves (82%) were of the preferred sex.

Conclusion

In summary, pregnancy rates for sexed semen in yearling heifers were 40 to 80% of those associated with conventional frozen semen controls in the first two years and as good or better than controls numerically in 1999, but with only 1% to 15% as many sperm per dose. In comparison, pregnancy rates for sexed semen with cows were less than half of those for conventional frozen semen in cows in the first year of cow breeding. We emphasize that there were large sire and technician effects on pregnancy rates that year for sexed semen treatments in the cows. Pregnancy rates with the more experienced technician and the more fertile bulls were nearly double those of the less experienced technician using lower fertility bulls. In the following year, pregnancy rates in cows for the sexed semen treatments improved and were 63% to 77% of those associated with frozen controls. Fertility of sorted sperm was higher for certain bulls; practical application of current technology may require identification of bulls whose sperm tolerate the stress of sorting. Further research is required into the effects of sexed semen on pregnancy rates, especially in cows.

We clearly have been able to significantly alter the sex ratio of calves in both primiparous and multiparous beef females. Altering the sex ratio will allow commercial producers to better use growth and carcass genetics in production of male market offspring, while capitalizing on maternal genetics and environment provided by the cow

from designated maternal lines. A particularly useful application will be to obtain female calves from virgin heifers; this will greatly reduce dystocia because heifer calves average about 2.3 kg less at birth than bull calves.

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CHAPTER 4
IMPACTS OF SEXED SEMEN UTILIZATION ON THE BIOLOGICAL
EFFICIENCY OF BEEF CATTLE PRODUCTION

Abstract

The Colorado Beef Cattle Production model was used to examine the effects of sexed semen technology on the biological efficiency of commercial beef production at both weaning and harvest (retained ownership). Sex ratios examined included 50% with natural service, 50% with artificial insemination involving conventional, unsexed semen, and 60, 70, 80 and 90% with artificial insemination with sexed semen. Production scenarios included a straightbred, straightbred X terminal and rotation-terminal mating systems using either artificial insemination followed by natural service or artificial insemination alone. Five products were simulated and included live weight at weaning (LWW), live weight at harvest (LW), carcass weight (CW), empty body weight at harvest (EBW) and fat free weight at harvest (FFW). The type of mating (maternal versus terminal) determined the direction in which the sex ratio was skewed. The number of cows required to produce female replacements decreased as much as 33% as the sex ratio increased from 50 to 90%. Biological efficiency at weaning and harvest increased in most instances when sexing was applied. Biological efficiency (kcal metabolizable energy per kg of beef product) for LWW increased 2.5 to 4.6% when artificial insemination was used followed by exposure to natural service cleanup. When using

artificial insemination as the sole method of breeding, efficiency increased as much as 6.8%. The largest increases were observed in the straightbred mating system and at sex control of 80%. For LW, biological efficiency increased 3.3 to 4.5% and 6.7 to 7.5% when artificial insemination was used in combination with natural service or as the sole method of breeding, respectively. The largest increases were observed in the straightbred mating system at 70% sex control (artificial insemination in combination with natural service) and rotation-terminal mating system at 90% sex control (artificial insemination only). Similar increases in efficiency were observed for CW, EBW and FFW. Sexed semen technology added value to artificial insemination. Results suggest that sex control is beneficial at varying levels of efficacy and that sexing does not have to be perfect to take advantage of increases in biological efficiency.

Introduction

Advances and new developments surrounding the current sexing technology appear to be paving the way for future application of sexed semen in beef cattle production. In theory, sex control could have a tremendous impact on beef production efficiency. Beef producers would be able to better utilize growth and carcass genetics in the production of male market offspring while capitalizing on maternal genetics and environment provided by the cow through the utilization of maternal lines of cattle.

Adoption of sexed semen technology will depend on individual production systems. Those with current artificial insemination programs will be the first to benefit; however, the availability of sexed semen may provide the economic incentive as well as genetic gain for producers to adopt artificial insemination into their production system.

One means of investigating the potential impacts of sex control on beef production efficiency is computer simulation. Although computers and our own knowledge of biological functions present limitations, modeling serves as an invaluable source of information for beef cattle production and its efficiency. Modeling is a primary source of information regarding production efficiencies due to its capability of evaluating a wide range of production scenarios given varied production input information. It serves to identify optimal combinations between production inputs and(or) biological cattle types under a variety of economic and physical environments. Modeling allows producers to evaluate the consequences of various management decisions pertaining to mating systems, breeding operations, weaning management, and culling policies. Furthermore, it allows evaluation of new technologies, such as sexed semen, prior to their implementation in order to evaluate the biological and economic effects of using such technology on a particular production scenario.

The objectives of this study were to use computer simulation to determine the biological efficiency of beef production at both weaning and slaughter in systems implementing sex control at various levels and to evaluate the biological merit of implementing artificial insemination given sex control.

Materials and Methods

Background

Data were generated using the Colorado Beef Cattle Production Model (CBCPM). This beef cattle simulation model is just one component of a bio-economic simulation model comprised of three primary programs. The component programs include the Simulation of Production and Utilization of Rangelands (SPUR and SPUR2) model

(Wight and Skiles, 1987; Hanson et al, 1992) to simulate a grassland ecosystem, CBCPM to simulate the beef production biology and management, and FORAGE (Baker et al., 1992) which is the interface between SPUR and CBCPM. A fourth simulation model. Firm Level Policy Simulation Model (FLIPSIM), is a stand-alone program which adds an economic component to the simulation model (Richardson and Nixon, 1986). The latter was not used in this study.

The Colorado Beef Cattle Production Model is a modified version of the Texas A&M Beef Production Model developed by Sanders (1977). Several modifications have been made to the original Texas A&M Beef Production Model since its inception in 1977 (Sanders and Cartwright, 1979a,b; Notter et al., 1979a,b,c). The current Colorado Beef Cattle Production Model was developed by Bourdon (1983) and has since been modified by W.S. Schafer (unpublished), Enns (1995), and Bourdon (unpublished).

The CBCPM models a single herd of variable size over a variable timestep and length of simulation. The model simulates individual animals within a herd. Various genotypes along with 18 genetically variable traits relating to animal growth, milk production, fertility, body composition and survival can be simulated currently. An animal's phenotype can be expressed as follows (Bourdon, unpublished):

$$P = f(BP, BCP, GCP, E_P, E_T, E_S)$$

Where:

P = phenotypic value in a specific production environment,

BP = breeding potential,

BCP = breed combination potential,

GCP = gene combination potential,

E_P = permanent environmental effects which are specific to the individual,

E_T = temporary environmental effects which are specific to the individual, and

E_S = environmental effects input to the simulation model or generated deterministically from model equations.

The effects $B_C P$ and E_S are considered fixed effects in that their origins are “known”.

B_P , $G_C P$, E_P and E_T make up the random (stochastic) component of the simulation. Input files (Tapes1-8) and FORTRAN subroutines establish the code for simulating various beef cattle management scenarios, including but not limited to, differences in mating systems, breeding operations, weaning management and culling policies. A more detailed description of CBCPM can be found in Fioretti (1994) and Bourdon (1996).

CBCPM Modifications

General. In order to accomplish said objectives, three mating systems were simulated: a straightbred mating system, a straightbred by terminal mating system, and a rotation-terminal mating system. The straightbred mating system included a cow herd of British breed type bred to a sire of same British breed type to produce both herd replacements and slaughter progeny. The example used for this study was an Angus cowherd bred to Angus bulls to produce both herd replacements and slaughter progeny. The straightbred by terminal mating system included a cow herd of British breed type split into two groups: one group consisting of younger females bred to sires of the same British breed type to produce herd replacements and one group consisting of mature females bred to sires of a continental breed type to produce slaughter progeny. In this study, an Angus cow herd was managed in two breed groups: one group consisting of the younger Angus females bred to Angus sires to produce herd replacements and one group

consisting of the mature Angus females bred to Charolais bulls to produce slaughter progeny. The rotation-terminal mating system is made up of three breed groups: two groups of younger females representing a two-breed British cross mated to a sire of the British breed type least represented in the cross, and one group consisting of older females mated to a sire of continental breed type to produce slaughter progeny. The example used in this study included a cow herd of Angus-Hereford crossbred females managed in three breed groups: two groups of younger Angus-Hereford crossbred females mated to the breed of sire least represented in the cross to produce herd replacements and one group consisting of the older crossbred females mated to Charolais bulls to produce slaughter progeny.

Within each mating system, three methods of breeding were evaluated; they included natural breeding (represented the base scenario within mating system), one artificial insemination period followed by a period of natural breeding, and artificial insemination only. Simulated sex ratios included 50% males (no sex control) and 60, 70, 80, 90% in favor of the preferred sex (sex control).

Sex control. In order to simulate sex control, modifications to the subroutine CONCEIVE were necessary. The CONCEIVE subroutine generates calves born within the herd. The variable SIRTYP (SIRe TYPE) was used to determine in which direction, male or female, the sex ratio was to be skewed, while the integer variable EIS14 determined what percent of each sex was desired. The variable EIS14 is an integer from 1 to 5. An EIS14 of 1 represents a 50% male:50% female sex ratio (no sex control), and EIS14 of 2, 3, 4, and 5 represent 60, 70, 80, and 90% of the preferred sex as determined by the particular mating, respectively. The variable SIRTYP represents the fetus' sire's

type: maternal (calving ease) or terminal (growth) bull as well as whether he is a natural cover or artificial insemination bull. Table 4.1 gives a more complete description of available sire types. An even SIRTYP code was used to designate a mature cow or terminal breeding in favor of a male calf while an odd SIRTYP code was used to designate a maternal breeding in favor of a female calf in producing herd replacements. See Appendix A for more complete details on calf sex determination and the CONCEIVE subroutine.

Table 4.1. SIRTYP description and purpose.

SIRTYP	Description*	Mate	Calf Produced	Preferred Sex**
1	Grade natural service bull- Calving ease	Heifer/young cow	Replacement	-
2	Grade natural service bull	Cow	Slaughter	-
3	Cleanup natural service bull - Calving ease	Heifer/young cow	Replacement	-
4	Cleanup natural service bull	Cow	Slaughter	-
5	Better natural service bull - Calving ease	Heifer/young cow	Replacement	-
6	Better natural service bull	Cow	Slaughter	-
7	Artificial insemination - Calving ease	Heifer/young cow	Replacement	Female
8	Artificial insemination	Cow	Slaughter	Male

*(Bourdon, personal communication)

**Given sex control.

Mating systems. Three mating systems implementing sex control were investigated and included a straightbred mating system, a straightbred by terminal mating system, and a rotation-terminal system. Modifications to the subroutines BREED, REPLACE, CULL, and DISPOSE were necessary to simulate the production systems.

The BREED subroutine determines which females are eligible for breeding, assigns females to breed groups, and assigns sire groups to be mated to female breed groups. For the purpose of efficiency, two versions of BREED were used: one for a

system using artificial insemination followed by natural service, and one for a system using only artificial insemination. In each, the Tape1 input variable SPCOD1 was used to identify a system using natural service alone (SPCOD1 = 3) versus a system using artificial insemination with or without natural service (SPCOD1 = 5). In BREED, it was necessary to identify the mating system to be simulated. The integer variable EIS12 in Tape8 identified the desired mating system as follows:

0 = straightbred mating system, 1 = straightbred X terminal mating system, and 2 = rota-terminal mating system.

Two breed groups were simulated for the straightbred and straightbred X terminal mating systems. One breed group to be mated to calving ease sires consisted of all available yearling heifers and a few young cows. The second breed group, consisting of the herd's older females, was to be mated to growth sires. Allocation of females was accomplished by ordering the females from oldest to youngest and assigning the older, mature cows to the terminal or growth breed group. The number of cows allocated to the terminal breed group (SPCOD3) was calculated using one of two equations depending upon the breeding scenario (natural service, artificial insemination or combination of the two). It was necessary to use two equations to allow for differences in method of breeding. In the case where artificial insemination was used once followed by natural service, it was not only necessary to account for pregnancy rate due to artificial insemination and the ensuing sex ratio but also the pregnancy rate and ensuing sex ratio (50%) from natural service. Thus, the scenarios using natural service allocated females to the terminal breed group as follows:

$$\text{SPCOD3} = \text{INT}(\text{TSIZ1} - (1 + \text{ERS31}) * (\text{EIS11} / \text{ERS31})), \text{ where}$$

INT = integer value of the computation,

TSIZ1 = target herd size of producing females (excludes yearling heifers),

ERS31 = expected proportion of maternal female calves born, and

EIS11 = the number of needed maternal yearling replacement females.

In this particular equation, the portion $(1+ERS31)$ represents an adjustment to account for the potential deviation from the expected sex distribution of maternal calves and takes into account the simulated weaning rate among maternal calves in the maternal breed group, minimal culling at weaning and ensuing pregnancy rate among replacement heifers. The scenario implementing only artificial insemination used an equation allocating females as follows:

$SPCOD3 = INT(TSIZ1 - (ERS32 * (EIS11 / ERS31)))$, where all are defined as above with the addition of ERS32 which represents an adjustment factor similar to $(1+ERS31)$ to account for the simulated weaning percent among maternal calves, minimal culling at weaning and the ensuing heifer pregnancy. In either case, the remaining young females and yearling heifers were assigned to the maternal breed group in the straightbred and straightbred X terminal mating system; however, in the rota-terminal mating system, the remaining young females and yearling heifers were assigned to one of two maternal breed groups depending upon breed composition. For more information on the exact programming of BREED, please see Appendix B.

The REPLACE subroutine (Appendix C) determines which weanling heifers are kept as potential replacements and which yearling heifers become replacements. Only maternal heifers were considered for replacements. All terminal heifers were culled at weaning from the breeding herd. Maternal refers to those heifers out of a calving ease

sire while terminal refers to any heifer out of a growth bull. At weaning, 10% of the maternal weanling heifer crop were culled on the basis of weaning weight. Only the heaviest weanling heifers were kept for breeding. In determining the number of needed bred yearling replacements, REPLACE first counted the number of cows kept in the herd and then figures the number of heifers needed to meet the target herd size. Once the number of needed heifers was calculated, the available bred yearling replacements were ordered by conception date and taken in order of conception date from earliest to latest until the needed number is met.

The CULL subroutine (Appendix D) determines which animals were to be culled. Culling occurred at weaning. All non-pregnant and unsound breeding females were removed from the breeding herd as well as those above the maximum dam age as set in Tape2. Terminal heifers were also culled from the breeding herd. No natural service bulls were kept beyond 4 years of age.

The DISPOSE subroutine (Appendix E) determines the status of culled animals as they move from one enterprise to another. Animals that are removed from the cow-calf enterprise can be sold, put into a stocker operation, and(or) fed. Maternal males, terminal males, and terminal females were pastured and then fed. Maternal long yearlings were fed. Cull cows were sold at weaning.

Simulation Procedures

Cattle and genetics. For the straightbred and straightbred X terminal mating systems, a foundation herd of 400 Angus breeding females and 180 yearling heifers was simulated. The foundation herd in the rota-terminal simulations consisted of 400 Angus-Hereford crossbred cows. Half were sired by Angus bulls and the other half by Hereford

bulls. Also simulated in the foundation were 180 Angus-Hereford F₁ heifers. The initial age distribution of cows was simulated to reflect a near linear decrease in cow numbers per age group as age increased. The exact number per age group in the foundation cow herd can be found in Appendix F under Tape4 for straightbred and straightbred X terminal simulations and Appendix F under Tape4 for the rota-terminal simulations. Breeding value or potential in CBCPM is made up of a starting value and a random deviation from that starting value (Hyde and Bourdon, 1998). Starting values are theoretical quantities and must be estimated based on literature values or other sources. Starting genetic (breeding potentials) values for the foundation cow herd were 34.6 kg, 308.9 kg, 536 kg, and 9.4 kg for birth weight, yearling weight, mature weight and milk production, respectively (Gregory et al., 1993).

Starting genetic (breeding potentials) values for sire groups can be found in Table 4.2. Prediction error variance for all natural service sires used for this project reflected a BIF accuracy of .4 while all artificial insemination sires' prediction error variance reflected a BIF accuracy of .9. The number of sires simulated per sire group depended upon the number of females in a particular breed group and reflected a 50:1 ratio for sires used for artificial insemination and 30:1 for natural service bulls.

Table 4.2. Starting values for growth and milk for Angus, Hereford, and Charolais sires.

Breed	Birth Wt, Kg	Yearling Wt, kg	Mature Wt, kg	Milk Production, kg
Angus	34.6	308.9	536.0	9.4
Angus: Calving Ease*	30.3	270.3	469.0	9.4
Hereford: Calving Ease*	30.4	250.3	549.5	8.5
Charolais	43.0	357.0	815.0	9.9

(Gregory et al., 1993; DECI, 1999)

*Calving ease values reflect lower starting genetic values for growth relative to breed average.

I used the SIRTREND subroutine which creates a linear trend in the breeding values of sires beginning in the year designated by the input variable CUTOFF (Bourdon, unpublished) to simulate the genetic lead or superiority of artificial insemination sires over natural service sires. For the purposes of this study, only yearling weight trend was used in order to allow for increases in growth while keeping cow size relatively the same. Table 4.3 lists the criteria used in determining the genetic lead of particular sire groups (Table 4.1) relative to the cow herd. The equation used to calculate the starting genetic value for a particular sire group is as follows:

$$SVYW(K)^* = SVYW(K) + GLEAD(SGPTYP(K)) * STYW(SGPTYP(K)) * GI$$

Where:

$SVYW(K)^*$ = adjusted starting breeding potential for yearling weight of sire group K,

$SVYW(K)$ = starting value input for yearling weight of sire group K,

$GLEAD(SGPTYP(K))$ = genetic lead of sire group type K in generations of sire trend,

$STYW(SGPTYP(K))$ = sire trend for yearling weight of sire group type K, and

GI = generation interval.

In this particular study, a value of 1.3 kg was used for STYW, and GI was 5 years.

Table 4.3. Genetic lead (GLEAD) values for sire group types.

Sire Group Type	GLEAD Ahead of Cowherd
1 Grade natural service bull - calving ease	0.00
2 Grade natural service bull	0.00
3 Cleanup natural service bull - calving ease	2.75
4 Cleanup natural service bull	2.75
5 Better natural service bull - calving ease	3.50
6 Better natural service bull	3.50
7 Artificial insemination bull - calving ease	5.50
8 Artificial insemination bull	5.50

CBCPM has the ability to simulate specific levels hybrid vigor. In his review of beef cattle crossbreeding literature, Long (1980) reported a range of 1 to 11% for birth weight, with a mean of 4%; a range of 2 to 7% for yearling weight, with mean of 4%; a range of -1 to 7% for mature weight, with a mean of 2.5%; and a range of 2.8 to 6.1% for milk yield, with a mean of 4.5%. Using these percentages and assuming no reciprocal cross differences, estimates of hybrid vigor were calculated. In CBCPM, hybrid vigor affects the persistence of lactation rather than peak milk production (Bourdon, 1996; Hyde and Bourdon, 1998). Heterosis for milk increased monthly by a fixed rate over an eight-mo period. Hybrid vigor for milk production was assumed to be 4% initially and increased to a total of 32% at eight mo.

Management and nutrition. The computer simulation was designed to represent commercial beef production in a northern plains, range environment. The breeding season began on May 31 and ended August 2, representing a 64-d breeding season. This allowed each female three opportunities to become pregnant (assuming a 21-d estrous cycle). Three breeding scenarios were simulated. In the scenario of natural service breeding, yearling heifers and cows were exposed to live bulls for the entire period of breeding. In the scenario of one artificial insemination period followed by a period of

natural service, females were exposed to artificial insemination for 21 d followed by exposure to a live bull for the remainder of the breeding season. In the third breeding scenario of artificial insemination exposure alone, females were exposed to artificial insemination during the 64-d breeding season. Cow:bull breeding ratios were 50:1 and 30:1 for artificial insemination and natural breeding, respectively. Male calves were castrated in late May. Calves were weaned in October. The target herd size was 400 cows. Each simulated mating system produced its own replacements from maternal matings, representing a calving ease sire bred to a designated maternal breed group of females. Each year 10% of the maternal weaned female calf crop was culled on the basis of weight with the remaining heifers being kept through breeding. All heifers not conceiving were culled from the breeding herd. Replacements were chosen from the remaining pregnant heifers on the basis of conception date. Those with the earliest conception dates were placed into the herd until the number of needed replacements was met. Nonpregnant cows and remaining exposed heifers were culled at weaning. All steers (from maternal and terminal matings) and heifers from terminal matings (out of growth sires) were backgrounded and then fed as fat cattle.

Cows grazed 20,000 acres of grassland typical of the Pawnee National Grasslands throughout the year. The Grassland simulation was made possible through the parameterization for the forage, wildlife, and insect species present on the Grasslands (Hanson et al., 1992). A climate file representing 30 years of temperature ranges, precipitation, solar radiation, and wind run was used to simulate weather fluctuations on the Grasslands. Cows were supplemented with harvested forage (57% digestibility; 16% crude protein) when target empty body fat levels fell below 15 to 17% during winter.

During summers in drought years, harvested forage was supplemented to the cows if target empty body fat levels fell below 8%. Yearling heifer replacements were treated similarly but were supplemented when empty body fat target levels fell below 11% during the winter months and 8% during summer months. The yearling heifers also received a developing ration (65% digestibility; 12% crude protein) when supplementation was necessary. Bull supplementation was similar to the cows' with the addition of an energy supplement (90% digestibility; 9.6% crude protein). Stocker calves grazed the same 20,000 acres of grassland and were supplemented with harvested forage and an energy supplement (90% digestibility; 9.6% crude protein) if target empty body fat fell below 9% during the winter months. Feeder calves starting on feed were fed a starter ration (75% digestibility; 12% crude protein) and then transferred to a higher energy finishing ration (85% digestibility; 12% crude protein). For more information regarding the nutrition management including feed groups, days of feeding, month-by-month target empty body fat levels, and supplement nutrient information, refer to Appendix F.

An example of input files needed to run CBCPM can be found in Appendix F. Output was generated and summarized via the SUMMARIZ subroutine.

Parameterization and data simulation. Table 4.4 describes the simulated performance for each mating system scenario. Production parameters were primarily based on data taken from the John E. Rouse Beef Improvement Center, Saratoga, WY (Ripley et al., 1998), previous sex control research (See Chapter 3), experience (Tom Geary, personal communication) and industry targets (Taylor and Field, 1999).

Table 4.4 Simulated cow herd performance																	
Management Scenario	Herd Size	Replacement Rate	%			% Pregnant				Sex Ratio at Birth: AI				Sex Ratio at Birth: Natural Breeding			
			Culling Loss	Weaning Rate	Heifer AI	Heifer Natural	Cow AI	Cow Natural	% Male	% Female	% Male	% Female	% Male	% Female	% Male	% Female	
Natural Service																	
Straightbred:	397	17.6	5.2	86.3	-	94.7	-	94.9	-	-	-	-	50.1	49.9	49.3	50.7	
Straightbred X Terminal:	387	17.4	5.2	85.6	-	94.5	-	95.2	-	-	-	-	50.3	49.7	49.6	50.2	
Rota-Terminal:	396	17.3	4.9	86.1	-	94.9	-	95.1	-	-	-	-	49.5	50.5	49.1	50.9	
Artificial Insemination: Natural Service																	
Straightbred:	397	18.2	5.2	86.7	60.2	92.9	57.9	93.0	50.4	49.6	50.2	49.6	50.3	49.7	50.4	49.6	
50%	396	18.4	5.0	86.7	55.4	92.6	52.8	92.9	40.2	59.8	59.7	40.3	50.4	49.6	48.9	51.1	
60%	395	18.9	5.1	86.8	55.0	92.6	53.3	93.2	28.4	70.6	69.3	30.7	50	50	50	50	
70%	397	18.1	5.1	86.9	55.1	93.0	53.1	93.2	19.4	80.6	78.7	20.3	51.3	48.7	48.2	50.8	
80%	396	18.8	5.2	87	55.3	92.6	52.9	93.3	10.7	89.3	90.3	9.7	50.5	49.5	49.7	50.3	
Straightbred X Terminal:																	
50%	397	18.9	5.2	85.1	59.6	92.6	57.7	93.2	50.0	50.0	49.2	50.8	50.1	49.9	49.6	50.4	
60%	396	18.6	4.9	86.3	54.5	92.7	53.3	93.1	39.4	60.6	60.0	40.0	50.8	49.2	50.5	49.5	
70%	396	18.8	5.0	85.7	55.5	92.4	52.8	92.9	30.4	69.6	68.6	31.2	50.6	49.4	49.4	50.6	
80%	396	18.7	5.3	86.3	54.8	92.9	52.9	93.4	20.4	78.6	80.0	20.0	49.7	50.3	50.5	49.5	
90%	399	18.8	5.1	85.7	55.0	92.9	53.2	93.0	9.2	90.3	90.1	9.9	49.5	50.5	50.8	49.2	
Rota-Terminal:																	
50%	397	18.9	5.2	86	60.0	92.6	58.0	93.1	50.1	49.9	51.2	48.8	49.6	50.4	50.7	49.3	
60%	397	19.2	5.2	86.4	55.3	92.8	53.1	92.8	40.0	60.0	60.0	40.0	50.8	49.2	51	49	
70%	385	19.0	5.4	86.2	54.6	92.2	52.9	93.4	28.8	70.2	71.7	28.3	49.9	50.1	49.3	50.7	
80%	397	18.5	5.4	86	55.1	92.8	53.3	93.2	20.0	80.0	80.2	19.8	49.7	50.3	50.5	49.5	
90%	398	19.0	5.2	86.5	55.1	92.2	52.7	92.9	10.2	89.8	90.0	10.0	50.3	49.7	49.6	50.4	
Artificial Insemination																	
Straightbred:	397	20.6	5.1	86.4	92.0	-	90.6	-	48.6	51.4	48.7	51.3	-	-	-	-	
50%	396	22.6	5.3	86.6	90.1	-	88.2	-	38.4	60.6	59.8	40.2	-	-	-	-	
60%	395	23.2	5.0	86.9	90.0	-	88.0	-	30.8	69.2	69.5	30.5	-	-	-	-	
70%	396	23.0	5.6	86.8	90.0	-	88.2	-	20.5	78.5	78.8	20.2	-	-	-	-	
80%	398	23.0	5.3	86.8	90.0	-	88.4	-	10.1	89.9	90.0	10.0	-	-	-	-	
Straightbred X Terminal:																	
50%	398	20.0	4.9	86.2	91.8	-	91.1	-	49.8	50.2	50.7	49.3	-	-	-	-	
60%	394	22.9	5.2	86.3	89.9	-	88.2	-	39.8	60.2	60.8	39.2	-	-	-	-	
70%	396	22.5	5.1	86.2	90.4	-	88.7	-	29.1	70.9	68.3	31.7	-	-	-	-	
80%	397	23.1	5.4	85.7	90.4	-	88.0	-	20.3	79.7	79.3	20.7	-	-	-	-	
90%	397	23.0	5.3	85.9	90.5	-	88.3	-	9.8	90.2	90.0	10.0	-	-	-	-	
Rota-Terminal:																	
50%	397	20.5	5.4	86.4	92.0	-	90.5	-	50.3	49.7	51.1	48.9	-	-	-	-	
60%	395	22.8	5.1	86.7	90.3	-	87.9	-	40.2	59.8	59.4	40.6	-	-	-	-	
70%	394	22.7	5.3	86.2	90.0	-	88.1	-	29.4	70.6	70.6	29.4	-	-	-	-	
80%	395	22.6	5.4	86.2	90.1	-	88.2	-	20.3	79.7	79.6	20.4	-	-	-	-	
90%	396	22.2	5.1	86.3	90.5	-	89.3	-	9.8	90.2	90.1	9.9	-	-	-	-	

The length of each simulation was 26 years. The first 11 years of simulation were considered as a warm-up period to allow herd numbers to stabilize at target levels, particularly in those systems solely implementing the use artificial insemination. Although this was not as much of a problem in the systems using natural service or combination of natural service and artificial insemination, the simulations were treated similarly to eliminate confounding between length of simulation (in particular sire trend) and differences in efficiency due to production. Five replicates were made for each mating system (straightbred, straightbred X terminal, and rota-terminal) by breeding scenario (natural service, artificial insemination and natural service, artificial insemination only) combination. Results are based on the averages from the last 15 years of simulated production data for the five replicates for each management scenario (mating system by method of breeding).

Biological Efficiency Analysis

Many cow-calf producers market calves and cull cows at weaning while others retain ownership through the stocker and feeder phases and sell feds at slaughter on a live weight or even carcass weight basis. Thus, efficiency ratios were calculated at both weaning and slaughter. Five products were simulated: live weight of calves and cows at weaning (LWW), live weight of animals at slaughter (LW), carcass weight of animals (CW), empty body weight of animals at slaughter (EBW) and fat free weight of animals at slaughter (FFW). Empty body weight was converted to FFW assuming 25% and 15% empty body fat for fed animals and cull cows, respectively (NRC, 1996). Bourdon and Brinks (1987) used FFW to represent lean meat yield due to consumers' emphasis on a lean retail product, and the same is done here. For purposes of this study, cull cow and

maternal heifer LWW would also be representative of their LW. Maternal cull heifers represent those heifers that were bred but were not put into the herd as replacements.

Biological efficiency was measured as feed energy input per unit of beef output in terms of kcal of metabolizable energy per unit of product. Bio-economic efficiency was measured similarly but product was weighted to account for differences in product value. Ratios for the relative values of both heifer calf/fed heifer product and cull cow product to steer calf or fed basis were calculated using Colorado price data from the mid-1990's (Steve Koontz, personal communication). For heifer LWW, LW, CW, EBW, and FFW, these ratios were .89, 1.00, .64, .92, and .69, respectively. For cull cow LWW, LW, CW, EBW, and FFW, these ratios were .64, .82, .46, .67, and .57, respectively. Maternal cull heifer ratios for LWW, LW, CW, EBW, and FFW were .68, .87, .49, .71, and .61, respectively.

Results and Discussion

Herd Structure

Under natural sex ratios, twice as many cows must be mated as the number of progeny of the desired sex. Thus, one of the proposed benefits of commercially available sexed semen is its ability to decrease the number of cows required to produce herd replacements. Furthermore, the remaining cows could be bred to specialized beef bulls in the production of slaughter progeny.

Table 4.5 shows the changes in herd structure associated with varying levels of sex control and mating by breeding system combinations. Under natural sex ratios and the use of natural service sires, the percentage of females allocated to produce herd replacements was approximately 62%. As the ratio of female to male calves increased,

Table 4.5. Distribution of cow herd for various management scenarios

Table 4.5. Distribution of cow herd for various management scenarios					
Management Scenario	Herd Size	Replacement Rate	2-Yr Olds	Mature Cows	
			Maternally Bred	Maternally Bred	Terminally Bred
Natural Service:					
Straightbred:	397	17.6	70	177	151
Straightbred X Terminal:	397	17.4	69	174	154
Rota-Terminal	396	17.3	68	178	149
Artificial Insemination:Natural Service					
Straightbred:					
50%	397	19.2	76	187	133
60%	396	19.4	77	166	153
70%	395	18.9	74	135	185
80%	397	19.1	76	135	187
90%	396	18.8	75	124	198
Straightbred X Terminal:					
50%	397	18.9	75	184	138
60%	396	18.8	74	163	158
70%	396	18.8	74	146	175
80%	398	18.7	74	132	191
90%	399	18.8	75	123	201
Rota-Terminal:					
50%	397	18.9	75	188	134
60%	397	19.2	76	164	157
70%	395	19.0	75	148	172
80%	397	18.5	73	131	194
90%	398	19.0	76	125	198
Artificial Insemination					
Straightbred:					
50%	397	20.6	82	196	120
60%	396	22.8	90	171	135
70%	395	23.2	92	134	170
80%	396	23.0	91	103	201
90%	398	23.0	91	80	226
Straightbred X Terminal:					
50%	398	20.0	80	207	111
60%	394	22.9	90	159	144
70%	396	22.5	89	131	175
80%	397	23.1	92	102	203
90%	397	23.0	91	80	225
Rota-Terminal:					
50%	397	20.5	82	210	105
60%	395	22.8	90	162	143
70%	394	22.7	90	131	173
80%	395	22.6	89	102	205
90%	396	22.2	88	78	231

the number of cows required to produce herd replacements decreased; thus, allowing the number of cows allocated to the terminal breeding group to increase.

In the management scenarios using artificial insemination with conventional, unsexed semen or artificial insemination with unsexed semen in combination with natural service, the number of females allocated to produce herd replacements increased slightly compared to the natural service scenarios when there was no sex control. This is in part due to the differences in pregnancy rates associated with the use artificial insemination. These differences were overcome in those systems using artificial insemination when the desired sex ratio increased to 60:40 female to male offspring in those systems using artificial insemination once versus 70:30 when artificial insemination was used as the sole method of breeding.

In the management scenarios implementing sex control at a ratio of 90% sex ratio of the preferred sex, the percent females allocated to the terminal breeding group increased as much as 55%. This is similar to the reported 45% increase by Hyde and Bourdon (1998). The number of maternal females required to produce female herd replacements decreased as much as 33% and is similar to the 35% reduction reported by Hyde and Bourdon (1998). Haaland-Holmes et al. (1982) reported reductions in the range of 44% to 46% in a study of straightbred, rota-terminal and three-breed terminal mating systems implementing sex control.

Upon further evaluation of herd structure, it is felt that even greater changes in female allocation would be feasible. In simulating female allocation among the maternal and terminal breed groups, the number of females needed each year for herd replacements was dependent upon the previous year's need. Thus, the number of females allocated to

produce herd replacements was inflated many years depending upon the previous year's replacement rate.

Live Weight at Weaning

Biological efficiency of LWW increased in all three mating systems when sexed semen was applied (Table 4.6). When using artificial insemination followed by natural service cleanup, the largest increase in efficiency was observed in the straightbred mating system using 80% sort efficacy (4.6%) followed by straightbred X terminal using 80% efficacy (2.8%) and rotation-terminal mating system using 90% efficacy (2.5%). When using artificial insemination as the sole method of breeding, the largest increase in biological efficiency was observed in the straightbred mating system using an 80% sort efficacy (6.8%) followed by the rotation-terminal mating system using 90% efficacy (4.9%) and the straightbred X terminal mating system using 90% efficacy (4.6%). The biological efficiencies related to cull weight production generally increased. Efficiencies associated with calf weight production fluctuated from slightly below the base scenario to slightly higher than the base scenario within mating system. Decreased calf numbers and subsequently LWW/cow due to lowered pregnancy rates associated with sexed semen treatments explain the lower calf LWW efficiencies relative to base scenarios. Live weight production per cow at weaning increased in all three mating systems when sexed semen was applied. The only exception was in the straightbred X terminal mating system using artificial insemination with 60% sexed inseminate followed by natural service. Here, the production was similar to the base scenario. The increase in production for the other scenarios was related to increases in steer and cull weight production (Table 4.7).

Table 4.6. Biological efficiency for live weight at weaning (LWW) of calves and cull cows for various management scenarios (kcal of metabolizable energy/kg of beef product).

Management Scenario	Calf LWW	Percent*	Cull LWW**	Percent*	Total LWW	Percent*
NATURAL						
Straightbred	153.2	100.0	197.4	100.0	84.4	100.0
Straight X Terminal	139.0	100.0	200.3	100.0	80.4	100.0
Rota-Terminal	147.1	100.0	192.7	100.0	81.7	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	146.8	104.4	189.1	104.4	81.8	103.1
60%	147.8	103.7	186.0	106.2	81.5	103.5
70%	141.3	108.5	192.6	102.5	80.8	104.4
80%	147.3	104.0	181.3	108.9	80.6	104.6
90%	150.2	102.0	178.0	110.9	80.9	104.3
Straightbred X Terminal:						
50%	141.3	98.4	192.2	104.2	80.6	99.7
60%	140.1	99.2	189.2	105.9	79.8	100.7
70%	138.7	100.2	189.5	105.7	79.4	101.2
80%	137.5	101.1	184.2	108.7	78.2	102.8
90%	142.4	97.6	179.0	111.9	78.8	102.0
Rota-Terminal:						
50%	146.3	100.5	183.9	104.7	80.7	101.2
60%	144.3	101.9	187.3	102.9	80.8	101.1
70%	144.9	101.5	185.1	104.1	80.6	101.3
80%	141.9	103.6	188.5	102.2	80.4	101.6
90%	145.6	101.0	178.4	108.0	79.7	102.5
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	144.7	105.9	178.4	110.7	79.9	105.6
60%	159.2	96.2	161.8	122.0	80.2	105.1
70%	153.5	99.8	165.0	119.6	79.5	106.1
80%	151.2	101.3	165.6	119.2	79.0	106.8
90%	148.5	103.2	169.6	116.4	79.2	106.6
Straightbred X Terminal:						
50%	144.1	96.5	174.4	114.8	78.9	101.9
60%	145.5	95.5	170.9	117.2	78.6	102.2
70%	143.9	96.6	169.0	118.5	77.7	103.4
80%	143.2	97.0	167.4	119.7	77.2	104.1
90%	140.6	98.9	169.5	118.2	76.8	104.6
Rota-Terminal:						
50%	149.8	98.1	170.7	112.8	79.8	102.3
60%	149.6	98.3	165.7	116.3	78.6	103.9
70%	151.2	97.3	164.6	117.0	78.8	103.6
80%	146.2	100.6	167.0	115.4	77.9	104.8
90%	142.4	103.3	171.7	112.2	77.8	104.9

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.7. Live weight production per cow at weaning (LWW).

Management Scenario	Steer Calf		Heifer Calf		Cull		Total Calf		Total	
	LWW/ cow, kg	Percent*	LWW/ cow, kg	Percent*	LWW/ cow**, kg	Percent*	LWW/ cow, kg	Percent*	LWW/ cow, kg	Percent*
NATURAL										
Straightbred	90.4	100.0	41.1	100.0	98.2	100.0	131.6	100.0	229.8	100.0
Straight X Terminal	96.2	100.0	47.9	100.0	96.5	100.0	144.1	100.0	240.6	100.0
Rota-Terminal	96.0	100.0	46.6	100.0	105.0	100.0	142.7	100.0	247.6	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	93.5	103.4	38.6	93.8	100.7	102.5	132.1	100.4	232.8	101.3
60%	91.1	100.8	40.5	98.5	102.8	104.7	131.7	100.1	234.5	102.1
70%	92.1	101.9	44.0	106.9	98.4	100.2	136.1	103.5	234.5	102.1
80%	92.1	101.8	40.1	97.5	105.9	107.9	132.2	100.5	238.2	103.7
90%	93.3	103.2	37.5	91.0	108.9	110.9	130.8	99.4	239.7	104.3
Straightbred X Terminal:										
50%	93.9	97.6	43.1	90.0	99.0	102.6	137.0	95.1	236.0	98.1
60%	94.4	98.1	44.3	92.5	101.1	104.7	138.6	96.2	239.8	99.6
70%	94.2	97.9	46.2	96.4	101.3	104.9	140.3	97.4	241.6	100.4
80%	98.0	101.9	44.5	92.9	105.0	108.8	142.4	98.9	247.5	102.9
90%	97.2	101.1	40.6	84.9	108.4	112.3	137.9	95.7	246.2	102.3
Rota-Terminal:										
50%	97.3	101.3	41.4	88.9	108.5	103.4	138.8	97.3	247.2	99.8
60%	97.4	101.4	43.6	93.6	106.9	101.9	141.0	98.9	248.0	100.1
70%	97.4	101.4	43.8	93.8	108.9	103.7	141.1	98.9	250.0	101.0
80%	100.5	104.7	43.2	92.7	106.9	101.8	143.7	100.8	250.6	101.2
90%	99.9	104.1	41.5	89.0	114.1	108.7	141.4	99.1	255.5	103.2
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	95.0	105.1	36.1	87.7	106.3	108.3	131.1	99.7	237.4	103.3
60%	87.3	96.6	34.5	83.8	119.9	122.1	121.8	92.6	241.7	105.2
70%	92.3	102.1	33.3	80.9	116.8	119.0	125.6	95.5	242.5	105.5
80%	99.8	110.4	27.9	67.7	116.6	118.7	127.7	97.1	244.3	106.3
90%	111.5	123.3	18.2	44.2	113.5	115.6	129.7	98.6	243.2	105.9
Straightbred X Terminal:										
50%	96.3	100.1	37.0	77.4	110.2	114.1	133.3	92.5	243.5	101.2
60%	94.6	98.3	38.3	79.9	113.1	117.1	132.9	92.2	245.9	102.2
70%	98.3	102.2	36.4	76.1	114.8	118.9	134.7	93.5	249.5	103.7
80%	105.1	109.3	30.8	64.3	116.3	120.4	135.9	94.3	252.1	104.8
90%	119.0	123.7	19.5	40.7	114.9	119.0	138.5	96.1	253.4	105.3
Rota-Terminal:										
50%	99.7	103.8	34.9	74.8	118.1	112.5	134.6	94.3	252.7	102.1
60%	95.9	99.9	39.6	84.9	122.3	116.6	135.5	95.0	257.9	104.2
70%	98.4	102.5	36.1	77.5	123.5	117.7	134.5	94.3	258.1	104.2
80%	109.0	113.6	30.3	64.9	121.9	116.2	139.3	97.6	261.2	105.5
90%	123.0	128.1	20.0	42.9	118.6	113.0	143.0	100.2	261.6	105.7

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as replacements.

Bio-economic efficiency (weights adjusted for product value differentiation) increased in all three mating systems when sexing was applied with the exception mentioned above in which the straightbred X terminal system at 60% sexing efficacy was similar to the straightbred X terminal base scenario (Table 4.8). Increases differed among mating systems and efficacy of sexing. The largest increase was achieved for the straightbred mating system at a 70% sexing efficacy (4.5%) while increases in the straightbred X terminal and rotation-terminal mating systems were 2.1 and 1.9 at sexing efficacies of 80 and 90%, respectively. The increase in bio-economic efficiency at the 70% efficacy in straightbred mating compared to 80% when unadjusted is reflective of increases in calf output compared to cull output. In this particular case, there was a 6.9% increase in heifer LWW/cow along with an increase in steer LWW/cow of 1.9%. At the same time, cull LWW/cow decreased. Calf output carried more value compared to cull weight when adjusted for price relationships. When using artificial insemination as the sole method of breeding, the largest increase in bio-economic efficiency was in the straightbred mating system (6.0%) followed by the rotation-terminal mating system (4.9%) and the straightbred X terminal mating system (3.8%). All reached optimal efficiency with 90% sexed inseminates and reflect increases in adjusted steer LWW/cow. Generally, adjusted LWW per cow increased as the proportion of calves of the preferred sex increased from 50 to 90% (Table 4.9). There were a few instances in the scenarios using artificial insemination in combination with natural service within crossbreeding systems where the production started out slightly below or near the base scenario but then increased as sexing increased.

Table 4.8. Bio-economic efficiency for live weight at weaning (LWW) of calves and cull cows for various management scenarios (kcal of metabolizable energy/kg of beef product).

Management Scenario	Calf LWW	Percent*	Cull LWW**	Percent*	Total LWW	Percent*
NATURAL						
Straightbred	152.6	100.0	304.3	100.0	101.6	100.0
Straight X Term	139.3	100.0	308.9	100.0	96.0	100.0
Rota-Terminal	147.0	100.0	296.6	100.0	98.3	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	148.9	102.5	292.2	104.1	98.6	103.0
60%	150.3	101.5	287.3	105.9	98.7	103.0
70%	144.4	105.7	297.7	102.2	97.2	104.5
80%	150.3	101.5	279.4	108.9	97.7	104.0
90%	153.1	99.7	273.9	111.1	98.2	103.5
Straightbred X Terminal:						
50%	143.9	96.8	297.0	104.0	96.9	99.0
60%	143.0	97.4	292.1	105.8	96.0	100.0
70%	141.9	98.2	292.5	105.6	95.6	100.5
80%	140.6	99.0	283.8	108.8	94.0	102.1
90%	145.5	95.8	275.4	112.2	95.2	100.9
Rota-Terminal:						
50%	148.7	98.9	283.9	104.5	97.6	100.7
60%	147.0	100.0	289.6	102.4	97.5	100.8
70%	147.8	99.5	285.7	103.8	97.4	100.9
80%	144.9	101.5	290.8	102.0	96.7	101.6
90%	148.7	98.9	275.0	107.9	96.5	101.9
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	149.2	102.3	276.3	110.2	96.9	104.9
60%	164.4	92.9	250.5	121.5	99.2	102.4
70%	158.1	96.5	256.0	118.9	97.7	104.0
80%	154.9	98.5	256.8	118.5	96.6	105.2
90%	150.8	101.2	263.1	115.7	95.9	106.0
Straightbred X Terminal:						
50%	148.6	93.7	269.2	114.8	95.8	100.3
60%	150.2	92.7	265.5	116.4	95.9	100.1
70%	148.3	93.9	261.8	118.0	94.7	101.4
80%	146.9	94.9	259.7	119.0	93.8	102.3
90%	142.8	97.6	262.9	117.5	92.5	103.8
Rota-Terminal:						
50%	154.2	95.3	263.8	112.5	97.3	101.0
60%	154.5	95.1	257.3	115.3	96.5	101.8
70%	155.8	94.4	255.3	116.2	96.7	101.6
80%	149.7	98.2	259.3	114.4	94.9	103.6
90%	144.6	101.7	266.4	111.4	93.7	104.9

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as replacements.

Table 4.9. Value-adjusted live weight per cow at weaning (LWW) of calves and cull females for various management scenarios.

Management Scenario	Steer Calf LWW/ cow.		Heifer Calf LWW/ cow.		Cull LWW/ cow**		Total Calf LWW/ cow.		Total LWW/ cow.	
	kg	Percent*	kg	Percent*	kg	Percent*	kg	Percent*	kg	Percent*
NATURAL										
Straightbred	90.4	100.0	36.6	100.0	63.7	100.0	127.0	100.0	190.7	100.0
Straight X Terminal	96.2	100.0	42.6	100.0	62.6	100.0	138.8	100.0	201.4	100.0
Rota-Terminal	96.0	100.0	41.5	100.0	68.2	100.0	137.5	100.0	205.7	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	93.5	103.4	34.4	93.8	65.2	102.3	127.8	100.6	193.0	101.2
60%	91.1	100.8	36.1	98.5	66.5	104.5	127.2	100.1	193.8	101.6
70%	92.1	101.9	39.1	106.9	63.7	99.9	131.3	103.3	194.9	102.2
80%	92.1	101.8	35.7	97.5	68.7	107.9	127.8	100.6	196.5	103.0
90%	93.3	103.2	33.3	91.0	70.8	111.1	126.6	99.7	197.4	103.5
Straightbred X Terminal:										
50%	93.9	97.6	38.4	90.0	64.1	102.4	132.2	95.3	196.3	97.5
60%	94.4	98.1	39.4	92.5	65.5	104.6	133.8	96.4	199.3	98.9
70%	94.2	97.9	41.1	96.4	65.6	104.8	135.2	97.4	200.9	99.7
80%	98.0	101.9	39.6	92.9	68.2	108.9	137.5	99.1	205.7	102.1
90%	97.2	101.1	36.2	84.9	70.5	112.6	133.4	96.1	203.8	101.2
Rota-Terminal:										
50%	97.3	101.3	36.9	88.9	70.3	103.1	134.2	97.6	204.5	99.4
60%	97.4	101.4	38.8	93.6	69.2	101.5	136.2	99.1	205.4	99.9
70%	97.4	101.4	39.0	93.8	70.5	103.5	136.3	99.1	206.9	100.6
80%	100.5	104.7	38.5	92.7	69.3	101.6	139.0	101.1	208.3	101.3
90%	99.9	104.1	36.9	89.0	74.0	108.6	136.9	99.5	210.9	102.5
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	95.0	105.1	32.1	87.7	68.6	107.8	127.1	100.1	195.8	102.6
60%	87.3	96.6	30.7	83.8	77.4	121.5	118.0	92.9	195.4	102.4
70%	92.3	102.1	29.6	80.9	75.3	118.3	121.9	96.0	197.3	103.4
80%	99.8	110.4	24.8	67.7	75.2	118.0	124.6	98.1	199.8	104.8
90%	111.5	123.3	16.2	44.2	73.2	114.9	127.7	100.5	200.9	105.3
Straightbred X Terminal:										
50%	96.3	100.1	33.0	77.4	71.4	114.0	129.3	101.8	200.6	99.6
60%	94.6	98.3	34.1	79.9	72.8	116.3	128.6	101.3	201.5	100.0
70%	98.3	102.2	32.4	76.1	74.1	118.4	130.7	102.9	204.8	101.7
80%	105.1	109.3	27.4	64.3	74.9	119.7	132.5	104.3	207.4	103.0
90%	119.0	123.7	17.3	40.7	74.1	118.3	136.4	107.3	210.4	104.5
Rota-Terminal:										
50%	99.7	103.8	31.1	74.8	76.4	112.2	130.7	102.9	207.2	100.7
60%	95.9	99.9	35.3	96.3	78.8	115.6	131.2	103.3	210.0	102.1
70%	98.4	102.5	32.2	87.8	79.7	116.9	130.6	102.8	210.2	102.2
80%	109.0	113.6	26.9	73.5	78.5	115.2	136.0	107.0	214.5	104.3
90%	123.0	128.1	17.8	48.6	76.5	112.2	140.8	110.8	217.3	105.6

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system

**Includes all cull cows and exposed heifers not chosen as herd replacements.

Increases in efficiency and production were achieved with little to no increase in cow-calf inputs (Table 4.10). The input for the straightbred system (regardless of breeding method) was less than or equal to that of the base scenario. This most likely reflects the decrease in herd sire numbers. Increases were as much as .7% in the straightbred X terminal and rotation-terminal mating systems. The increases in cow-calf input were due to increases in cow and system requirements in raising crossbred offspring which outweigh any advantage obtained from reducing the number of herd sires within the system compared to base natural service scenarios. In regards to the rotation-terminal system, increases were also due in part to increases in cow maintenance associated with the crossbred dam and slightly larger mature size.

Biological efficiency, whether value-adjusted or not, is to be primarily a function of production due to the small increase, if any, in cow-calf inputs. This is demonstrated graphically in Figure 4.1 (straightbred mating system), Figure 4.2 (straightbred X terminal mating system) and Figure 4.3 (rotation-terminal mating system). In most cases, artificial insemination with conventional, unsexed inseminate increased biological efficiency above natural service base scenario. Sexing added value in terms of efficiency. It appears that sexing efficacy does not have to be 90% in order to take advantage of increases in biological efficiency. In some instances (straightbred and straightbred X terminal mating systems), peak efficiency was obtained at sexing levels of 70 to 80%. The greatest increases in efficiency were achieved when using artificial insemination as the sole method of breeding. Increases in both steer and heifer LWW/cow contributed to the increased efficiency observed in the straightbred mating system implementing artificial insemination and natural breeding. Increased efficiency appeared to be primarily

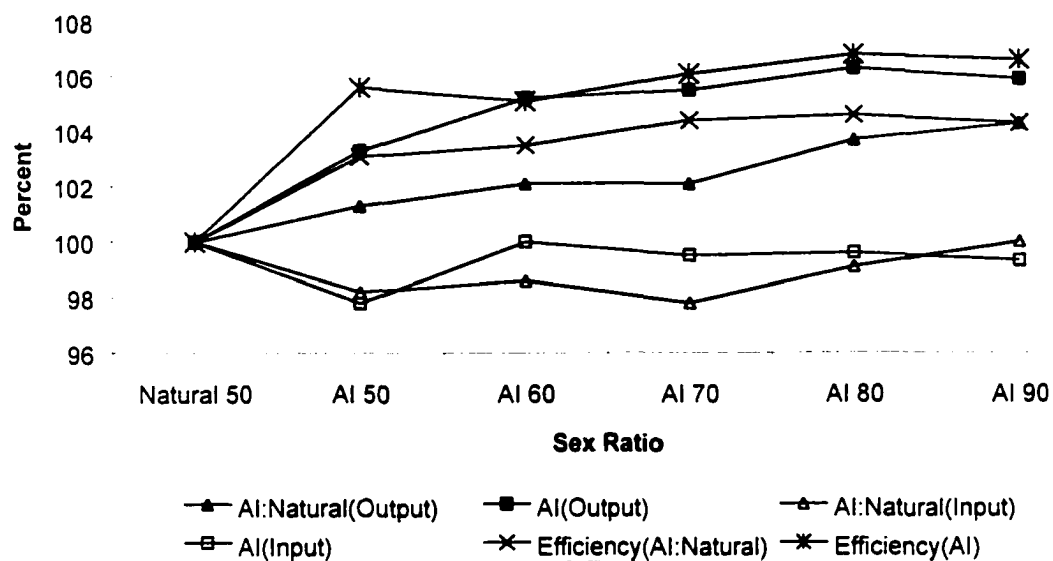
Table 4.10. Simulated input per cow for intake of kcals of metabolizable energy for the cow-calf, stocker and feeder enterprises.

Management Scenario	Input: Intake, (Total**)		Intake (Cow-calf).		Intake (Stocker).		Intake (Feeder).	
	kcal ME	Percent*	kcal ME	Percent*	kcal ME	Percent*	kcal ME	Percent*
Natural								
Straightbred	26796.2	100.0	19385.36	100.0	5732	100.0	1679	100.0
Straight X Terminal	27537.2	100.0	19335.45	100.0	6265	100.0	1937	100.0
Rota-Terminal	28485.4	100.0	20220.05	100.0	6236	100.0	2029	100.0
ARTIFICIAL INSEMINATION:NATURAL								
Straightbred:								
50%	26483.5	98.8	19040.45	98.2	5761	100.5	1682	100.1
60%	26728.7	99.7	19118.58	98.6	5785	100.9	1825	108.7
70%	26641.4	99.4	18953.16	97.8	5963	104.0	1725	102.7
80%	26691	99.6	19205.91	99.1	5768	100.6	1717	102.2
90%	26697	99.6	19386.92	100.0	5718	99.8	1592	94.8
Straightbred X Terminal:								
50%	26950.6	97.9	19028.19	98.4	6071	96.9	1852	95.6
60%	27229.2	98.9	19128.59	98.9	6185	98.7	1915	98.9
70%	27373.6	99.4	19193.88	99.3	6214	99.2	1966	101.5
80%	27614.4	100.3	19345.52	100.1	6257	99.9	2012	103.9
90%	27492.8	99.8	19402.48	100.3	6097	97.3	1994	102.9
Rota-Terminal:								
50%	27921.6	98.0	19950.89	98.7	6096	97.7	1875	92.4
60%	28228.3	99.1	20029.52	99.1	6212	99.6	1987	97.9
70%	28386.7	99.7	20148.29	99.6	6164	98.8	2074	102.2
80%	28470.8	99.9	20142.77	99.6	6286	100.8	2042	100.6
90%	28693.1	100.7	20351.73	100.7	6166	98.9	2175	107.2
ARTIFICIAL INSEMINATION								
Straightbred:								
50%	26387.8	98.5	18964.17	97.8	5777	100.8	1647	98.1
60%	26394.5	98.5	19393.1	100.0	5337	93.1	1665	99.1
70%	26432.2	98.6	19284.46	99.5	5489	95.8	1659	98.8
80%	26622	99.4	19309.08	99.6	5599	97.7	1714	102.1
90%	26774.2	99.9	19252.09	99.3	5726	99.9	1796	106.9
Straightbred X Terminal:								
50%	26947	97.9	19210.38	99.4	5850	93.4	1887	97.4
60%	27079.6	98.3	19328.33	100.0	5877	93.8	1874	96.8
70%	27330.1	99.2	19390.57	100.3	5940	94.8	2000	103.3
80%	27565.8	100.1	19456.7	100.6	6017	96.0	2092	108.0
90%	27792.4	100.9	19470.51	100.7	6204	99.0	2118	109.4
Rota-Terminal:								
50%	28060	98.5	20165.95	99.7	5878	94.3	2016	99.3
60%	28189.8	99.0	20273.19	100.3	5927	95.0	1990	98.1
70%	28283	99.3	20335.87	100.6	5867	94.1	2080	102.5
80%	28700.7	100.8	20355.98	100.7	6147	98.6	2198	108.3
90%	29031.5	101.9	20364.13	100.7	6361	102.0	2306	113.7

*Percent relative to the baseline where the baseline is natural breeding scenario within mating system.

**Total kcal intake of metabolizable energy(cow-calf, stocker and feeder enterprises).

Unadjusted for value of product:



Adjusted for value of product:

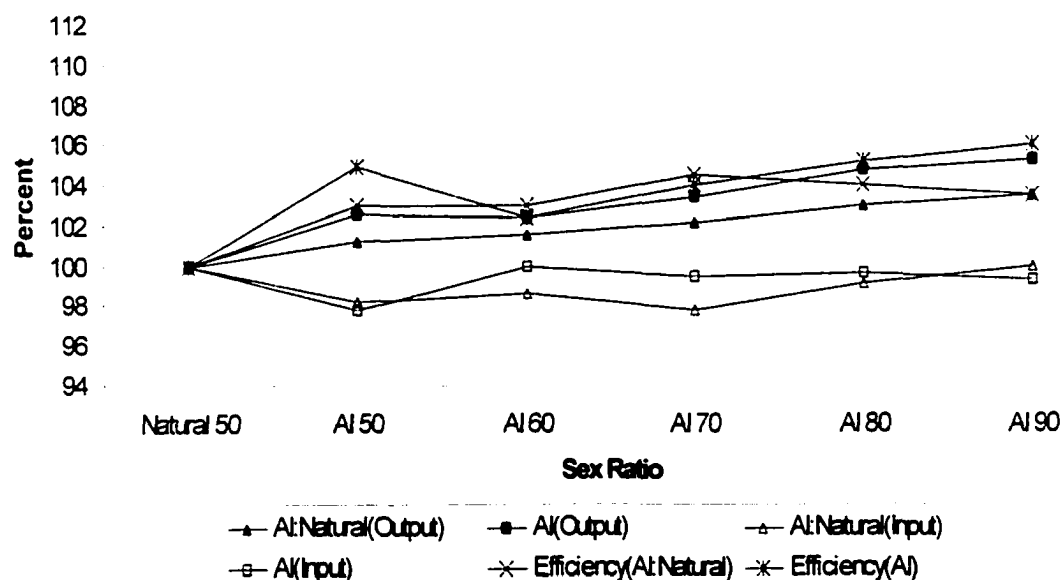
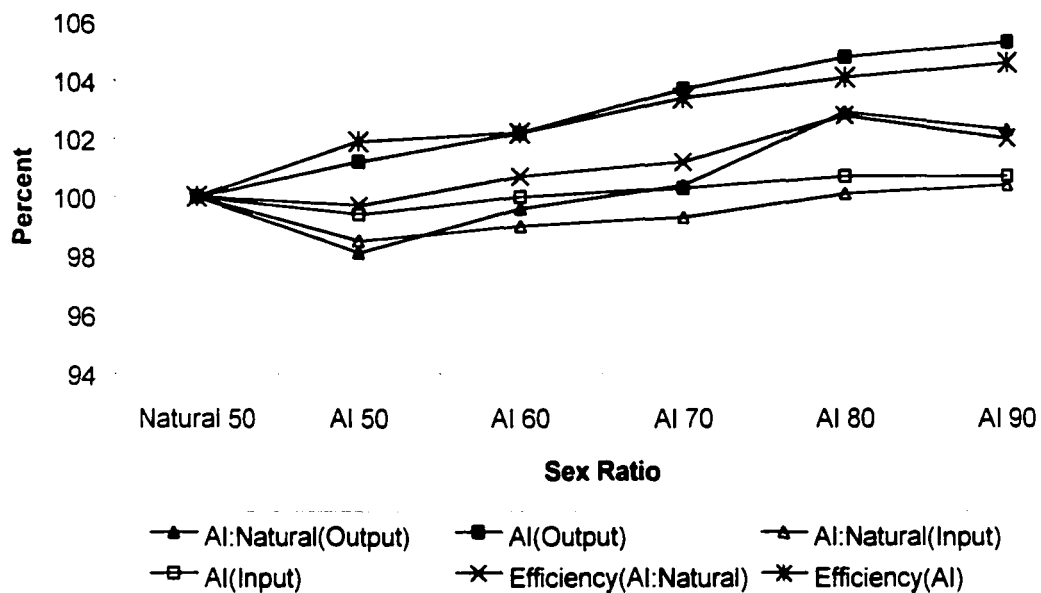


Figure 4.1. Production versus input (relative to the straightbred natural service base scenario) for live weight at weaning of straightbred management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

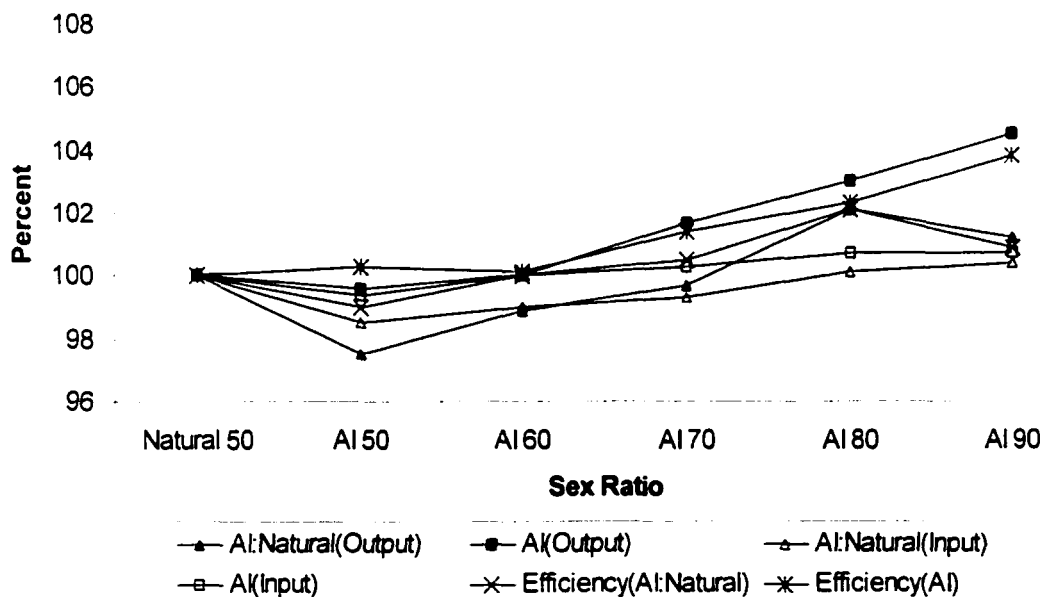
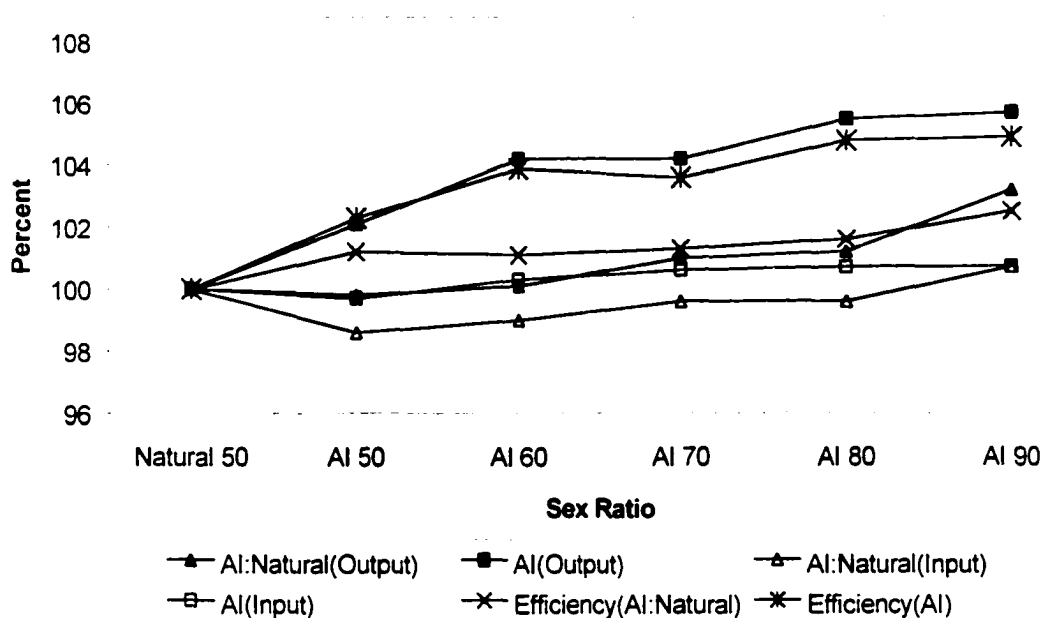


Figure 4.2. Production versus inputs (relative to the straightbred by terminal natural service base scenario) for live weight at weaning of straightbred by terminal management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

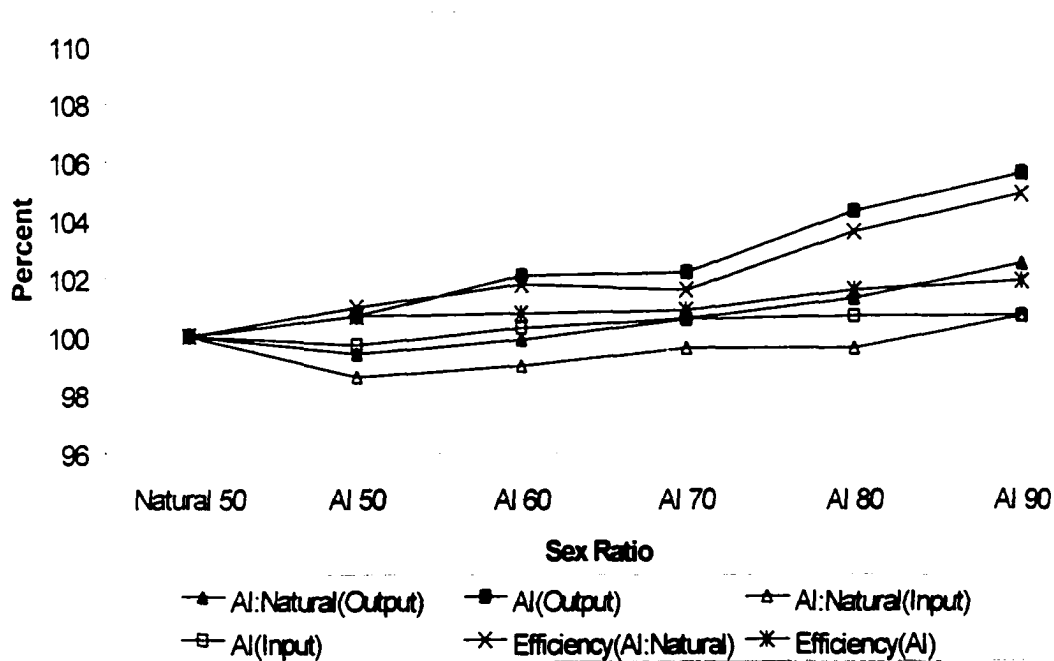


Figure 4.3. Production versus inputs (relative to the rota-terminal natural service base scenario) for live weight at weaning of rota-terminal management scenarios implementing sex control.

a function of increases in steer LWW/cow along with increases in cull LWW/cow in those scenarios implementing artificial insemination alone. Greater efficiencies, regardless of method of breeding, may be achieved if pregnancy rates were similar to those for natural service, thus increasing the number of calves and calf weight weaned per cow. Improvements in LWW per cow in the straightbred mating system were due primarily to increases in the proportion of calves of the desired sex and genetic improvement due to the use of superior genetics associated with artificial insemination. In crossbreeding systems, improvements in LWW per cow were primarily due to the proportional changes in the production of calves of the preferred sex and hybrid vigor. There appears to be potential to increase efficiency of LWW/cow production, given artificial insemination with sexed inseminates. Details on maternal calf, terminal calf and cull numbers along with average LWW can be found in Appendix G.

Live Weight at Slaughter

Biological efficiency of LW increased in all mating systems when sexing was applied with one exception being the straightbred X terminal scenario using artificial insemination followed by natural service and 60% sexing efficacy (Table 4.11). When using artificial insemination in combination with natural service, the largest increase was observed in the straightbred mating system using 70% efficacy (4.5%) followed by the straightbred X terminal mating system using 80% efficacy (3.5%) and rotation-terminal mating system using 90% efficacy (3.3%). If only artificial insemination is used, the largest increase was observed in the rotation-terminal mating system (7.5%) followed by the straightbred system (6.8%) and the straightbred X terminal mating system (6.7%). The straightbred increase represents 80% efficacy while the other two represent 90%

Table 4.11. Biological efficiency for live weight (LW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed LW	Percent*	Cull LW**	Percent*	Total LW	Percent*
NATURAL						
Straightbred	100.9	100.0	272.9	100.0	73.6	100.0
Straight X Terminal	92.0	100.0	285.2	100.0	69.6	100.0
Rota-Terminal	94.2	100.0	271.4	100.0	69.9	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	98.1	102.8	263.1	103.7	71.4	103.1
60%	98.6	102.3	260.0	105.0	71.5	103.0
70%	95.3	105.8	270.7	100.8	70.5	104.5
80%	99.0	101.9	251.9	108.3	71.0	103.7
90%	99.5	101.3	245.1	111.3	70.8	104.0
Straightbred X Terminal:						
50%	92.8	99.1	272.2	104.8	69.2	100.5
60%	96.7	95.2	269.3	105.9	71.1	97.8
70%	90.5	101.6	270.2	105.6	67.8	102.6
80%	90.3	101.9	262.9	108.5	67.2	103.5
90%	92.0	100.0	253.7	112.4	67.5	103.0
Rota-Terminal:						
50%	94.2	100.0	257.4	105.4	69.0	101.4
60%	93.2	101.0	264.0	102.8	68.9	101.5
70%	93.4	100.8	260.7	104.1	68.8	101.6
80%	92.7	101.6	266.4	101.9	68.8	101.7
90%	92.6	101.8	251.5	107.9	67.7	103.3
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	97.4	103.5	248.2	109.9	70.0	105.2
60%	102.2	98.7	220.2	123.9	69.8	105.5
70%	99.8	101.0	226.2	120.6	69.3	106.3
80%	98.8	102.1	228.3	119.5	69.0	106.8
90%	97.7	103.2	235.8	115.7	69.1	106.6
Straightbred X Terminal:						
50%	94.6	97.3	244.6	116.6	68.2	102.0
60%	93.0	98.9	239.5	119.1	67.0	103.9
70%	92.5	99.5	238.2	119.8	66.6	104.5
80%	90.6	101.6	237.1	120.3	65.5	106.1
90%	89.2	103.1	241.9	117.9	65.2	106.7
Rota-Terminal:						
50%	96.1	98.0	237.6	114.2	68.4	102.2
60%	95.5	98.7	230.4	117.8	67.5	103.6
70%	94.8	99.3	229.0	118.5	67.1	104.3
80%	90.7	103.8	235.4	115.3	65.5	106.8
90%	88.6	106.3	244.7	110.9	65.0	107.5

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as replacements.

efficacy. Biological efficiency for feeder and cull LW varied by mating system and sexing efficacy and did not necessarily increase linearly as sex control increased from 50% to 90%. In most cases, sexing increased efficiency above artificial insemination use with conventional, unsexed semen. Live weight production per cow at slaughter increased in all three mating systems when sexing was applied except in the straightbred X terminal mating system mentioned above as having lowered biological efficiency, presenting the reason for its lowered efficiency. Increases in total production were due to corresponding increases in fed steer LW as sexing increased from 50 to 90% (Table 4.12).

Bio-economic efficiency (weights adjusted for product value differentiation) increased in all three mating systems when sexing was implemented (Table 4.13). As in LWW, the straightbred X terminal mating system using sexed semen at 60% efficacy followed by natural service was the exception to this trend. Said increases differed among mating systems and efficacy of sexing. The largest increase was achieved for the straightbred mating system at a 70% sexing efficacy (4.5%) while increases in the straightbred X terminal and rotation-terminal mating systems were 3.3 and 3.1 at sexing efficacies of 80 and 90%, respectively. When using artificial insemination as the sole method of breeding, the largest increase in bio-economic efficiency was in the rotation-terminal mating system (7.1%) followed by the straightbred mating system (6.8%) and the straightbred X terminal mating system (6.1%). All were 90% efficacy inseminates except for the straightbred mating system which was achieved at 80% sexing efficacy. Adjusted LW per cow for the sexed treatments increased above base scenarios and were due to increases in fed weight produced (Table 4.14). The one exception to the trend was the straightbred X terminal mating system previously mentioned.

Table 4.12. Live weight production at harvest (LW) per cow.

Management Scenario	Fed Steer LW, kg	Percent*	Fed Heifer LW, kg	Percent*	Cull LW**, kg	Percent*	Total Fed LW, kg	Percent*	Total LW, kg	Percent*
NATURAL										
Straightbred	192.4	100.0	73.3	100.0	98.2	100.0	265.7	100.0	363.9	100.0
Straight X Terminal	209.2	100.0	90.1	100.0	96.5	100.0	299.3	100.0	395.8	100.0
Rota-Terminal	212.6	100.0	89.8	100.0	105.0	100.0	302.4	100.0	407.4	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	199.3	103.6	70.7	96.5	100.7	102.5	270.0	101.6	370.7	101.9
60%	195.5	101.6	75.7	103.3	102.8	104.7	271.1	102.1	374.0	102.8
70%	197.7	102.8	81.8	111.7	98.4	100.2	279.5	105.2	378.0	103.9
80%	196.5	102.2	73.2	99.9	105.9	107.9	269.7	101.5	375.7	103.2
90%	198.1	103.0	70.1	95.6	108.9	110.9	268.2	101.0	377.1	103.6
Straightbred X Terminal:										
50%	204.0	97.5	86.3	95.8	99.0	102.6	290.4	97.0	389.4	98.4
60%	194.5	93.0	87.1	96.7	101.1	104.7	281.6	94.1	382.7	96.7
70%	210.5	100.7	91.8	101.9	101.3	104.9	302.3	101.0	403.6	102.0
80%	219.7	105.0	86.2	95.6	105.0	108.8	305.9	102.2	410.9	103.8
90%	220.3	105.3	78.5	87.2	108.4	112.3	298.8	99.8	407.2	102.9
Rota-Terminal:										
50%	215.3	101.2	81.2	90.4	108.5	103.4	296.5	98.0	404.9	99.4
60%	216.8	102.0	86.0	95.8	106.9	101.9	302.8	100.1	409.8	100.6
70%	215.3	101.3	88.5	98.5	108.9	103.7	303.8	100.4	412.6	101.3
80%	222.7	104.7	84.5	94.1	106.9	101.8	307.2	101.6	414.1	101.6
90%	226.6	106.6	83.4	92.9	114.1	108.7	310.0	102.5	424.1	104.1
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	201.6	104.8	69.2	94.4	106.3	108.3	270.8	101.9	377.1	103.6
60%	189.8	98.6	68.5	93.5	119.9	122.1	258.3	97.2	378.2	103.9
70%	198.7	103.3	66.1	90.2	116.8	119.0	264.8	99.7	381.7	104.9
80%	214.4	111.4	55.0	75.0	116.6	118.7	269.4	101.4	386.0	106.1
90%	235.7	122.5	38.3	52.2	113.5	115.6	274.0	103.1	387.5	106.5
Straightbred X Terminal:										
50%	208.0	99.4	76.9	85.3	110.2	114.1	284.9	95.2	395.1	99.8
60%	210.2	100.5	81.0	89.9	113.1	117.1	291.2	97.3	404.3	102.1
70%	219.1	104.7	76.5	84.9	114.8	118.9	295.6	98.8	410.4	103.7
80%	241.9	115.7	62.4	69.2	116.3	120.4	304.3	101.7	420.6	106.2
90%	271.7	129.9	39.8	44.1	114.9	119.0	311.5	104.1	426.4	107.7
Rota-Terminal:										
50%	220.6	103.7	71.5	79.6	118.1	112.5	292.1	96.6	410.2	100.7
60%	213.4	100.3	81.9	91.2	122.3	116.6	295.3	97.6	417.7	102.5
70%	222.9	104.8	75.3	83.9	123.5	117.7	298.2	98.6	421.8	103.5
80%	249.9	117.6	66.5	74.0	121.9	116.2	316.4	104.6	438.3	107.6
90%	284.2	133.7	43.4	48.4	118.6	113.0	327.7	108.3	446.3	109.6

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.13. Bio-economic efficiency for live weight (LW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed LW	Percent*	Cull LW**	Percent*	Total LW	Percent*
NATURAL						
Straightbred	100.9	100.0	328.4	100.0	77.2	100.0
Straight X Terminal	92.0	100.0	343.5	100.0	72.6	100.0
Rota-Terminal	94.2	100.0	326.3	100.0	73.1	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	98.1	102.8	317.3	103.7	74.9	103.1
60%	98.6	102.3	313.6	105.0	75.0	103.0
70%	95.3	105.8	326.7	100.8	73.8	104.5
80%	99.0	101.9	303.1	108.3	74.6	103.7
90%	99.5	101.3	294.5	111.3	74.4	104.0
Straightbred X Terminal:						
50%	92.8	99.1	328.4	104.6	72.4	100.3
60%	96.7	95.2	324.6	105.8	74.5	97.4
70%	90.5	101.6	325.7	105.5	70.8	102.4
80%	90.3	101.9	316.3	108.6	70.2	103.3
90%	92.0	100.0	304.7	112.7	70.7	102.7
Rota-Terminal:						
50%	94.2	100.0	310.2	105.2	72.2	101.2
60%	93.2	101.0	318.7	102.4	72.1	101.3
70%	93.4	100.8	314.3	103.8	72.0	101.5
80%	92.7	101.6	320.9	101.7	71.9	101.7
90%	92.6	101.8	302.7	107.8	70.9	103.1
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	97.4	103.5	300.1	109.9	73.6	105.2
60%	102.2	98.7	266.2	123.9	73.8	105.5
70%	99.8	101.0	273.9	120.6	73.2	106.3
80%	98.8	102.1	276.4	119.5	72.8	106.8
90%	97.7	103.2	285.6	115.7	72.8	106.6
Straightbred X Terminal:						
50%	94.6	97.3	294.8	116.5	71.6	101.4
60%	93.0	98.9	290.4	118.3	70.4	103.0
70%	92.5	99.5	288.0	119.3	70.0	103.7
80%	90.6	101.6	287.2	119.6	68.9	105.4
90%	89.2	103.1	292.9	117.3	68.4	106.1
Rota-Terminal:						
50%	96.1	98.0	286.5	113.9	71.9	101.6
60%	95.5	98.7	279.3	116.8	71.1	102.7
70%	94.8	99.3	277.1	117.7	70.7	103.4
80%	90.7	103.8	285.4	114.3	68.8	106.2
90%	88.6	106.3	296.4	110.1	68.2	107.1

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as replacements.

Table 4.14. Value-adjusted simulated live weight (LW) at harvest per cow for various management scenarios.

Management Scenario	Fed Steer		Fed Heifer		Cull		Total Fed		Total	
	LW. kg	Percent*	LW. kg	Percent*	LW**, kg	Percent*	LW. kg	Percent*	LW. kg	Percent*
NATURAL										
Straightbred	192.4	100.0	73.3	100.0	81.6	100.0	265.7	100.0	347.3	100.0
Straight X Terminal	209.2	100.0	90.1	100.0	80.2	100.0	299.3	100.0	379.5	100.0
Rota-Terminal	212.6	100.0	89.8	100.0	87.3	100.0	302.4	100.0	389.7	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	199.3	103.6	70.7	96.5	83.5	102.3	270.0	101.6	353.5	101.8
60%	195.5	101.6	75.7	103.3	85.2	104.5	271.1	102.1	356.4	102.6
70%	197.7	102.8	81.8	111.7	81.5	99.9	279.5	105.2	361.1	104.0
80%	196.5	102.2	73.2	99.9	88.1	107.9	269.7	101.5	357.8	103.0
90%	198.1	103.0	70.1	95.6	90.6	111.1	268.2	101.0	358.8	103.3
Straightbred X Terminal:										
50%	204.0	97.5	86.3	95.8	82.1	102.4	290.4	97.0	372.4	98.1
60%	194.5	93.0	87.1	96.7	83.9	104.6	281.6	94.1	365.5	96.3
70%	210.5	100.7	91.8	101.9	84.0	104.8	302.3	101.0	386.4	101.8
80%	219.7	105.0	86.2	95.6	87.3	108.9	305.9	102.2	393.2	103.6
90%	220.3	105.3	78.5	87.2	90.2	112.6	298.8	99.8	389.1	102.5
Rota-Terminal:										
50%	215.3	101.2	81.2	90.4	90.0	103.1	296.5	98.0	386.5	99.2
60%	216.8	102.0	86.0	95.8	88.6	101.5	302.8	100.1	391.4	100.4
70%	215.3	101.3	88.5	98.5	90.3	103.5	303.8	100.4	394.1	101.1
80%	222.7	104.7	84.5	94.1	88.7	101.6	307.2	101.6	396.0	101.6
90%	226.6	106.6	83.4	92.9	94.8	108.6	310.0	102.5	404.8	103.9
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	201.6	104.8	69.2	94.4	87.9	107.8	270.8	101.9	358.7	103.3
60%	189.8	98.6	68.5	93.5	99.2	121.5	258.3	97.2	357.5	102.9
70%	198.7	103.3	66.1	90.2	96.5	118.3	264.8	99.7	361.3	104.0
80%	214.4	111.4	55.0	75.0	96.3	118.0	269.4	101.4	365.7	105.3
90%	235.7	122.5	38.3	52.2	93.8	114.9	274.0	103.1	367.7	105.9
Straightbred X Terminal:										
50%	208.0	99.4	76.9	85.3	91.4	114.0	284.9	95.2	376.4	99.2
60%	210.2	100.5	81.0	89.9	93.3	116.3	291.2	97.3	384.5	101.3
70%	219.1	104.7	76.5	84.9	94.9	118.4	295.6	98.8	390.5	102.9
80%	241.9	115.7	62.4	69.2	96.0	119.7	304.3	101.7	400.3	105.5
90%	271.7	129.9	39.8	44.1	94.9	118.4	311.5	104.1	406.4	107.1
Rota-Terminal:										
50%	220.6	103.7	71.5	79.6	97.9	112.2	292.1	96.6	390.0	100.1
60%	213.4	100.3	81.9	91.2	100.9	115.6	295.3	97.6	396.3	101.7
70%	222.9	104.8	75.3	83.9	102.1	116.9	298.2	98.6	400.3	102.7
80%	249.9	117.6	66.5	74.0	100.6	115.2	316.4	104.6	417.0	107.0
90%	284.2	133.7	43.4	48.4	97.9	112.2	327.7	108.3	425.6	109.2

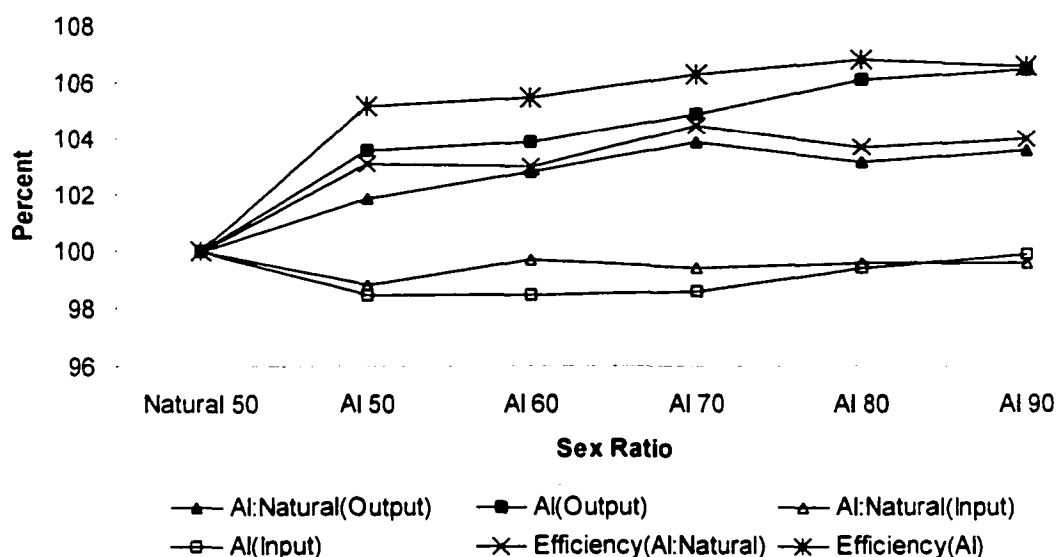
*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as replacements.

Increases in efficiency and production were achieved with little to no increase in system inputs (Table 4.10). System inputs (cow-calf, stocker and feeder phases of production) for the straightbred system (regardless of breeding method) were less than or equal to that of the base scenario. This most likely reflects the decrease in herd sire numbers. In the rotation-terminal mating system, increases in system inputs increased as much as .7 and 1.9% when using artificial insemination once versus as the sole method of breeding. As before in the cow-calf production system, increases in system input were related to increased nutritional requirements of a crossbred dam as well as the crossbred offspring. In the straightbred X terminal system, increases in inputs were as much as .9% and reflect increases in nutritional demand in producing crossbred offspring. Said increases appear to outweigh any advantage obtained from reducing the number of herd sires.

As with LWW, biological efficiency, whether value-adjusted or not, appears to be primarily a function of production due to the small increase, if any, in system inputs as demonstrated graphically in Figure 4.4 (straightbred mating system), Figure 4.5 (straightbred X terminal mating system) and Figure 4.6 (rotation-terminal mating system). Trends in biological efficiency of LW versus production and inputs were similar to LWW. As in LWW, biological efficiency did not necessarily peak at 90% sexing. In some instances, sexing beyond 70 to 80% returned less value in terms of biological efficiency per unit of sexing efficacy. The greatest increases in efficiency were achieved in systems using artificial insemination as the sole method of breeding. As observed in LWW, increases in efficiency in the straightbred mating system appeared to be primarily a function of increases in steer and heifer LW/cow when artificial insemination was used

Unadjusted for value of product:



Adjusted for value of product:

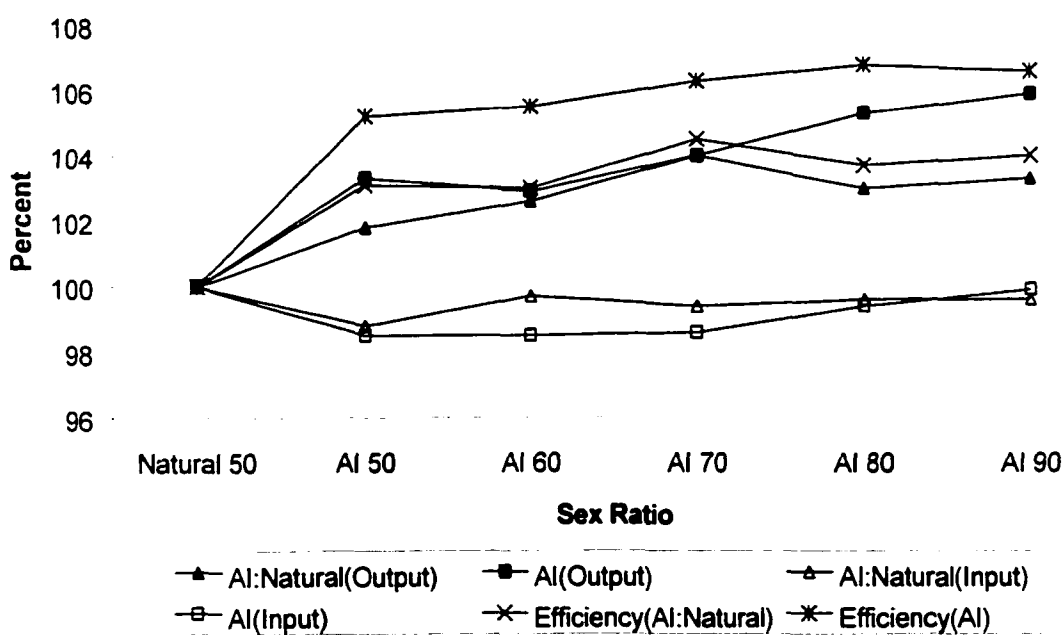
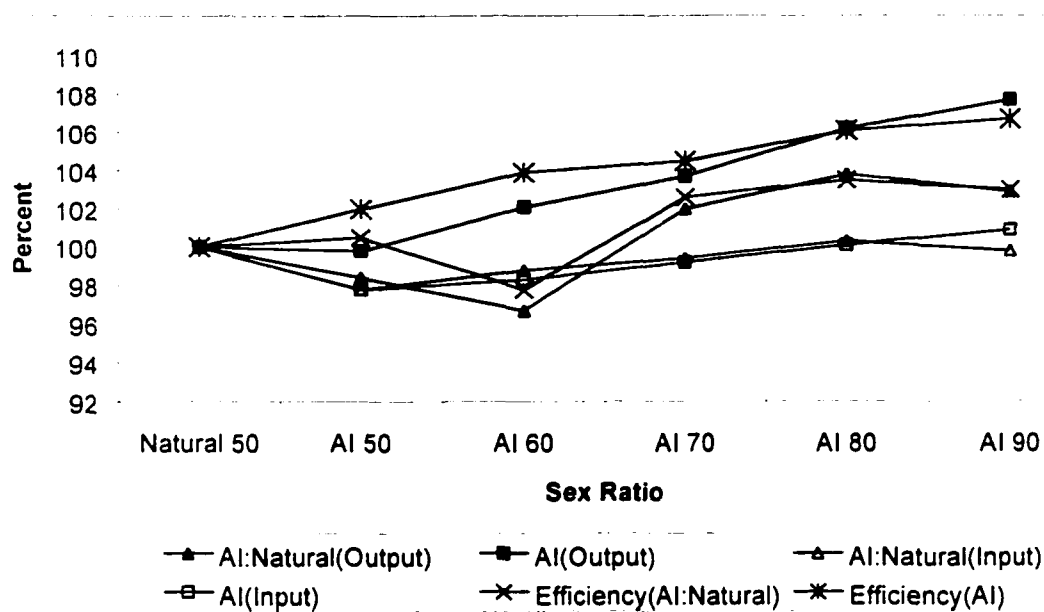


Figure 4.4. Production versus input (relative to the straightbred natural service base scenario) for live weight at harvest of straightbred management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

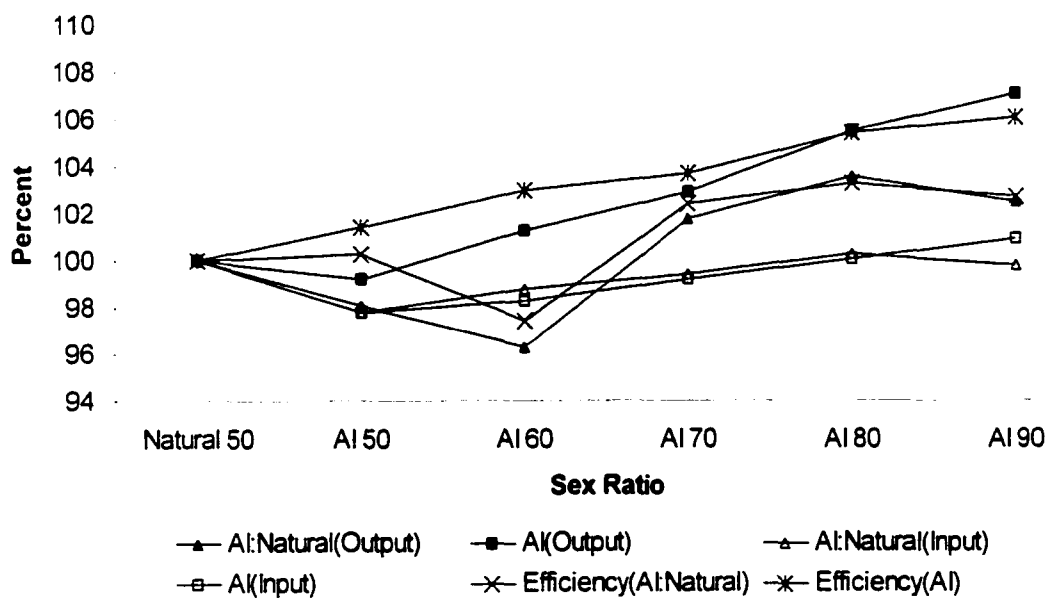
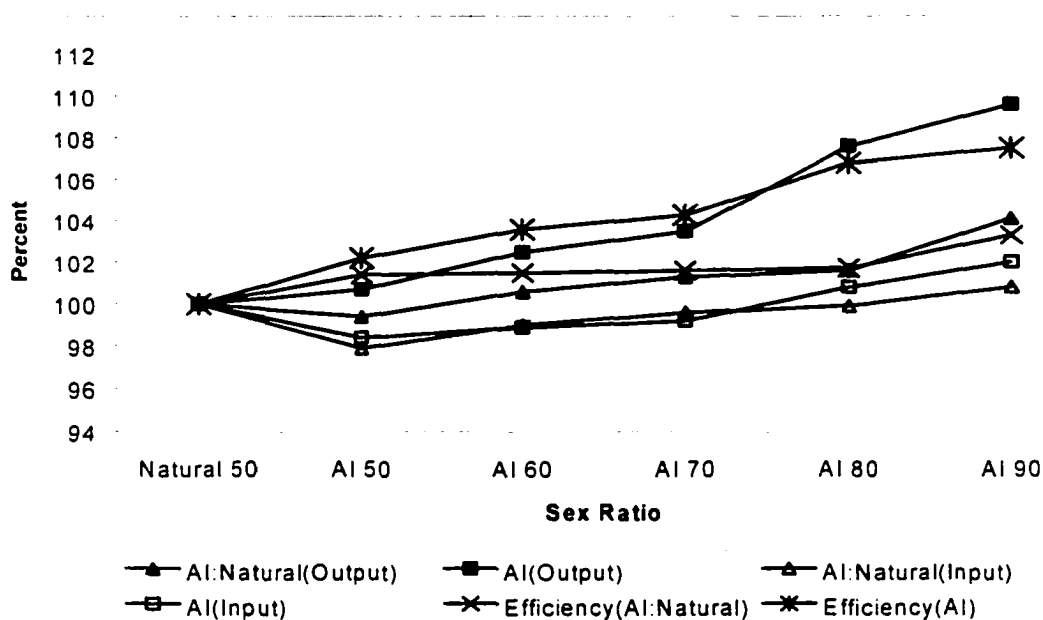


Figure 4.5. Production versus inputs (relative to straightbred by terminal natural service base scenario) for live weight at harvest.

Unadjusted for value of product:



Adjusted for value of product:

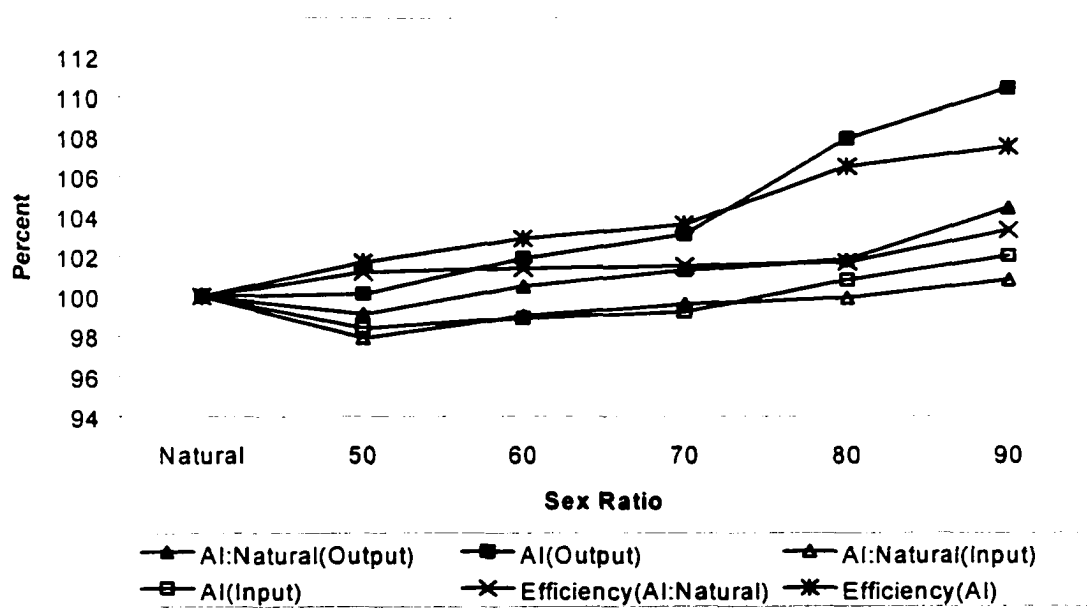


Figure 4.6. Production versus inputs (relative to the rota-terminal natural service base scenario) for live weight at harvest of rota-terminal management scenarios implementing sex control.

along with natural breeding; however, efficiency in most other cases was due specifically to increases in steer and cull LW/cow. There is potential to increase efficiency of LW/cow production, given artificial insemination with sexed inseminates. Details on maternal calf, terminal calf and cull numbers along with average LW can be found in Appendix H.

Carcass Weight

Biological efficiency of CW increased in all mating systems when sexing was applied with one exception being the straightbred X terminal scenario using artificial insemination followed by natural service and 60% sexing efficacy (Table 4.15). When using artificial insemination in combination with natural service, the largest increase was observed in the straightbred mating system using 70% efficacy (4.5%) followed by the straightbred X terminal mating system using 80% efficacy (3.6%) and rotation-terminal mating system using 90% efficacy (3.6%). If only artificial insemination is used, the largest increase was observed in the rotation-terminal mating system (8.2%) followed by the straightbred X terminal system (7.1%) and the straightbred mating system (6.8%). The straightbred increase represents 80% efficacy while the other two represent 90% efficacy. Biological efficiency for fed and cull CW varied among mating systems and efficacy of sexing and did not necessarily increase as sexing increased from 50 to 90%. However, fed CW production efficiency did increase as sexing efficacy increased in most cases involving crossbreeding. Carcass weight production per cow at slaughter increased in all three mating systems when sexing was applied with the one exception in the straightbred X terminal scenario mentioned previously. In most cases, production increased as sexing efficacy increased from 50 to 90% (Table 4.16). In the straightbred

Table 4.15. Biological efficiency for carcass weight (CW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed CW	Percent*	Cull CW**	Percent*	Total CW	Percent*
NATURAL						
Straightbred	160.4	100.0	489.7	100.0	120.8	100.0
Straight X Terminal	144.7	100.0	512.8	100.0	112.9	100.0
Rota-Terminal	148.0	100.0	486.3	100.0	113.5	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	155.6	102.8	473.4	103.7	117.1	103.1
60%	156.2	102.3	467.4	105.0	117.1	103.0
70%	151.1	105.8	486.8	100.8	115.3	104.5
80%	156.8	101.9	453.5	108.3	116.5	103.7
90%	157.9	101.3	440.9	111.3	116.2	104.0
Straightbred X Terminal:						
50%	146.2	99.0	489.7	104.7	112.6	100.3
60%	152.1	95.1	484.6	105.8	115.8	97.5
70%	142.1	101.8	486.3	105.5	110.0	102.6
80%	141.6	102.2	473.3	108.3	109.0	103.6
90%	144.1	100.4	457.0	112.2	109.5	103.0
Rota-Terminal:						
50%	148.1	99.9	460.7	105.6	112.1	101.2
60%	146.4	101.1	472.3	103.0	111.7	101.5
70%	146.5	101.0	466.8	104.2	111.5	101.8
80%	145.2	101.9	477.0	102.0	111.3	101.9
90%	144.8	102.2	450.2	108.0	109.5	103.6
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	154.5	103.5	445.6	109.9	114.7	105.2
60%	161.7	98.7	395.5	123.9	114.8	105.5
70%	157.9	101.0	406.3	120.6	113.7	106.3
80%	156.2	102.1	410.2	119.5	113.1	106.8
90%	154.2	103.2	423.8	115.7	113.1	106.6
Straightbred X Terminal:						
50%	148.8	97.2	440.1	116.5	111.2	101.5
60%	146.1	99.1	430.3	119.2	109.1	103.5
70%	144.8	100.0	428.4	119.7	108.2	104.3
80%	141.5	102.3	426.4	120.3	106.2	106.2
90%	139.1	104.0	435.2	117.8	105.4	107.1
Rota-Terminal:						
50%	150.9	98.1	424.8	114.5	111.3	101.9
60%	149.7	98.9	411.3	118.2	109.7	103.4
70%	148.3	99.8	409.1	118.9	108.8	104.3
80%	141.5	104.6	420.5	115.6	105.9	107.2
90%	138.0	107.2	437.3	111.2	104.9	108.2

*Percent relative to the baseline where the baseline is the straightbred, natural breeding management scenario.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.16. Carcass weight production at harvest (CW) per cow.

Management Scenario	Fed Steer CW, kg	Percent*	Fed Heifer CW, kg	Percent*	Cull CW**, kg	Percent*	Total Fed CW, kg	Percent*	Total CW, kg	Percent*
NATURAL										
Straightbred	121.3	100.0	45.7	100.0	54.7	100.0	167.0	100.0	221.7	100.0
Straight X Terminal	133.0	100.0	57.3	100.0	53.7	100.0	190.3	100.0	244.0	100.0
Rota-Terminal	135.4	100.0	57.1	100.0	58.6	100.0	192.5	100.0	251.0	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	125.9	103.8	44.3	97.0	55.9	102.3	170.2	101.9	226.2	102.0
60%	123.7	102.0	47.5	103.8	57.2	104.5	171.2	102.5	228.3	103.0
70%	125.0	103.0	51.3	112.2	54.7	100.0	176.3	105.5	231.0	104.2
80%	124.4	102.6	45.8	100.2	58.9	107.6	170.2	101.9	229.1	103.3
90%	125.3	103.3	43.8	95.9	60.5	110.7	169.1	101.2	229.7	103.6
Straightbred X Terminal:										
50%	129.5	97.4	54.9	95.8	55.0	102.5	184.4	96.9	239.4	98.1
60%	123.6	93.0	55.3	96.6	56.2	104.6	179.0	94.1	235.2	96.4
70%	134.3	101.0	58.3	101.9	56.3	104.8	192.6	101.2	248.9	102.0
80%	140.4	105.5	54.7	95.5	58.3	108.7	195.1	102.5	253.4	103.9
90%	140.9	106.0	49.9	87.1	60.2	112.0	190.8	100.3	251.0	102.9
Rota-Terminal:										
50%	136.9	101.1	51.6	90.4	60.6	103.5	188.5	98.0	249.1	99.2
60%	138.2	102.1	54.7	95.8	59.8	102.0	192.8	100.2	252.6	100.6
70%	137.5	101.6	56.3	98.6	60.8	103.8	193.8	100.7	254.6	101.4
80%	142.4	105.2	53.7	94.1	59.7	101.9	196.1	101.9	255.8	101.9
90%	145.2	107.2	53.0	92.9	63.7	108.8	198.2	103.0	262.0	104.4
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	127.5	105.1	43.4	94.9	59.2	108.2	170.8	102.3	230.0	103.7
60%	120.2	99.1	43.0	94.1	66.7	122.0	163.2	97.7	229.9	103.7
70%	125.9	103.8	41.5	90.8	65.0	118.9	167.4	100.2	232.5	104.8
80%	135.9	112.0	34.5	75.5	64.9	118.6	170.4	102.0	235.3	106.1
90%	149.6	123.3	24.0	52.6	63.2	115.5	173.6	103.9	236.8	106.8
Straightbred X Terminal:										
50%	132.1	99.3	48.9	85.4	61.2	114.0	181.1	95.2	242.3	99.3
60%	134.0	100.7	51.4	89.8	62.9	117.2	185.4	97.4	248.3	101.8
70%	140.1	105.4	48.6	84.9	63.8	118.8	188.8	99.2	252.6	103.5
80%	155.2	116.7	39.6	69.1	64.7	120.4	194.8	102.4	259.5	106.4
90%	174.5	131.2	25.2	44.0	63.9	118.9	199.7	105.0	263.6	108.0
Rota-Terminal:										
50%	140.5	103.8	45.5	79.7	66.1	112.8	186.0	96.6	252.1	100.4
60%	136.2	100.6	52.1	91.3	68.5	117.0	188.3	97.9	256.9	102.3
70%	142.8	105.4	48.0	84.1	69.1	118.0	190.7	99.1	259.9	103.5
80%	160.5	118.6	42.3	74.1	68.2	116.5	202.8	105.4	271.0	108.0
90%	182.8	135.0	27.6	48.3	66.4	113.3	210.3	109.3	276.7	110.2

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

and straightbred X terminal mating systems using artificial insemination in combination with natural service, peak production occurred at 70 and 80% efficacy, respectively.

Bio-economic efficiency (weights adjusted for product value differentiation) increased as sexing was implemented in most cases (Table 4.17). Said increases differed among mating systems and efficacy of sexing. In the straightbred X terminal mating system using artificial insemination in combination with natural service, the bio-economic efficiency decreased due to decreases in CW production. The largest increase was achieved for the straightbred mating system at a 70% sexing efficacy (4.7%) while increases in the straightbred X terminal and rotation-terminal mating systems were 3.8 and 4.1 at sexing efficacies of 80 and 90%, respectively. When using artificial insemination as the sole method of breeding, the largest increase in bio-economic efficiency was in the rotation-terminal mating system (13.8%) followed by the straightbred mating system (10.4%) and the straightbred X terminal mating system (12.1%). All were sexed inseminates at 90% efficacy. Adjusted CW per cow increased in all three mating systems due to increases in fed steer weight produced (Table 4.18). Carcass weight production increased with increased sexing ability in most scenarios; however, CW production was highest within the straightbred mating system using artificial insemination in combination with natural service at 70% sexing efficacy. This was due primarily to the increase in fed CW. Said increases in efficiency and production were achieved with little to no increase in system inputs (Table 4.10). See the previous discussion under LW for a more detailed description of input relationships.

Biological efficiency, whether value-adjusted or not, is primarily a function of production due to the small increase, if any, in system inputs. This is demonstrated

Table 4.17. Bio-economic efficiency for carcass weight (CW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed CW	Percent*	Cull CW**	Percent*	Total CW	Percent*
NATURAL						
Straightbred	178.0	100.0	1050.1	100.0	152.2	100.0
Straight X Terminal	162.3	100.0	1100.2	100.0	141.4	100.0
Rota-Terminal	165.7	100.0	1041.3	100.0	143.0	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	171.7	103.7	1017.2	103.2	146.9	103.6
60%	173.5	102.6	1004.4	104.6	147.9	102.9
70%	168.8	105.4	1046.7	100.3	145.4	104.7
80%	173.6	102.5	972.0	108.0	147.3	103.3
90%	174.1	102.2	943.6	111.3	147.0	103.5
Straightbred X Terminal:						
50%	163.7	99.2	1052.6	104.5	141.7	99.9
60%	171.2	94.8	1040.7	105.7	147.0	96.2
70%	159.5	101.8	1044.2	105.4	138.4	102.2
80%	157.5	103.1	1014.4	108.5	136.3	103.8
90%	159.0	102.1	977.7	112.5	136.8	103.4
Rota-Terminal:						
50%	164.3	100.8	989.1	105.3	140.9	101.5
60%	163.0	101.6	1015.8	102.5	140.5	101.8
70%	163.6	101.3	1002.3	103.9	140.6	101.6
80%	161.1	102.9	1023.3	101.8	139.2	102.7
90%	160.2	103.4	964.9	107.9	137.4	104.1
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	170.0	104.7	960.1	109.4	144.4	105.4
60%	178.7	99.6	852.1	123.2	147.7	103.0
70%	173.4	102.7	876.7	119.8	144.7	105.1
80%	168.5	105.6	884.9	118.7	141.5	107.5
90%	162.3	109.6	914.6	114.8	137.9	110.4
Straightbred X Terminal:						
50%	164.9	98.4	944.7	116.5	140.4	100.8
60%	162.3	100.0	929.7	118.3	138.2	102.4
70%	159.6	101.7	923.1	119.2	136.1	104.0
80%	152.7	106.3	920.3	119.5	130.9	108.0
90%	145.8	111.4	938.8	117.2	126.2	112.1
Rota-Terminal:						
50%	165.4	100.2	912.8	114.1	140.0	102.1
60%	166.2	99.7	888.4	117.2	140.0	102.1
70%	163.1	101.6	882.5	118.0	137.6	103.9
80%	153.0	108.3	908.4	114.6	131.0	109.2
90%	144.9	114.4	943.8	110.3	125.6	113.8

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.18. Value-adjusted simulated carcass weight (CW) at harvest per cow for various management scenarios.

Management Scenario	Fed Steer CW, kg	Percent*	Fed Heifer CW, kg	Percent*	Cull CW**, kg	Percent*	Total Fed CW, kg	Percent*	Total CW, kg	Percent*
NATURAL										
Straightbred	121.3	100.0	29.3	100.0	25.5	100.0	150.6	100.0	176.1	100.0
Straight X Terminal	133.0	100.0	36.7	100.0	25.0	100.0	169.7	100.0	194.7	100.0
Rota-Terminal	135.4	100.0	36.5	100.0	27.4	100.0	171.9	100.0	199.3	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	125.9	103.8	28.4	97.0	26.0	102.0	154.2	102.4	180.3	102.4
60%	123.7	102.0	30.4	103.8	26.6	104.3	154.1	102.3	180.7	102.6
70%	125.0	103.0	32.8	112.2	25.5	99.7	157.8	104.8	183.3	104.1
80%	124.4	102.6	29.3	100.2	27.5	107.6	153.8	102.1	181.2	102.9
90%	125.3	103.3	28.1	95.9	28.3	110.9	153.3	101.8	181.6	103.1
Straightbred X Terminal:										
50%	129.5	97.4	35.1	95.8	25.6	102.3	164.7	97.1	190.3	97.7
60%	123.6	93.0	35.4	96.6	26.2	104.5	159.1	93.8	185.2	95.1
70%	134.3	101.0	37.3	101.9	26.2	104.7	171.6	101.2	197.8	101.6
80%	140.4	105.5	35.0	95.5	27.2	108.8	175.4	103.4	202.6	104.1
90%	140.9	106.0	31.9	87.1	28.1	112.4	172.9	101.9	201.0	103.2
Rota-Terminal:										
50%	136.9	101.1	33.0	90.4	28.2	103.2	169.9	98.9	198.2	99.4
60%	138.2	102.1	35.0	95.8	27.8	101.6	173.2	100.7	201.0	100.8
70%	137.5	101.6	36.0	98.6	28.3	103.5	173.5	100.9	201.8	101.3
80%	142.4	105.2	34.4	94.1	27.8	101.7	176.7	102.8	204.6	102.7
90%	145.2	107.2	33.9	92.9	29.7	108.7	179.1	104.2	208.9	104.8
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	127.5	105.1	27.8	94.9	27.5	109.8	155.2	103.1	182.7	103.8
60%	120.2	99.1	27.5	94.1	31.0	123.8	147.7	98.1	178.7	101.5
70%	125.9	103.8	26.6	90.8	30.2	120.5	152.5	101.3	182.6	103.7
80%	135.9	112.0	22.1	75.5	30.1	120.2	158.0	104.9	188.1	106.8
90%	149.6	123.3	15.4	52.6	29.3	117.0	165.0	109.6	194.2	110.3
Straightbred X Terminal:										
50%	132.1	99.3	31.3	85.4	28.5	111.8	163.4	96.3	192.0	98.6
60%	134.0	100.7	32.9	89.8	29.1	114.1	166.9	98.4	196.0	100.7
70%	140.1	105.4	31.1	84.9	29.6	116.0	171.3	101.0	200.9	103.2
80%	155.2	116.7	25.3	69.1	30.0	117.4	180.6	106.4	210.5	108.1
90%	174.5	131.2	16.1	44.0	29.6	116.0	190.7	112.4	220.3	113.1
Rota-Terminal:										
50%	140.5	103.8	29.1	79.7	30.7	112.4	169.6	98.7	200.4	100.6
60%	136.2	100.6	33.3	91.3	31.7	116.0	169.6	98.6	201.3	101.0
70%	142.8	105.4	30.7	84.1	32.1	117.2	173.5	100.9	205.5	103.1
80%	160.5	118.6	27.1	74.1	31.6	115.5	187.6	109.1	219.2	110.0
90%	182.8	135.0	17.7	48.3	30.8	112.4	200.4	116.6	231.2	116.0

*Percent relative to the baseline where the baseline is the straightbred, natural breeding management scenario.

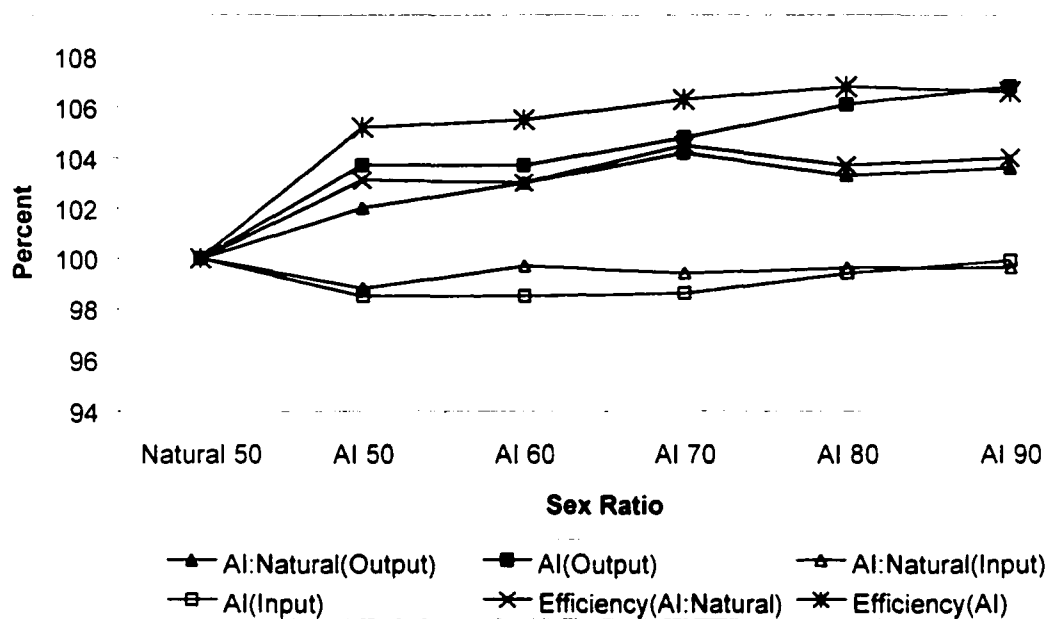
**Includes cull cows and exposed heifers not chosen as herd replacements.

graphically in Figure 4.7 (straightbred mating system), Figure 4.8 (straightbred X terminal mating system) and Figure 4.9 (rotation-terminal mating system). Similar trends exist for CW as for LW due to the relationship between the two traits. Artificial insemination with conventional, unsexed inseminate produced biological efficiencies better or similar to the natural service base scenario. Sexing added value to artificial insemination in terms of efficiency. The greatest increases in efficiency were achieved in systems using artificial insemination as the sole method of breeding. As observed in both LW and LWW, increases in efficiency in the straightbred mating system using artificial insemination with natural breeding appeared to be due primarily to increases in both steer and heifer CW/cow while efficiency appeared to be primarily a function of steer and cull CW/cow in all other systems. Again, there is potential to increase efficiency of CW/cow production, given artificial insemination with sexed inseminates. Details on maternal calf, terminal calf and cull numbers along with average CW can be found in Appendix I.

Empty Body Weight

Biological efficiency of EBW increased in all mating systems when sexing was applied with the exception of the straightbred X terminal scenario using artificial insemination followed by natural service and 60% sexing efficacy (Table 4.19). When using artificial insemination in combination with natural service, the largest increase was observed in the straightbred mating system using 70% efficacy (4.6%) followed by the straightbred X terminal mating system using 80% efficacy (3.4%) and rotation-terminal mating system using 90% efficacy (3.3%). If only artificial insemination is used, the largest increase was observed in the rotation-terminal mating system (7.5%) followed by the straightbred X terminal mating system (6.5%) and the straightbred mating system

Unadjusted for value of product:



Adjusted for value of product:

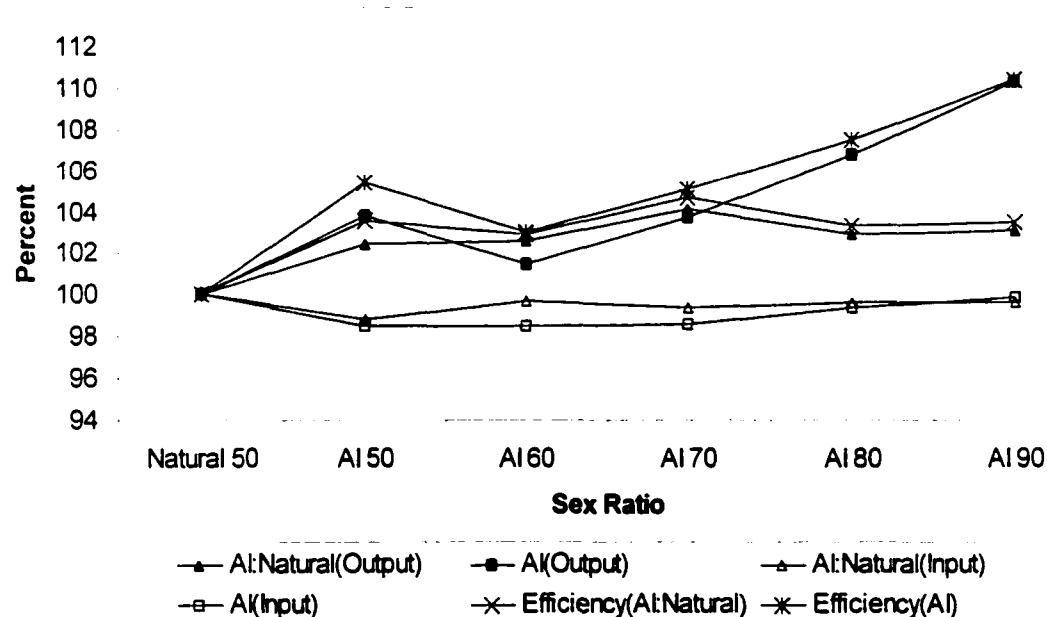
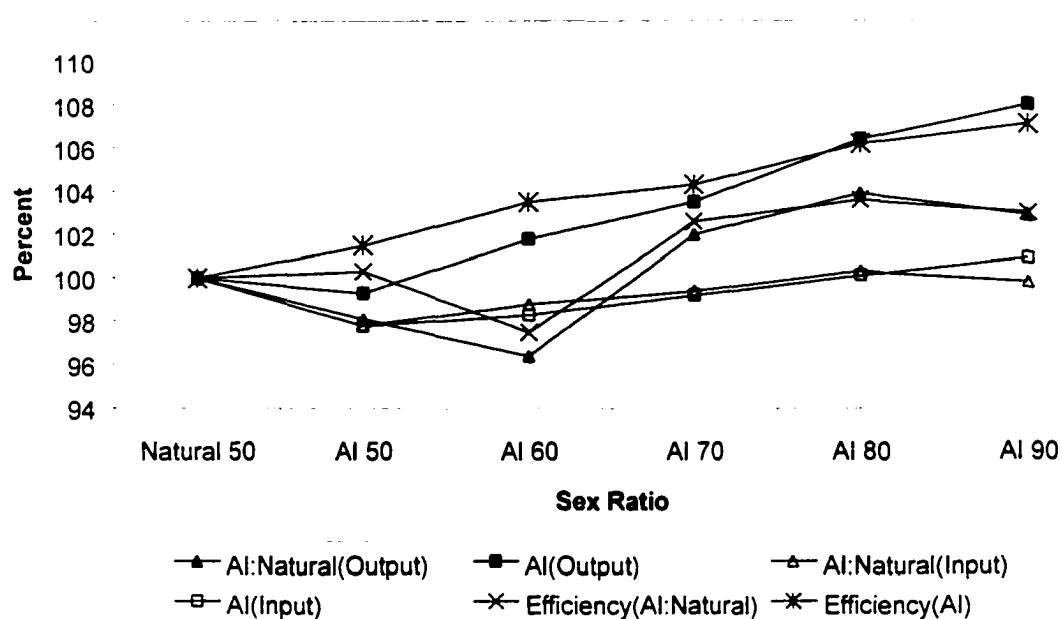


Figure 4.7. Production versus inputs (relative to the straightbred natural service base scenario) for carcass weight at harvest of straightbred management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

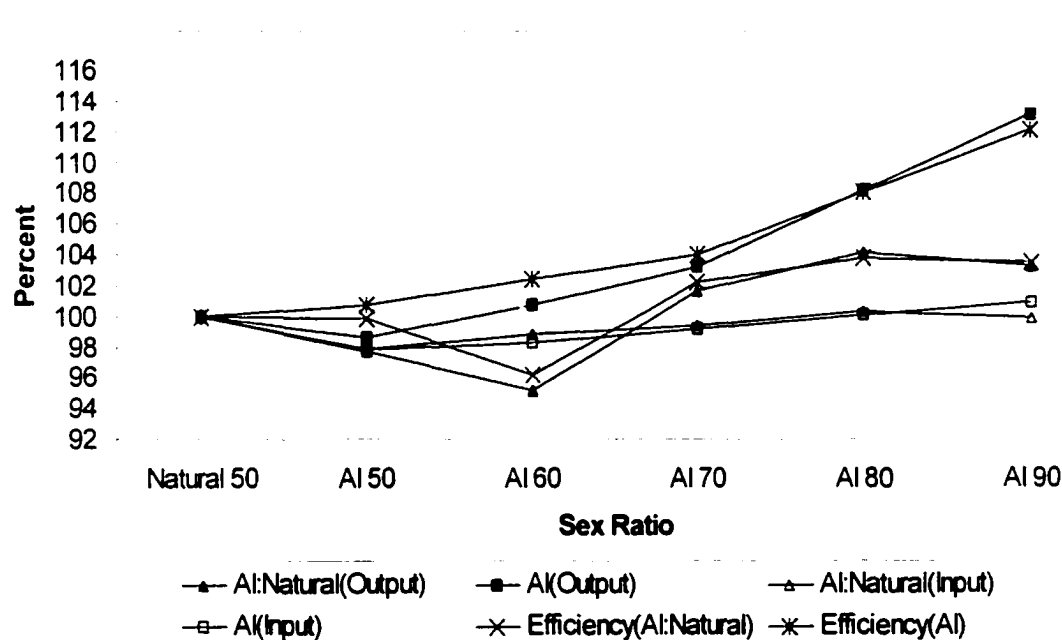
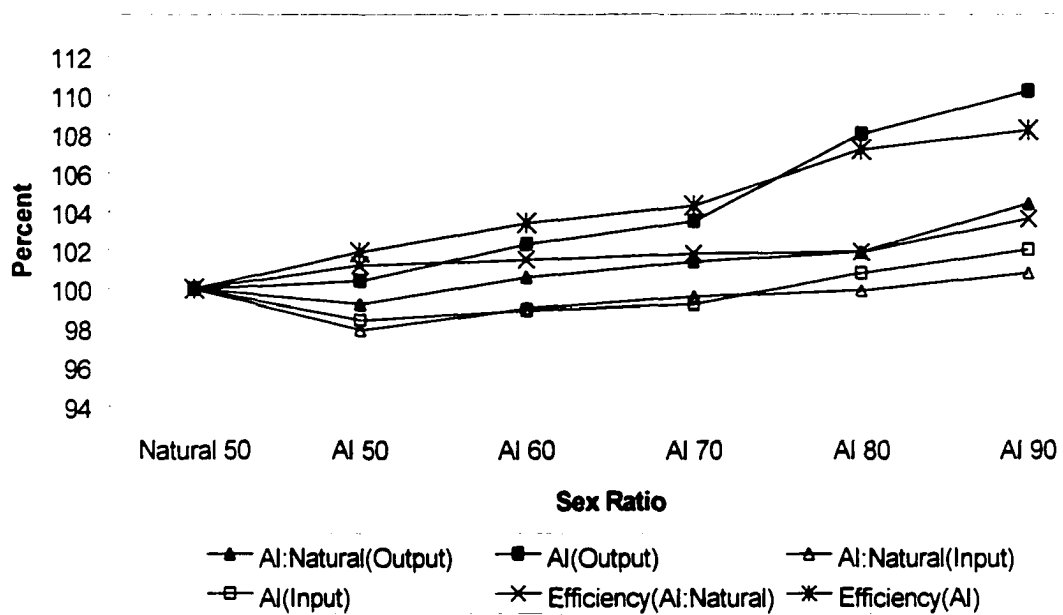


Figure 4.8. Production versus inputs (relative to the straightbred by terminal natural service base scenario) for carcass weight at harvest of straightbred by terminal management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

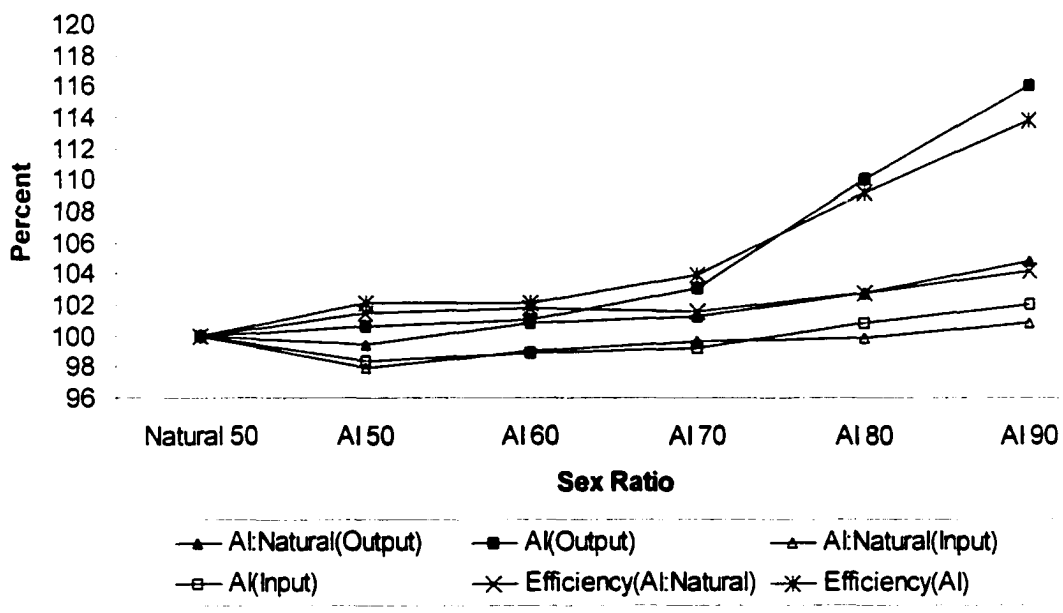


Figure 4.9. Production versus inputs (relative to the rota-terminal natural service base scenario) for carcass weight at harvest of rota-terminal management scenarios implementing sex control

Table 4.19. Biological efficiency for empty body weight (EBW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed EBW	Percent*	Cull EBW**	Percent*	Total EBW	Percent*
NATURAL						
Straightbred	109.3	100.0	331.1	100.0	82.1	100.0
Straight X Terminal	99.5	100.0	346.6	100.0	77.3	100.0
Rota-Terminal	101.8	100.0	329.6	100.0	77.8	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	106.2	102.8	319.4	103.7	79.7	103.0
60%	106.7	102.4	315.6	104.9	79.7	103.0
70%	103.2	105.8	328.7	100.7	78.6	104.6
80%	107.1	102.0	305.9	108.2	79.4	103.5
90%	107.9	101.3	297.5	111.3	79.2	103.7
Straightbred X Terminal:						
50%	100.4	99.1	330.6	104.8	77.0	100.4
60%	104.6	95.1	327.1	106.0	79.2	97.5
70%	97.9	101.6	328.2	105.6	75.4	102.5
80%	97.6	101.9	319.4	108.5	74.8	103.4
90%	99.4	100.1	308.2	112.5	75.2	102.8
Rota-Terminal:						
50%	101.9	100.0	312.5	105.5	76.8	101.3
60%	100.8	101.0	320.7	102.8	76.7	101.4
70%	101.0	100.8	316.6	104.1	76.6	101.6
80%	100.2	101.7	323.5	101.9	76.5	101.7
90%	100.0	101.8	305.4	107.9	75.3	103.3
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	105.6	103.5	301.3	109.9	78.2	105.1
60%	110.6	98.7	267.3	123.9	78.2	105.0
70%	108.1	101.1	274.6	120.6	77.6	105.9
80%	107.0	102.1	277.2	119.5	77.2	106.4
90%	105.8	103.3	286.4	115.6	77.3	106.3
Straightbred X Terminal:						
50%	102.3	97.3	297.1	116.6	76.1	101.6
60%	100.6	98.9	290.9	119.1	74.7	103.4
70%	99.9	99.6	289.3	119.8	74.3	104.1
80%	97.9	101.7	288.1	120.3	73.1	105.8
90%	96.4	103.2	294.0	117.9	72.6	106.5
Rota-Terminal:						
50%	103.9	98.0	288.4	114.3	76.4	101.9
60%	103.2	98.7	279.7	117.8	75.4	103.2
70%	102.5	99.4	278.0	118.6	74.9	103.9
80%	98.0	103.9	285.9	115.3	73.0	106.6
90%	95.7	106.4	297.2	110.9	72.4	107.5

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

(6.4%). The straightbred increase represents 80% efficacy while the other two represent 90% sexing efficacy. Biological efficiency for fed and cull EBW varied among mating systems and efficacy of sexing and did not necessarily increase as sexing increased from 50 to 90%. However, fed EBW production efficiency did increase as sexing efficacy increased in most cases involving the crossbreeding systems. Empty body weight production per cow at slaughter increased in all three mating systems when sexing was applied (Table 4.20) . In most cases, production increased as sexing efficacy increased from 50 to 90%. In the straightbred and straightbred X terminal mating systems using artificial insemination in combination with natural service, peak production occurred at 70 and 80% efficacy, respectively. When using artificial insemination only, peak production occurred at 90% sexing efficacy.

Bio-economic efficiency (weights adjusted for product value differentiation) increased in most instances as sexing was implemented (Table 4.21). Said increases differed among mating systems and efficacy of sexing. In the straightbred X terminal mating system using artificial insemination with 60% sexed inseminate in combination with natural service, the bio-economic efficiency decreased due to decreases in EBW production. The largest increase was achieved for the straightbred mating system at a 70% sexing efficacy (4.7%) while increases in the straightbred X terminal and rotation-terminal mating systems were 3.2 and 3.1 at sexing efficacies of 80 and 90%, respectively. When using artificial insemination as the sole method of breeding, the largest increase in bio-economic efficiency was in the rotation-terminal mating system (8.2%) followed by the straightbred X terminal mating system (6.8%) and the straightbred mating system (6.4%). All were sexed inseminates at 90% sexing accuracy. Adjusted

Table 4.20. Empty body weight production at harvest (EBW) per cow.

Management Scenario	Fed Steer EBW, kg	Percent*	Fed Heifer EBW, kg	Percent*	Cull EBW**, kg	Percent*	Total Fed EBW, kg	Percent*	Total EBW, kg	Percent*
NATURAL										
Straightbred	177.7	100.0	67.6	100.0	80.9	100.0	245.3	100.0	326.2	100.0
Straight X Terminal	193.4	100.0	83.3	100.0	79.5	100.0	276.8	100.0	356.2	100.0
Rota-Terminal	196.7	100.0	83.1	100.0	86.4	100.0	279.8	100.0	366.2	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	184.0	103.6	65.3	96.5	82.9	102.4	249.3	101.6	332.2	101.8
60%	180.6	101.7	69.8	103.3	84.7	104.6	250.5	102.1	335.2	102.8
70%	182.6	102.8	75.5	111.7	81.1	100.2	258.1	105.2	339.2	104.0
80%	181.6	102.2	67.5	99.9	87.3	107.8	249.1	101.6	336.4	103.1
90%	182.9	103.0	64.5	95.4	89.7	110.9	247.4	100.9	337.1	103.4
Straightbred X Terminal:										
50%	188.6	97.5	79.8	95.8	81.5	102.6	268.4	97.0	349.9	98.2
60%	179.8	93.0	80.6	96.7	83.2	104.8	260.3	94.1	343.6	96.5
70%	194.7	100.7	84.9	101.8	83.4	105.0	279.6	101.0	363.0	101.9
80%	203.2	105.1	79.7	95.6	86.5	108.8	282.9	102.2	369.4	103.7
90%	203.9	105.4	72.6	87.1	89.2	112.3	276.5	99.9	365.7	102.7
Rota-Terminal:										
50%	199.1	101.2	75.1	90.4	89.3	103.4	274.1	98.0	363.5	99.3
60%	200.6	102.0	79.6	95.8	88.0	101.9	280.1	100.1	368.1	100.5
70%	199.2	101.3	81.8	98.5	89.6	103.7	281.1	100.5	370.7	101.2
80%	206.1	104.8	78.2	94.1	88.0	101.8	284.3	101.6	372.3	101.7
90%	209.9	106.7	77.2	92.9	94.0	108.7	287.0	102.6	381.0	104.0
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	186.2	104.8	63.8	94.4	87.6	108.2	250.0	101.9	337.6	103.5
60%	175.3	98.7	63.2	93.5	98.8	122.0	238.6	97.3	337.3	103.4
70%	183.6	103.3	61.0	90.2	96.3	118.9	244.6	99.7	340.8	104.5
80%	198.0	111.5	50.7	75.0	96.0	118.7	248.8	101.4	344.8	105.7
90%	217.8	122.6	35.3	52.2	93.5	115.5	253.1	103.2	346.6	106.3
Straightbred X Terminal:										
50%	192.3	99.4	71.1	85.4	90.7	114.1	263.4	95.2	354.1	99.4
60%	194.4	100.5	74.9	89.8	93.1	117.1	269.2	97.3	362.3	101.7
70%	202.7	104.8	70.8	84.9	94.5	118.9	273.5	98.8	367.9	103.3
80%	224.0	115.8	57.7	69.2	95.7	120.4	281.7	101.8	377.3	105.9
90%	251.6	130.1	36.7	44.1	94.5	119.0	288.4	104.2	382.9	107.5
Rota-Terminal:										
50%	204.0	103.7	66.1	79.6	97.3	112.6	270.2	96.6	367.5	100.3
60%	197.4	100.4	75.8	91.2	100.8	116.6	273.2	97.7	374.0	102.1
70%	206.3	104.9	69.7	83.9	101.8	117.7	276.1	98.7	377.8	103.2
80%	231.5	117.7	61.5	74.0	100.4	116.2	293.0	104.7	393.4	107.4
90%	263.3	133.8	40.2	48.4	97.7	113.0	303.4	108.5	401.1	109.5

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.21. Bio-economic efficiency for empty body weight (EBW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed EBW	Percent*	Cull EBW**	Percent*	Total EBW	Percent*
NATURAL						
Straightbred	111.7	100.0	487.9	100.0	90.9	100.0
Straight X Terminal	102.0	100.0	510.9	100.0	85.0	100.0
Rota-Terminal	104.3	100.0	485.0	100.0	85.8	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	108.5	103.0	471.6	103.4	88.2	103.0
60%	109.1	102.4	466.0	104.7	88.4	102.8
70%	105.7	105.7	485.6	100.5	86.8	104.7
80%	109.5	102.0	450.6	108.3	88.1	103.2
90%	110.2	101.4	437.7	111.5	88.0	103.3
Straightbred X Terminal:						
50%	102.9	99.1	488.3	104.6	85.0	100.0
60%	107.2	95.1	482.6	105.9	87.7	96.9
70%	100.3	101.6	484.3	105.5	83.1	102.3
80%	99.8	102.1	470.4	108.6	82.4	103.2
90%	101.6	100.4	453.1	112.7	83.0	102.4
Rota-Terminal:						
50%	104.1	100.1	461.1	105.2	85.0	101.0
60%	103.1	101.1	473.8	102.4	84.7	101.4
70%	103.4	100.9	467.2	103.8	84.7	101.4
80%	102.4	101.8	476.9	101.7	84.3	101.8
90%	102.2	102.1	449.8	107.8	83.3	103.1
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	107.8	103.7	445.9	109.4	86.8	104.7
60%	113.0	98.8	395.6	123.3	87.9	103.4
70%	110.3	101.3	407.0	119.9	86.8	104.8
80%	108.8	102.7	410.8	118.8	86.0	105.7
90%	107.0	104.4	424.5	114.9	85.5	106.4
Straightbred X Terminal:						
50%	104.6	97.5	438.3	116.6	84.4	100.7
60%	102.9	99.1	431.7	118.3	83.1	102.3
70%	102.0	99.9	428.3	119.3	82.4	103.1
80%	99.5	102.5	427.2	119.6	80.7	105.3
90%	97.4	104.7	435.7	117.3	79.6	106.8
Rota-Terminal:						
50%	105.9	98.5	425.9	113.9	84.8	101.2
60%	105.5	98.8	415.0	116.9	84.1	102.0
70%	104.6	99.7	411.8	117.8	83.4	102.9
80%	99.6	104.7	424.2	114.3	80.7	106.4
90%	96.7	107.9	440.6	110.1	79.3	108.2

*Percent relative to the baseline where the baseline natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

EBW per cow increased in all three mating systems and were due to increases in fed weight produced, primarily fed steer weight (Table 4.22). Empty body weight production increased with increased sexing ability; however, EBW production was highest within the straightbred mating system using artificial insemination in combination with natural service at 70% sexing efficacy. This was due primarily to the increase in fed EBW. The straightbred X terminal mating system achieved peak EBW production at 80% efficacy when using artificial insemination in combination with natural service. All other peak EBW production was achieved at 90% sexing efficacy. Said increases in efficiency and production were achieved with little to no increase in system inputs (Table 4.10). See the discussion of system inputs under LW.

Biological efficiency, whether value-adjusted or not, is to be primarily a function of production due to the small increase, if any, in system inputs as demonstrated graphically in Figure 4.10 (straightbred mating system), Figure 4.11 (straightbred X terminal mating system) and Figure 4.12 (rotation-terminal mating system). Similar trends exist between the previous production traits and EBW due to the relationships among these traits. Increases in efficiency were the greatest when using artificial insemination as the sole method of breeding. Increases in both steer and heifer EBW/cow contributed to increases in efficiency in the straightbred mating system using artificial insemination and natural breeding; however, increases in efficiency in all other systems appeared to be primarily due to increases in steer and cull EBW/cow. Increasing returns in efficiency appear to exist in the rotation-terminal system as sexing was applied; however, diminishing returns in efficiency as sexing was applied were observed in straightbred and straightbred by terminal (artificial insemination followed by natural

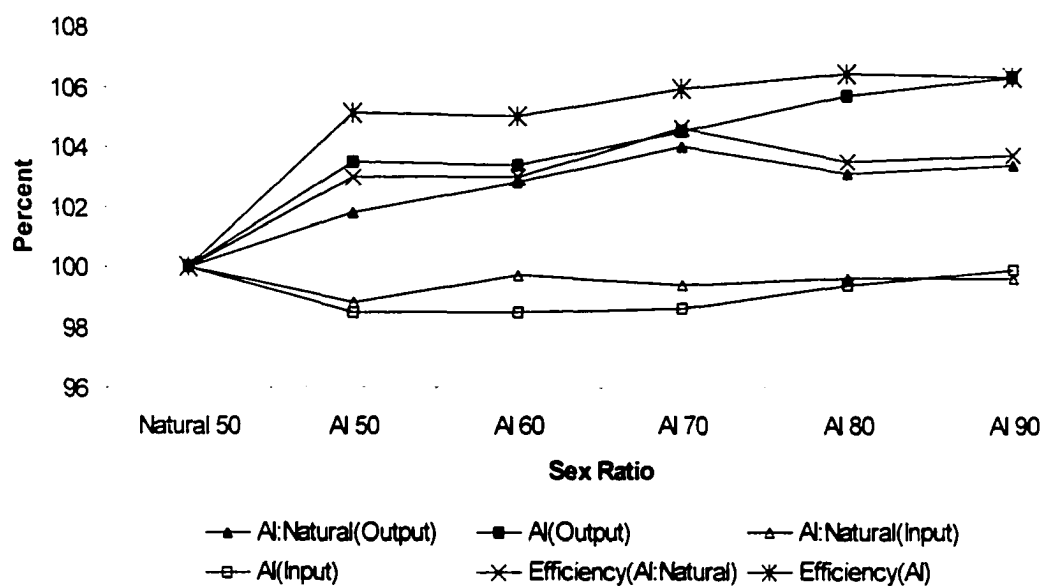
Table 4.22. Value-adjusted simulated empty body weight (EBW) at harvest per cow for various management scenarios.

Management Scenario	Fed Steer EBW, kg	Percent*	Fed Heifer EBW, kg	Percent*	Cull EBW**, kg	Percent*	Total Fed EBW, kg	Percent*	Total EBW, kg	Percent*
NATURAL										
Straightbred	177.7	100.0	62.2	100.0	54.9	100.0	239.9	100.0	294.8	100.0
Straight X Terminal	193.4	100.0	76.7	100.0	53.9	100.0	270.1	100.0	324.0	100.0
Rota-Terminal	196.7	100.0	76.4	100.0	58.7	100.0	273.1	100.0	331.9	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	184.0	103.6	60.0	96.5	56.2	102.2	244.1	101.8	300.2	101.8
60%	180.6	101.7	64.3	103.3	57.4	104.4	244.9	102.1	302.2	102.5
70%	182.6	102.8	69.5	111.7	54.9	99.9	252.1	105.1	306.9	104.1
80%	181.6	102.2	62.1	99.9	59.2	107.9	243.7	101.6	302.9	102.8
90%	182.9	103.0	59.3	95.4	61.0	111.1	242.3	101.0	303.3	102.9
Straightbred X Terminal:										
50%	188.6	97.5	73.4	95.8	55.2	102.4	262.0	97.0	317.2	97.9
60%	179.8	93.0	74.1	96.7	56.4	104.7	253.9	94.0	310.3	95.8
70%	194.7	100.7	78.1	101.8	56.5	104.9	272.8	101.0	329.3	101.7
80%	203.2	105.1	73.3	95.6	58.7	108.9	276.6	102.4	335.3	103.5
90%	203.9	105.4	66.8	87.1	60.7	112.6	270.7	100.2	331.4	102.3
Rota-Terminal:										
50%	199.1	101.2	69.1	90.4	60.6	103.1	268.1	98.2	328.7	99.0
60%	200.6	102.0	73.2	95.8	59.6	101.4	273.7	100.2	333.3	100.4
70%	199.2	101.3	75.3	98.5	60.8	103.5	274.5	100.5	335.3	101.0
80%	206.1	104.8	71.9	94.1	59.7	101.6	278.0	101.8	337.7	101.8
90%	209.9	106.7	71.0	92.9	63.8	108.6	280.8	102.8	344.6	103.8
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	186.2	104.8	58.7	94.4	59.2	107.7	244.9	102.1	304.1	103.1
60%	175.3	98.7	58.2	93.5	66.7	121.5	233.5	97.4	300.2	101.9
70%	183.6	103.3	56.1	90.2	64.9	118.3	239.7	99.9	304.6	103.3
80%	198.0	111.5	46.7	75.0	64.8	118.0	244.7	102.0	309.5	105.0
90%	217.8	122.6	32.5	52.2	63.1	114.8	250.3	104.3	313.3	106.3
Straightbred X Terminal:										
50%	192.3	99.4	65.4	85.4	61.5	114.1	257.7	95.4	319.2	98.5
60%	194.4	100.5	68.9	89.8	62.7	116.4	263.2	97.5	326.0	100.6
70%	202.7	104.8	65.1	84.9	63.8	118.4	267.8	99.2	331.6	102.4
80%	224.0	115.8	53.0	69.2	64.5	119.7	277.0	102.6	341.6	105.4
90%	251.6	130.1	33.8	44.1	63.8	118.4	285.4	105.7	349.2	107.8
Rota-Terminal:										
50%	204.0	103.7	60.8	79.6	65.9	112.2	264.9	97.0	330.8	99.7
60%	197.4	100.4	69.7	91.2	67.9	115.7	267.2	97.8	335.1	101.0
70%	206.3	104.9	64.1	83.9	68.7	116.9	270.5	99.0	339.2	102.2
80%	231.5	117.7	56.6	74.0	67.7	115.2	288.1	105.5	355.7	107.2
90%	263.3	133.8	37.0	48.4	65.9	112.2	300.2	109.9	366.1	110.3

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Unadjusted for value of product:



Adjusted for value of product:

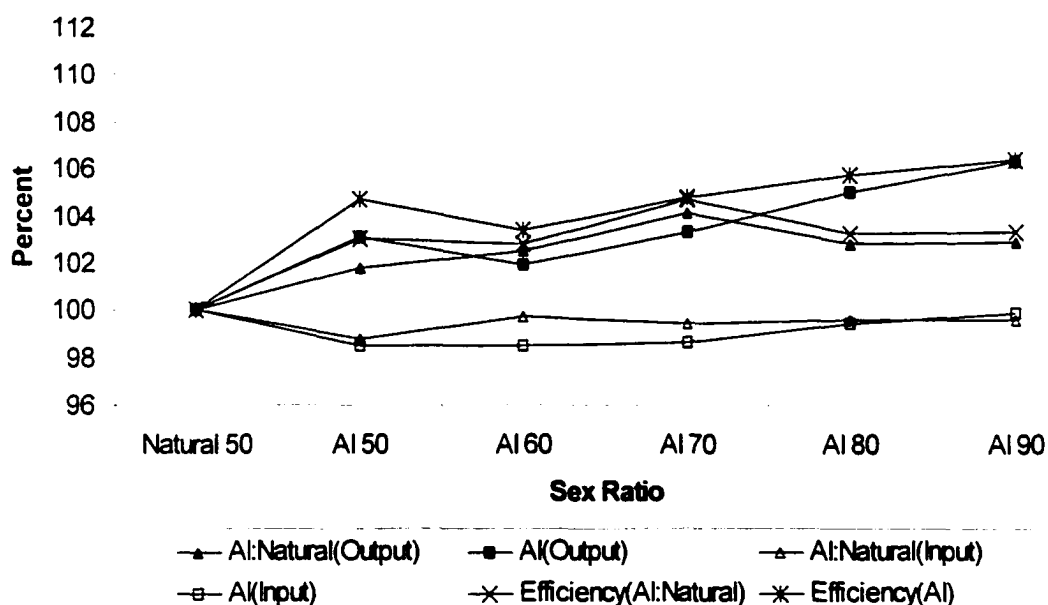
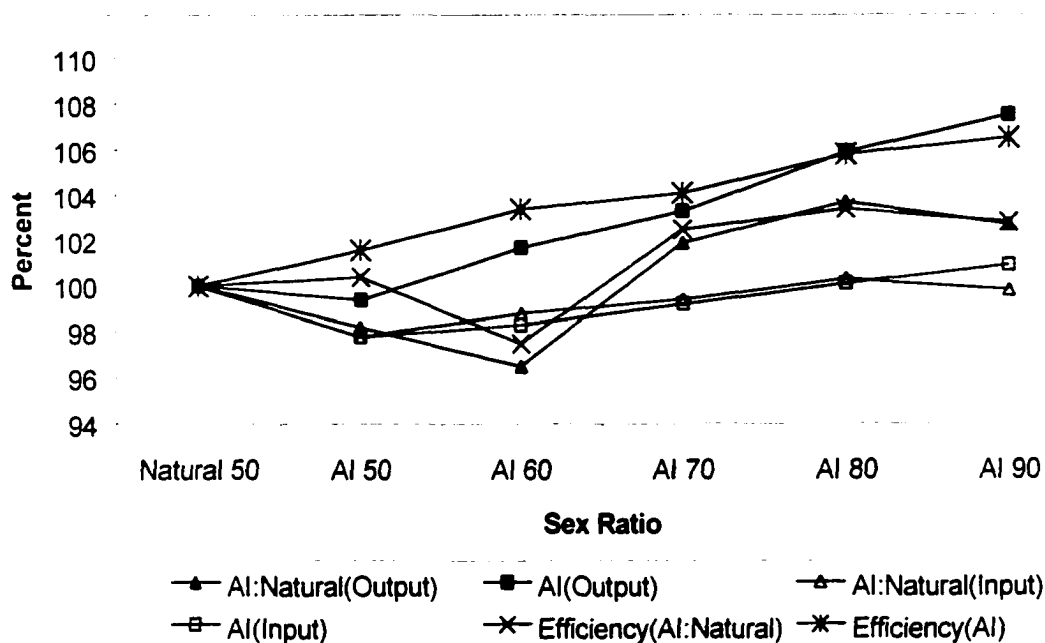


Figure 4.10. Production versus inputs (relative to the straightbred natural service base scenario) for empty body weight at harvest of straightbred management scenarios implementing sex control

Unadjusted for value of product:



Adjusted for value of product:

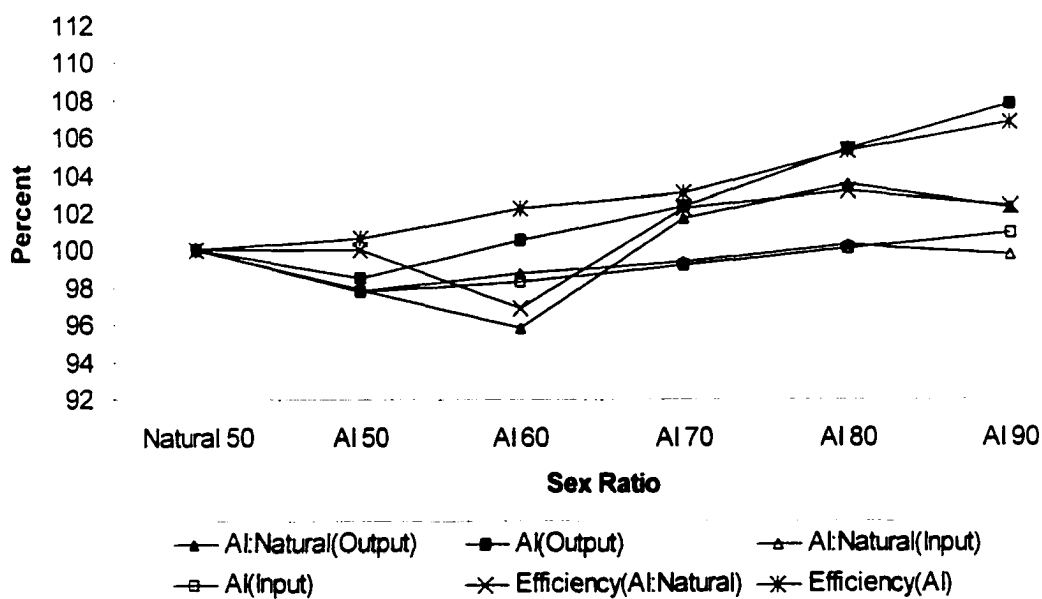
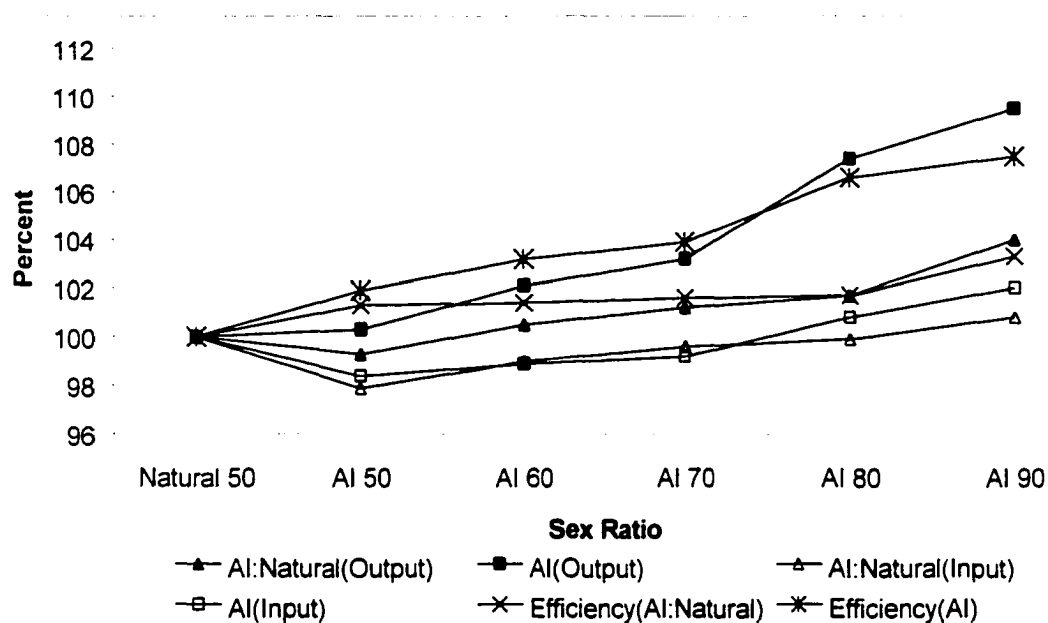


Figure 4.11. Production versus inputs (relative to the straightbred by terminal natural service base scenario) for empty body weight at harvest of straightbred by terminal management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

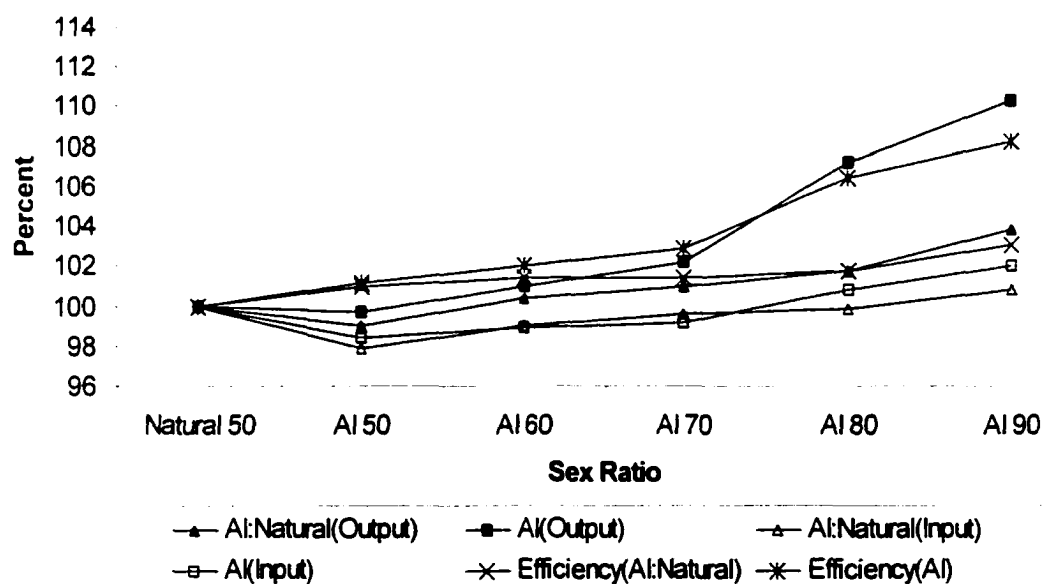


Figure 4.12. Production versus inputs (relative rota-terminal natural service base scenario) for empty body weight at harvest of rota-terminal management scenarios implementing sex control.

service) mating systems. Nonetheless, there is potential to increase efficiency of EBW/cow production, given artificial insemination with sexed inseminates. Details on maternal calf, terminal calf and cull numbers along with average EBW can be found in Appendix J.

Fat Free Weight

Biological efficiency of FFW increased in all mating systems when sexing was applied with one exception being the straightbred X terminal scenario using artificial insemination followed by natural service and 60% sexing efficacy (Table 4.23). When using artificial insemination in combination with natural service, the largest increase was observed in the straightbred mating system using 70% efficacy (4.7%) followed by the straightbred X terminal mating system using 80% efficacy (3.6%) and rotation-terminal mating system using 90% efficacy (3.4%). If only artificial insemination was used, the largest increase was observed in the rotation-terminal mating system (7.6%) followed by the straightbred X terminal mating system (6.8%) and the straightbred mating system (6.8%). The straightbred increase represents 80% efficacy while the other two represent 90% sexing efficacy. Biological efficiency for fed and cull FFW varied among mating systems and efficacy of sexing and did not necessarily increase as sexing increased from 50 to 90%. Fat free weight production per cow at slaughter increased in all three mating systems when sexing was applied (Table 4.24). In most cases, production increased as sexing efficacy increased from 50 to 90%. In the straightbred and straightbred X terminal mating systems using artificial insemination in combination with natural service, peak production occurred at 70 and 80% efficacy, respectively. When using artificial insemination only, peak production occurred at 90% sexing efficacy.

Table 4.23. Biological efficiency for fat free weight (FFW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed FFW	Percent*	Cull FFW**	Percent*	Total FFW	Percent*
NATURAL						
Straightbred	145.7	100.0	389.1	100.0	106.0	100.0
Straight X Terminal	132.7	100.0	407.2	100.0	100.1	100.0
Rota-Terminal	135.8	100.0	387.3	100.0	100.5	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	141.7	102.8	375.4	103.7	102.8	103.1
60%	142.3	102.4	370.9	104.9	102.8	103.1
70%	137.2	106.2	386.2	100.8	101.2	104.7
80%	142.9	102.0	359.5	108.3	102.2	103.7
90%	143.8	101.3	349.6	111.3	101.9	104.0
Straightbred X Terminal:						
50%	133.9	99.1	388.5	104.8	99.6	100.5
60%	139.4	95.1	384.4	106.0	102.3	97.8
70%	130.5	101.6	385.7	105.6	97.5	102.6
80%	130.1	101.9	375.3	108.5	96.6	103.6
90%	132.6	100.1	362.1	112.5	97.0	103.1
Rota-Terminal:						
50%	135.8	100.0	367.3	105.5	99.1	101.4
60%	134.4	101.0	376.8	102.8	99.0	101.5
70%	134.7	100.8	372.1	104.1	98.9	101.7
80%	133.5	101.7	380.2	101.9	98.8	101.7
90%	133.3	101.8	358.8	107.9	97.2	103.4
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	140.7	103.5	354.0	109.9	100.7	105.2
60%	147.5	98.7	314.0	123.9	100.4	105.6
70%	144.1	101.1	322.7	120.6	99.6	106.4
80%	142.7	102.1	325.7	119.5	99.2	106.8
90%	141.1	103.3	336.5	115.6	99.4	106.6
Straightbred X Terminal:						
50%	136.4	97.3	349.1	116.6	98.1	102.0
60%	134.1	98.9	341.9	119.1	96.3	103.9
70%	133.2	99.6	340.0	119.8	95.7	104.5
80%	130.5	101.7	338.6	120.3	94.2	106.2
90%	128.5	103.2	345.5	117.9	93.7	106.8
Rota-Terminal:						
50%	138.5	98.0	338.9	114.3	98.3	102.2
60%	137.6	98.7	328.7	117.8	97.0	103.7
70%	136.6	99.4	326.6	118.6	96.3	104.4
80%	130.6	103.9	336.0	115.3	94.0	106.9
90%	127.6	106.4	349.2	110.9	93.4	107.6

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.24. Fat free weight production at harvest (FFW) per cow.

Management Scenario	Fed Steer FFW, kg	Percent*	Fed Heifer FFW, kg	Percent*	Cull FFW**, kg	Percent*	Total Fed FFW, kg	Percent*	Total FFW, kg	Percent*
NATURAL										
Straightbred	133.3	100.0	50.7	100.0	68.9	100.0	183.9	100.0	252.8	100.0
Straight X Terminal	145.1	100.0	62.5	100.0	67.6	100.0	207.6	100.0	275.2	100.0
Rota-Terminal	147.5	100.0	62.3	100.0	73.6	100.0	209.8	100.0	283.4	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	138.0	103.6	48.9	96.5	70.6	102.5	187.0	101.6	257.5	101.9
60%	135.5	101.7	52.4	103.3	72.1	104.7	187.9	102.1	259.9	102.8
70%	136.9	102.8	57.2	112.9	69.0	100.2	194.2	105.6	263.1	104.1
80%	136.2	102.2	50.6	99.9	74.3	107.8	186.8	101.6	261.1	103.3
90%	137.2	103.0	48.5	95.6	76.4	110.9	185.6	100.9	262.0	103.6
Straightbred X Terminal:										
50%	141.4	97.5	59.9	95.8	69.4	102.6	201.3	97.0	270.7	98.4
60%	134.8	93.0	60.4	96.7	70.8	104.8	195.3	94.1	266.1	96.7
70%	146.1	100.7	63.7	101.8	71.0	105.0	209.7	101.0	280.7	102.0
80%	152.4	105.1	59.8	95.6	73.6	108.8	212.2	102.2	285.8	103.8
90%	152.9	105.4	54.5	87.1	75.9	112.3	207.4	99.9	283.3	102.9
Rota-Terminal:										
50%	149.3	101.2	56.3	90.4	76.0	103.4	205.6	98.0	281.6	99.4
60%	150.4	102.0	59.7	95.8	74.9	101.9	210.1	100.1	285.0	100.6
70%	149.4	101.3	61.4	98.5	76.3	103.7	210.8	100.5	287.1	101.3
80%	154.6	104.8	58.6	94.1	74.9	101.8	213.2	101.6	288.1	101.7
90%	157.4	106.7	57.9	92.9	80.0	108.7	215.3	102.6	295.2	104.2
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	139.6	104.8	47.9	94.4	74.5	108.2	187.5	101.9	262.0	103.6
60%	131.5	98.7	47.4	93.5	84.0	122.0	178.9	97.3	263.0	104.0
70%	137.7	103.3	45.7	90.2	81.9	118.9	183.4	99.7	265.3	105.0
80%	148.5	111.5	38.0	75.0	81.7	118.7	186.6	101.4	268.3	106.1
90%	163.3	122.6	26.5	52.2	79.6	115.5	189.8	103.2	269.4	106.6
Straightbred X Terminal:										
50%	144.2	99.4	53.4	85.4	77.2	114.1	197.6	95.2	274.7	99.8
60%	145.8	100.5	56.2	89.8	79.2	117.1	201.9	97.3	281.1	102.2
70%	152.0	104.8	53.1	84.9	80.4	118.9	205.1	98.8	285.5	103.7
80%	168.0	115.8	43.2	69.2	81.4	120.4	211.2	101.8	292.7	106.3
90%	188.7	130.1	27.6	44.1	80.4	119.0	216.3	104.2	296.7	107.8
Rota-Terminal:										
50%	153.0	103.7	49.6	79.6	82.8	112.6	202.6	96.6	285.4	100.7
60%	148.1	100.4	56.8	91.2	85.8	116.6	204.9	97.7	290.7	102.6
70%	154.8	104.9	52.3	83.9	86.6	117.7	207.0	98.7	293.6	103.6
80%	173.6	117.7	46.1	74.0	85.4	116.2	219.7	104.7	305.2	107.7
90%	197.5	133.8	30.1	48.4	83.1	113.0	227.6	108.5	310.7	109.6

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Bio-economic efficiency (weights adjusted for product value differentiation) increased as sexing was implemented in most cases (Table 4.25). Said increases differed among mating systems and efficacy of sexing. In the straightbred X terminal mating system using artificial insemination in combination with natural service at a 60% sexing efficacy, the bio-economic efficiency decreased due to decreases in FFW production. The largest increase was achieved for the straightbred mating system at a 70% sexing efficacy (4.5%) while increases in the straightbred X terminal and rotation-terminal mating systems were 3.7 and 3.7% at sexing efficacies of 80 and 90%, respectively. When using artificial insemination as the sole method of breeding, the largest increase in bio-economic efficiency was in the rotation-terminal mating system (11.9%) followed by the straightbred X terminal mating system (10.7%) and the straightbred mating system (9.3%). All were sexed inseminates at 90% sexing efficacy. Adjusted FFW per cow increased in all three mating systems due to increases in fed steer weight produced (Table 4.26). Empty body weight production increased with increased sexing ability; however, FFW production was highest within the straightbred mating system using artificial insemination in combination with natural service at 70% sexing efficacy. This was due primarily to the increase in fed FFW. The straightbred X terminal mating system achieved peak FFW production at 80% efficacy when using artificial insemination in combination with natural service. All other maximums in EBW production were achieved at 90% sexing efficacy. Said increases in efficiency and production were achieved with little to no increase in system inputs (Table 4.10). See input discussion under LW.

Table 4.25. Bio-economic efficiency for fat free weight (FFW) of fed and cull animals at harvest for various management scenarios (kcal of metabolizable energy/kg of beef product output).

Management Scenario	Fed FFW	Percent*	Cull FFW**	Percent*	Total FFW	Percent*
NATURAL						
Straightbred	159.3	100.0	672.4	100.0	128.8	100.0
Straight X Terminal	146.3	100.0	704.2	100.0	121.1	100.0
Rota-Terminal	149.5	100.0	668.3	100.0	122.2	100.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	154.2	103.3	650.2	103.4	124.6	103.3
60%	155.7	102.3	642.5	104.7	125.4	102.7
70%	151.0	105.5	669.6	100.4	123.2	104.5
80%	156.0	102.1	621.0	108.3	124.7	103.3
90%	156.5	101.8	603.0	111.5	124.2	103.7
Straightbred X Terminal:						
50%	147.5	99.2	673.3	104.6	121.0	100.1
60%	154.2	94.9	665.3	105.8	125.2	96.8
70%	144.1	101.6	667.6	105.5	118.5	102.2
80%	142.6	102.6	648.3	108.6	116.9	103.7
90%	144.3	101.4	624.3	112.8	117.2	103.3
Rota-Terminal:						
50%	148.4	100.7	635.7	105.1	120.3	101.5
60%	147.3	101.5	653.3	102.3	120.2	101.6
70%	148.0	101.0	644.0	103.8	120.4	101.5
80%	146.0	102.4	657.4	101.7	119.5	102.3
90%	145.4	102.8	619.9	107.8	117.8	103.7
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	152.8	104.2	615.0	109.3	122.4	105.2
60%	160.7	99.1	545.6	123.3	124.1	103.7
70%	156.2	102.0	561.4	119.8	122.2	105.4
80%	152.3	104.6	566.7	118.6	120.1	107.3
90%	147.4	108.0	585.7	114.8	117.8	109.3
Straightbred X Terminal:						
50%	148.9	98.3	604.1	116.6	119.4	101.4
60%	146.8	99.7	595.7	118.2	117.8	102.9
70%	144.9	101.0	590.8	119.2	116.3	104.1
80%	139.3	105.0	589.4	119.5	112.7	107.5
90%	133.8	109.4	601.0	117.2	109.4	110.7
Rota-Terminal:						
50%	149.8	99.8	587.1	113.8	119.4	102.3
60%	150.5	99.3	572.6	116.7	119.2	102.5
70%	148.2	100.9	568.1	117.6	117.5	103.9
80%	139.7	107.0	585.3	114.2	112.8	108.3
90%	133.0	112.4	607.9	109.9	109.1	111.9

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

**Includes cull cows and exposed heifers not chosen as herd replacements.

Table 4.26. Value-adjusted simulated fat free weight (FFW) at harvest per cow for various management scenarios.

Management Scenario	Fed Steer FFW, kg	Percent*	Fed Heifer FFW, kg	Percent*	Cull FFW**, kg	Percent*	Total Fed FFW, kg	Percent*	Total FFW, kg	Percent*
NATURAL										
Straightbred	133.3	100.0	35.0	100.0	39.9	100.0	168.2	100.0	208.1	100.0
Straight X Terminal	145.1	100.0	43.1	100.0	39.1	100.0	188.2	100.0	227.3	100.0
Rota-Terminal	147.5	100.0	43.0	100.0	42.6	100.0	190.5	100.0	233.1	100.0
ARTIFICIAL INSEMINATION:NATURAL										
Straightbred:										
50%	138.0	103.6	33.8	96.5	40.7	102.2	171.8	102.1	212.5	102.1
60%	135.5	101.7	36.1	103.3	41.6	104.4	171.6	102.0	213.2	102.5
70%	136.9	102.8	39.5	112.9	39.8	99.8	176.4	104.9	216.2	103.9
80%	136.2	102.2	34.9	99.9	43.0	107.9	171.1	101.7	214.1	102.9
90%	137.2	103.0	33.4	95.6	44.3	111.1	170.6	101.4	214.9	103.3
Straightbred X Terminal:										
50%	141.4	97.5	41.3	95.8	40.0	102.4	182.7	97.1	222.8	98.0
60%	134.8	93.0	41.7	96.7	40.9	104.7	176.5	93.8	217.5	95.7
70%	146.1	100.7	43.9	101.8	41.0	104.8	190.0	100.9	231.0	101.6
80%	152.4	105.1	41.2	95.6	42.6	108.9	193.7	102.9	236.3	103.9
90%	152.9	105.4	37.6	87.1	44.0	112.6	190.5	101.2	234.5	103.2
Rota-Terminal:										
50%	149.3	101.2	38.8	90.4	43.9	103.1	188.1	98.8	232.1	99.5
60%	150.4	102.0	41.2	95.8	43.2	101.4	191.6	100.6	234.8	100.7
70%	149.4	101.3	42.4	98.5	44.1	103.4	191.8	100.7	235.9	101.2
80%	154.6	104.8	40.5	94.1	43.3	101.6	195.0	102.4	238.3	102.2
90%	157.4	106.7	39.9	92.9	46.3	108.6	197.3	103.6	243.6	104.5
ARTIFICIAL INSEMINATION										
Straightbred:										
50%	139.6	104.8	33.0	94.4	42.9	107.7	172.7	102.6	215.6	103.6
60%	131.5	98.7	32.7	93.5	48.4	121.4	164.2	97.6	212.6	102.2
70%	137.7	103.3	31.6	90.2	47.1	118.1	169.2	100.6	216.3	104.0
80%	148.5	111.5	26.3	75.0	47.0	117.9	174.8	103.9	221.8	106.6
90%	163.3	122.6	18.3	52.2	45.7	114.7	181.6	107.9	227.3	109.2
Straightbred X Terminal:										
50%	144.2	99.4	36.8	85.4	44.6	114.1	181.0	96.2	225.6	99.3
60%	145.8	100.5	38.7	89.8	45.5	116.2	184.5	98.0	230.0	101.2
70%	152.0	104.8	36.6	84.9	46.3	118.3	188.7	100.2	234.9	103.4
80%	168.0	115.8	29.8	69.2	46.8	119.6	197.8	105.1	244.6	107.6
90%	188.7	130.1	19.0	44.1	46.2	118.2	207.7	110.4	254.0	111.7
Rota-Terminal:										
50%	153.0	103.7	34.2	79.6	47.8	112.1	187.3	98.3	235.1	100.8
60%	148.1	100.4	39.2	91.2	49.2	115.5	187.3	98.3	236.5	101.5
70%	154.8	104.9	36.1	83.9	49.8	116.8	190.8	100.2	240.6	103.2
80%	173.6	117.7	31.8	74.0	49.0	115.0	205.4	107.8	254.5	109.2
90%	197.5	133.8	20.8	48.4	47.8	112.0	218.2	114.5	266.0	114.1

*Percent relative to the baseline where the baseline is the natural breeding scenario within mating system.

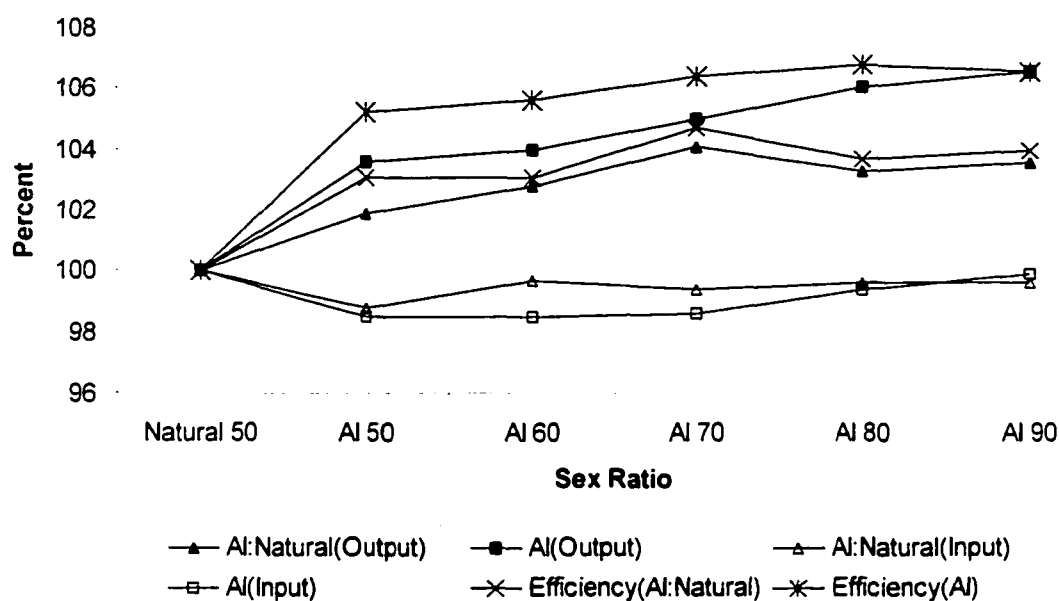
**Includes cull cows and exposed heifers not chosen as herd replacements.

Biological efficiency, whether value-adjusted or not, is to be primarily a function of production due to the small increase, if any, in system inputs. This is demonstrated graphically in Figure 4.13 (straightbred mating system), Figure 4.14 (straightbred X terminal mating system) and Figure 4.15 (rotation-terminal mating system). Again, trends in biological efficiency were similar to those observed for the other production traits. Sexing added value to artificial insemination in most cases. There is potential to increase efficiency of FFW/cow production, given artificial insemination with sexed inseminates. Details on maternal calf, terminal calf and cull numbers along with average FFW can be found in Appendix K.

Conclusions and Implications

In summary, when using artificial insemination followed by natural service cleanup, increases in biological efficiency due to sexing were the largest in the straightbred mating system. Improvement was achieved at sexing efficacy of 70 to 80%, suggesting that sex control does not have to be perfect before producers realize potential gains in efficiency. When artificial insemination was used alone, the largest increases were observed in the straightbred mating system for LWW but rotation-terminal mating system for all harvest production traits. These results were achieved at sex control levels of 80 and 90% for the straightbred and rotation-terminal mating systems, respectively. Sexing of an artificial insemination dose added value to the inseminate although the efficacy of sexing necessary to achieve the greatest gain in biological efficiency depended upon mating system. Potentially greater increases in efficiency, especially in production, would be achieved if artificial insemination with sexed inseminates produced similar pregnancy rates to those of artificial insemination with conventional, unsexed semen or

Unadjusted for value of product:



Adjusted for value of product:

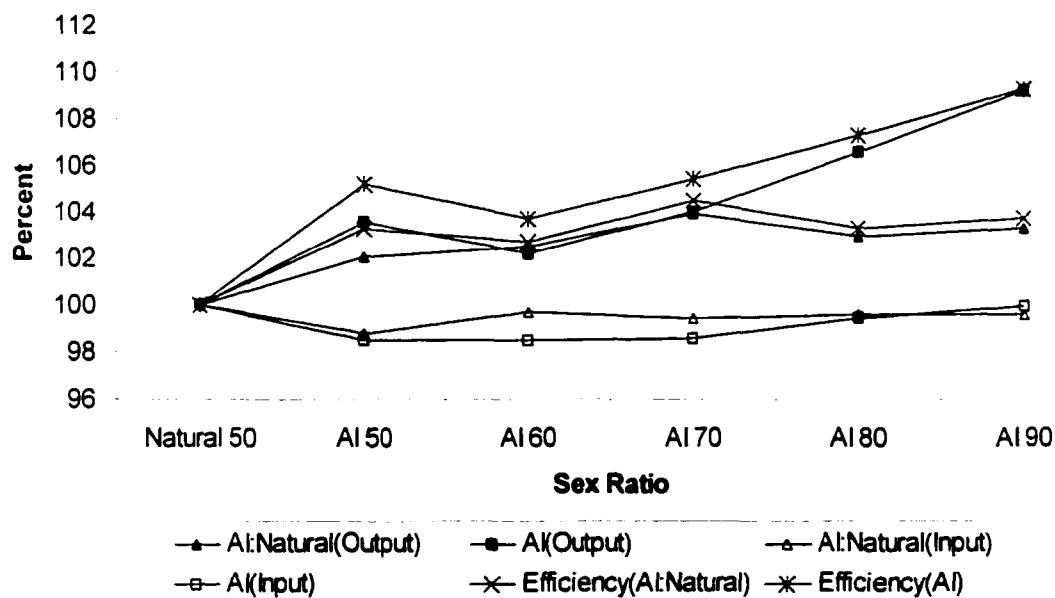
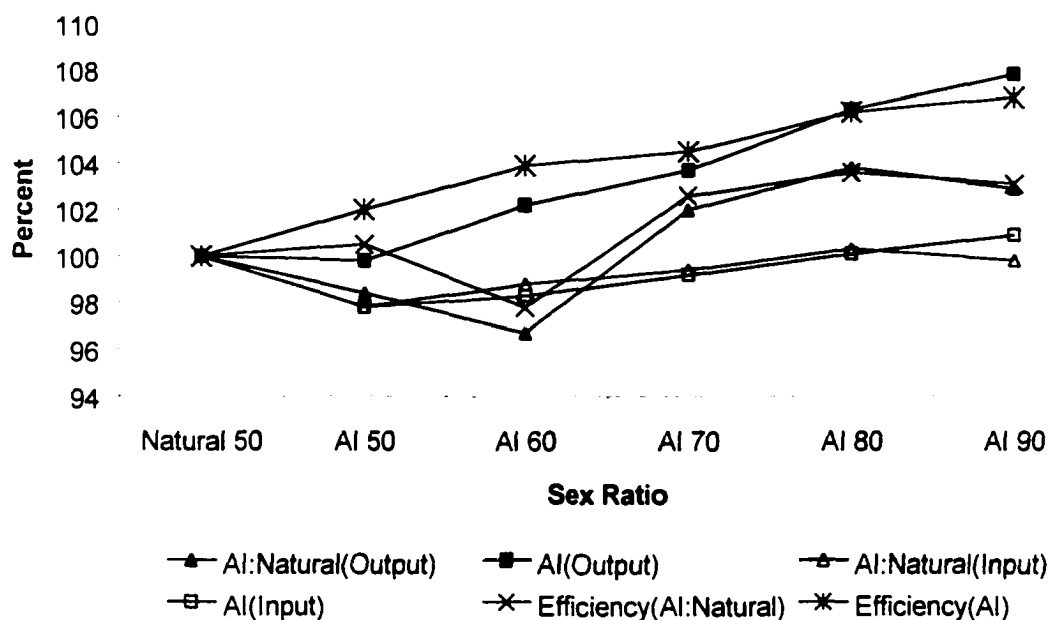


Figure 4.13. Production versus inputs (relative to the straightbred natural service base scenario) for fat free weight at harvest of straightbred management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

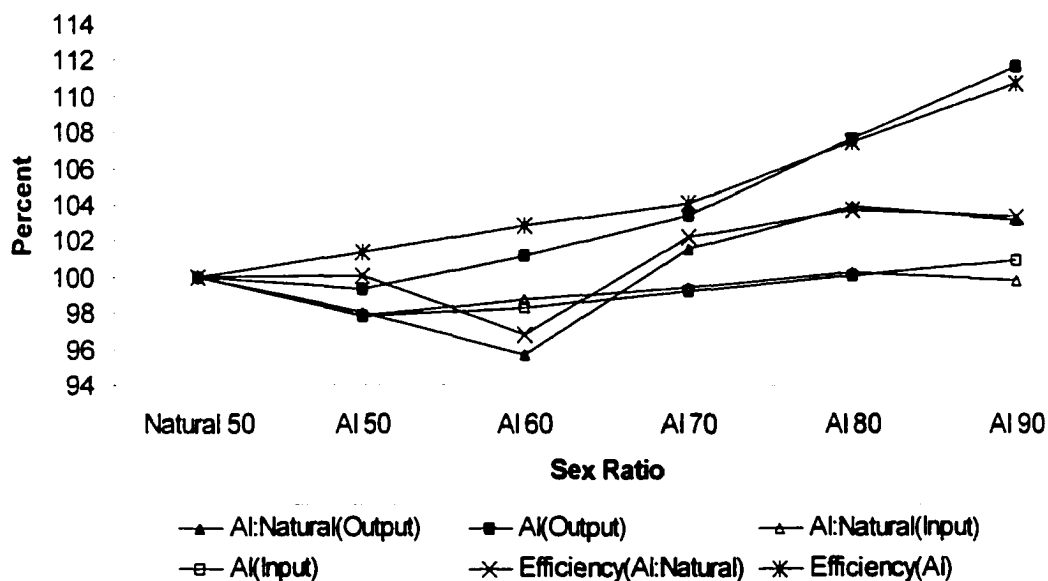
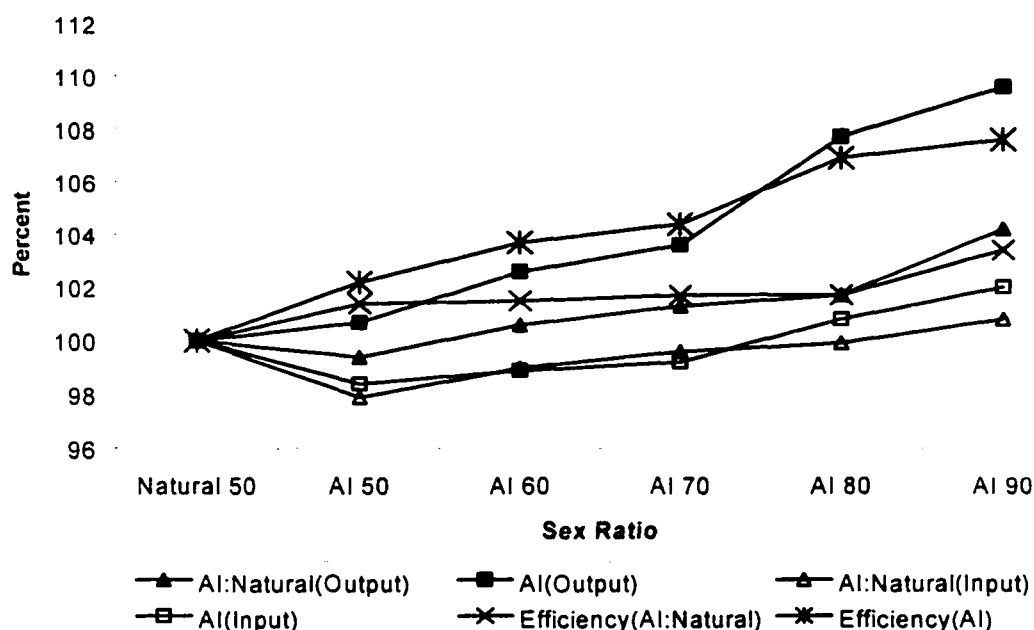


Figure 4.14. Production versus inputs (relative to the straightbred by terminal natural service base scenario) for fat free weight at harvest of straightbred by terminal management scenarios implementing sex control.

Unadjusted for value of product:



Adjusted for value of product:

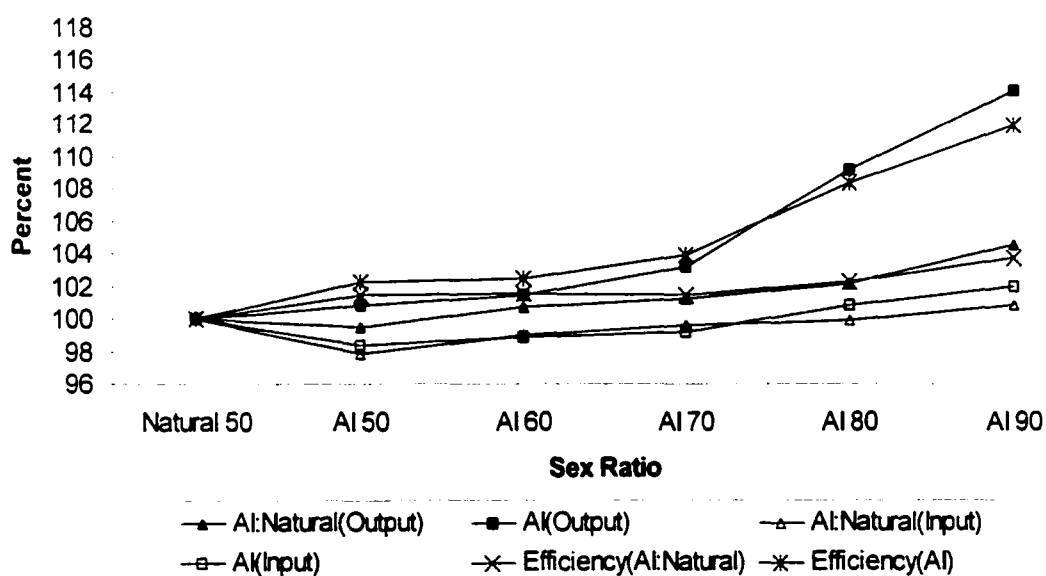


Figure 4.15. Production versus inputs (relative to the rota-terminal natural service base scenario) for fat free weight at harvest of rota-terminal management scenarios implementing sex control.

even natural service. Results suggest that the levels of efficacy currently achieved with sexing technology already make it a viable biological production option as a means to increase efficiency of production in commercial beef production.

More efficient herd allocation into maternal and terminal breeding groups would take advantage of genetic improvement in maternal characteristics in female replacements while capitalizing on hybrid vigor and breed complementarity in the production of male market offspring. A crossbred maternal line would take advantage of maternal hybrid vigor and increased reproductive rates.

The potential benefits of commercially available sexed semen include more efficient beef production, more efficient allocation of beef genetics, and the propagation of a "value-added" product that brings with it the quality and consistency that beef consumers desire.

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CHAPTER 5

VALUE OF SEXED SPERM IN COMMERCIAL BEEF PRODUCTION

Abstract

Simulated production via the Colorado Beef Cattle Production Model and budget data representing cow-calf production in Colorado were used to evaluate the economic value of sexed semen on commercial beef production at weaning. Five sex ratios (50, 60, 70, 80 and 90%), three mating systems (straightbred, straightbred by terminal, and rotation-terminal), and three methods of breeding (natural service, one period of artificial insemination followed by exposure to natural service, and artificial insemination only) were evaluated. Weaning rates included 80, 85 and 90%. The base scenario within each mating system included natural service breeding, an 85% weaning rate, and 15% replacement rate. Within each mating system, heifers and youngest cows were bred to produce female herd replacements while the remaining older cows were bred to produce male market offspring. As the ability determine the sex of offspring increased from 50 to 90%, the number of cows needed to produce the required number of female herd replacements decreased 34.2 to 44.4%, allowing a larger number of cows to be transferred to the terminal breeding group to produce male market offspring. Average weaning weight per cow increased, resulting in increases of gross revenue from calf sales as much as 11.8, 9.1 and 9.8% for the straightbred, straightbred by terminal and rotation-terminal mating systems, respectively. Given average market prices, the value of a sexed sperm

inseminate targeting 90% sex ratio in favor of the preferred sex of offspring ranged from \$9.24 to \$10.57 in a straightbred mating system, depending on whether artificial insemination was used as the sole method of breeding or used once in combination with natural breeding. These values ranged from \$1.01 to \$3.93 and \$3.30 to \$5.72 for the straightbred by terminal and rota-terminal mating systems using artificial insemination with natural breeding versus alone, respectively. Besides cost and efficacy of the sexing technology, this value is dependent upon several factors, such as weaning rate (meaning pregnancy rates and calf survival), mating system, artificial insemination program, and market conditions. Based on the assumptions of this study, the cost of sexed semen needs to be relatively close to that of an unsexed dose of semen in a straightbred production system; however, sexed semen may not be economically viable in crossbreeding systems.

Introduction

Controlling the sex ratio in beef cattle production has considerable biological and economic potential. The ability to predetermine the sex of offspring would allow cattlemen to produce the optimum proportion of males and females to take advantage of phenotypic and genotypic differences of sex-influenced, sex-limited and sex-linked traits and would provide an opportunity to increase selection pressure and optimize genetic gain (Foote and Miller, 1971). Furthermore, genetic antagonisms such as those that appear to exist between maternal and terminal characteristics may be better managed with the development of commercially viable sexed sperm, allowing producers to target female production possessing increased fertility and mothering ability and male production focusing on growth and carcass attributes for the meat industry.

Adoption of sexed sperm technology will depend on individual production systems and the many control and state variables which influence them and producers' decisions to adopt or reject new technologies and production practices. Control variables are those factors we can influence such as weaning rate, replacement rate, and sex ratio (given sex control), but state variables are those influences we have little or no control over such as market price.

Advances and new developments surrounding the current sexing technology appear to be paving the way for future application of sexed semen in beef cattle production. Beef production systems currently using artificial insemination will be the first to benefit; however, the availability of sexed semen may provide the economic incentive as well as genetic gain for producers to adopt artificial insemination into their production system. For sexed sperm technology to be adopted commercially, the beef producer must realize an economic benefit. There exists a price at which the producer would be willing to pay for the additional profit, if any, associated with implementing the use of sexed sperm versus current production practices; thus, the benefit is synonymous for the threshold between adopting and not adopting the new technology. As long as the added revenue outweighs the additional cost due to implementing the technology, the producer should be more willing to adopt sexed sperm.

The objective of this study was to evaluate the value of sexed semen in a commercial beef herd given various abilities to determine the sex ratio of offspring for commercial beef production selling calves at weaning.

Materials and Methods

Cow-calf management has become increasingly difficult in more recent years due to the rapidly changing production and economic conditions in which we operate. Producers are flooded daily with information on new production practices and emerging technologies; however, not all of these new practices and technologies fit all production systems.

Along with deciding what output or enterprise to produce, cattlemen must decide on the inputs and practices in which to produce these outputs. With the increasing number of alternative production practices and inputs, methods such as enterprise and partial budgeting become invaluable in their ability to evaluate current and proposed production practices. Said budgeting allows for the comparison of revenues and costs associated with particular production practices in evaluating their effects on system production and profitability.

To study the effects of the use of sexed semen in commercial beef production, partial budgeting was used to modify the beef cow-calf enterprise budget developed by Colorado Cooperative Extension for 1998 (Sharp, 1999). Costs are on a per cow unit and are assumed to include the cow, her calf until weaning and her proportional share of replacement heifers and bulls. Said enterprise budget was modified to reflect similar production parameters simulated in Chapter 4 in regards to a 400 head cow herd, system inputs, and weaning outputs. The percent differences of system inputs in regards to nutritional intakes and weaning performance data for each mating system by method of breeding combination and sex ratio scenario can be found in Appendix L.

Costs associated with artificial insemination were added to the animal expense section of the Colorado budget. The costs incurred when one period of artificial insemination was used included a synchronization charge of \$5.31, representing the approximate cost of the Select Synch synchronization protocol (includes one 100 µg injection of GnRH followed by 25 mg of prostaglandin F-2-alpha) in the cows and MGA in the heifers, a \$5.00 artificial insemination charge, and a \$3.60 labor charge per cow (adapted from Tom Geary, personal communication; Hogan, 2000). In those scenarios involving the sole use of artificial insemination, up to three matings per cow were required to achieve the desired pregnancy and subsequent weaning rates. In order to calculate an average artificial insemination charge per cow, it was necessary to determine the percent of cows exposed at the first mating, exposed to a second mating, and exposed to a third mating. Subsequently, a weighted average was calculated. The resulting expenses under a 50% sex ratio were one synchronization charge of \$5.31, a \$4.81 labor charge and a \$6.68 artificial insemination service charge. Conversely, the artificial insemination expense under a sex ratio greater than 50% was the one synchronization charge of \$5.31 as above but a \$4.91 labor charge and a \$6.81 artificial insemination service charge per cow.

Upon evaluation of herd structure in Chapter 4, it was felt that even greater changes in female allocation would be feasible. In simulating female allocation among the maternal and terminal breed groups, the number of females needed each year for herd replacements was dependent upon the previous year's need. Thus, the number of females allocated to produce herd replacements was inflated many years depending upon the

previous year's replacement rate. Hence, allocation of females was re-evaluated with the number of females allocated to producing terminal offspring calculated as follows:

$$TF = THS - [(NHR/WR/SR)*1.2]$$

Where:

TF = number of females allocated to terminal breed group,

THS = target herd size,

NHR = number of needed herd replacements,

WR = weaning rate, and

SR = preferred sex ratio in favor of maternal female calves.

In addition, the 1.2 adjustment factor in the calculation allows for 10% culling at weaning as well as adjusting for prospective yearlings that fail to become bred and thus enter the cow herd (given artificial insemination as the sole method of breeding). Adjustments were necessary in those scenarios applying artificial insemination and natural service.

Several control variables and one state variable were varied to study the production and economic conditions under which sexed sperm insemination was economically feasible. Control variables varied included mating system, method of breeding, sex ratio of calves, weaning rate, and replacement rate. The three mating systems evaluated were a straightbred mating system, a straightbred by terminal mating system, and a rotation-terminal mating system. Three methods of breeding were evaluated and included natural service, one artificial insemination period followed by natural service clean-up, and artificial insemination. For a more detailed description of each mating system and method of breeding, refer to Chapter 4, Materials and Methods. For the scenarios using any natural service, the number of bulls needed during the

breeding season was calculated at a ratio of 30:1. A bull culling rate of 25% was assumed for all production scenarios.

Five levels of sex ratio were analyzed and included: 50, 60, 70, 80, and 90%. The base scenario for each mating system by method of breeding combination at a 50% sex ratio assumed an 85% weaning rate (target industry optimum; Taylor and Field, 1999) and 15% replacement rate. In the base scenario, weaning rate for both natural service and artificial insemination scenarios were considered equal. However, in the evaluation of alternate production practices, weaning rate was lowered 80% in the scenarios involving artificial insemination in combination with sexed sperm in order to evaluate the value of sexed sperm inseminate, given current lowered pregnancy rates associated with such treatments (Chapter 3). A weaning rate of 90% and replacement rate of 20% were also examined.

The state variable analyzed included market prices for steer and heifer weanling calves, cull cows and cull bulls. Ten years (1989-1998) of calf and cull cow price data were obtained from Colorado Agricultural Statistics Annual Reports (1996,1999). The ten year horizon was chosen to reflect one cycle in the cattle market. Using price relationships from weekly LS-214's for Colorado from 1992 to 1998 (Steve Koontz, personal communication), price differentials between steer and heifer calves were calculated and extrapolated to the ten year price data. From said data, average, low and high economic conditions as reflected in prices paid for various classes of livestock were produced. Prices per livestock class for each economic condition can be found in Table 5.1. No differentiation in pricing was made between straightbred and crossbred calves.

Table 5.1. Market prices per livestock class reflecting average, low and high economic conditions.

Class of Livestock	Economic Scenario		
	Average (\$/cwt)	Low (\$/cwt)	High (\$/cwt)
Steer calves	92.92	79.80	106.05
Heifer calves	84.98	71.85	98.10
Cull cows	44.89	36.53	53.25
Cull bulls	48.34	40.79	55.88

Value of sexed semen was determined by the contribution to net receipts from the use of sexed sperm relative to the base scenario within mating system. More specifically, total operating expenses were subtracted from gross revenues; the resulting residual or net value represents the value of sexed sperm under the given production scenario. This value represents the value of a sexed inseminate in those scenarios implementing sex control and the use of artificial insemination once followed by natural service. In order to calculate the value of an inseminate in those scenarios using artificial insemination only, the value of sexed semen is divided by the mean number of inseminates per cow. Assuming 60% and 55% AI rates for unsexed and sexed inseminates, respectively, the mean number of inseminates per cow was 1.6 and 1.7. Examples of the cow-calf budgets for the 85% weaning rate and 15% replacement rate in a straightbred, straightbred by terminal and rotation-terminal mating system can be found in Appendices M through O, respectively.

Results

Herd Structure

Herd allocation for the base scenario, regardless of mating system, can be found in Table 5.2. Also found in Table 5.2 is the female allocation when an 80% weaning rate was used to allow for depressed fertility of sexed inseminates.

The number of cows needed to produce the required number of female herd replacements decreased 34.3 and 44.4% when using artificial insemination along with natural breeding and artificial insemination only, respectively, allowing a larger number of cows to be transferred to the terminal breeding group to produce male market offspring. These agree with earlier findings by Haaland-Homes et al. (1982). Subsequently, the number of steer calves marketed at weaning increased 42.4% while heifer marketing decreased 69.4% when using artificial insemination as the sole method of breeding. In comparison, the number of steer calves marketed increased 19.4% while heifer marketing decreased 29.5% when using artificial insemination followed by natural breeding.

In a crossbreeding system, sexed semen allows for the maximization of breed complementarity and hybrid vigor in 72 to 76% of the cow herd when using artificial insemination sexed at 90% rather than 58% when using natural service bulls. Under 50% sex ratio, approximately 73% of the total calves marketed were sired by terminal genetics versus 89 to 95% when using artificial insemination and sexed semen sorted at 90%.

Table 5.2. Female allocation into maternal and terminal breed groups of a 400 head cow herd with a 15% replacement rate, either an 85 or 80% weaning rate, and differing abilities to alter the sex ratio of offspring.

Weaning Rate (%)	Sex Ratio (%) ¹	No. Maternally Exposed ²		No. Terminally Exposed		% Maternally Exposed		% Terminally Exposed	
85	50 ³	169		231		42		58	
		<u>AI-⁴</u>	<u>AI+⁵</u>	<u>AI-</u>	<u>AI+</u>	<u>AI-</u>	<u>AI+</u>	<u>AI-</u>	<u>AI+</u>
	60	141	150	259	250	35	38	65	62
	70	121	136	279	264	30	34	70	66
	80	106	125	294	275	26	31	74	69
	90	94	111	306	289	24	28	76	72
80	50 ³	180		220		45		55	
		<u>AI-</u>	<u>AI+</u>	<u>AI-</u>	<u>AI+</u>	<u>AI-</u>	<u>AI+</u>	<u>AI-</u>	<u>AI+</u>
	60	150	159	250	241	38	40	62	60
	70	129	145	271	255	32	36	68	64
	80	113	133	288	267	28	33	72	67
	90	100	118	300	282	25	30	75	70

¹Percent of the preferred sex of calf produced (i.e. maternal calf = female calf).

²Includes herd replacements.

³Includes 50% sex ratio regardless of breeding protocol (natural, AI only, AI+natural breeding).

⁴AI-: Artificial insemination only.

⁵AI+: Artificial insemination followed by natural breeding.

Straightbred Mating System

As the proportion of calves of the preferred sex increased from 50% under natural breeding to 90% with artificial insemination followed by natural breeding (50%) in a commercial straightbred mating system with a weaning rate of 85% and a 15% replacement rate, the following results were obtained (Table 5.3). Average weaning weight for steer calves per cow increased 27.4%. Average weaning weight per cow increased 6.9%. The average live weight marketed at weaning per cow increased 1.9%.

Table 5.3. Production and associated revenues and expenses for a straightbred mating system using artificial insemination followed by natural service with an 85% weaning rate and 15% replacement rate versus the straightbred base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	167	172	180	190	203
Avg. weaning weight (lbs./cow)	203.94	207.39	209.00	226.36	240.80	259.82
No. of heifers (N)	105	105	101	94	84	74
Avg. weaning weight (lbs./cow)	120.01	126.32	123.98	111.47	98.68	86.38
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	156.58	157.32	156.91	156.97	158.14
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	372.53	374.32	374.16	379.47	382.04	389.80
Gross revenue from calf sales	291.49	300.06	299.56	305.05	307.60	314.83
Cash operating expenses	310.83	322.46	323.59	321.77	321.14	322.53
Non-cash operating expenses	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	19.51	14.68	13.38	20.51	23.72	30.08
Value of inseminate (\$/cow)*	0.00	(4.83)	(6.13)	1.00	4.21	10.57

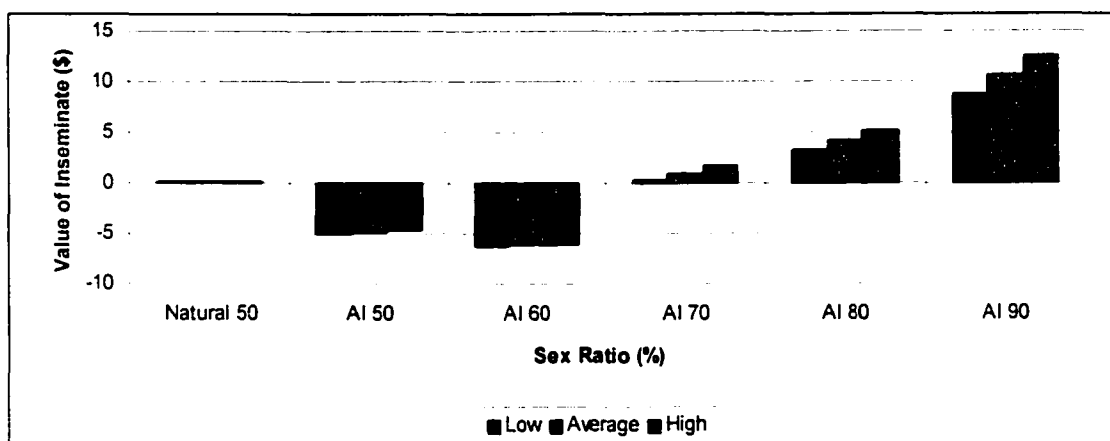
*Inseminate value equal to net receipts for AI minus net receipts for natural service.

Gross revenues per cow increased 4.6%. Gross revenue from calf sales increased 8%. Variable costs increased less than 4%. The increase in variable costs reflects increases in animal expenses due to a 93.5% increase in medical and breeding expenses (primarily costs associated with artificial insemination) and an increase in selling commissions and yardage near 5%. Although variable costs increased, fixed costs decreased due to a reduction in depreciation dollars due to the reduction in live bull numbers. Compared to natural service, net receipts per cow increased 54.2% (90% sex

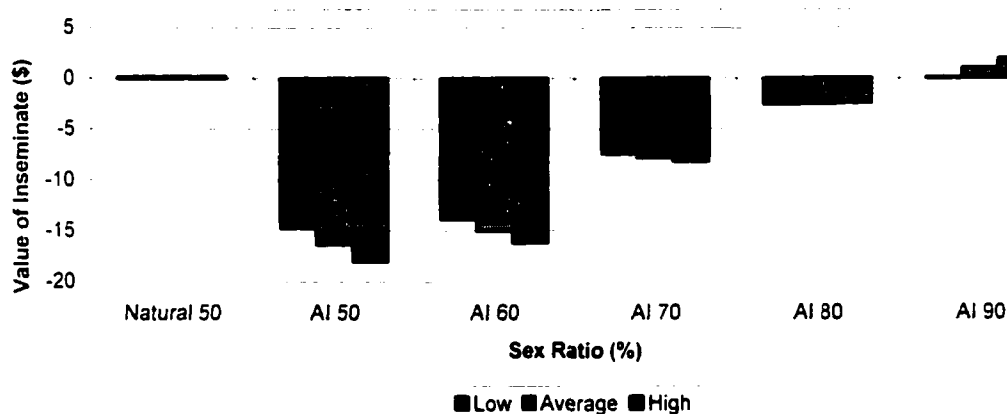
ratio); however, it is important to note that net receipts decreased below the natural service scenario when using artificial insemination with 50% and 60% inseminate sex ratios. Values for inseminates sexed for 80% and 90% were \$4.21/cow and \$10.57/cow, respectively. Under low market prices, these values decreased to \$3.30/cow for 80% and \$8.71/cow for 90% sexed inseminate. In contrast, high cattle prices increase the values to \$5.12/cow and \$12.45/cow for 80% and 90% sexed inseminates, respectively (Figure 5.1).

Currently, artificial insemination pregnancy rates tend to be lower than natural service pregnancy rates. In order to investigate the effects of lowered pregnancy rates, the system using artificial insemination followed by natural service possessed a weaning rate of 80% while the natural service base scenario had a weaning rate of 85%. As the proportion of offspring of the desired sex increased from 50% to 90%, the following results were obtained (Table 5.4). The number of marketed steers increased 10.6% while the number of marketed heifers decreased approximately 35.2%. Average weaning per cow decreased 1.3%. The average weaning weight per cow for steer calves increased 17.8%. Compared to natural service, the average live weight marketed per cow when sexing at 90% decreased 3.6%.

Straightbred Mating System:



Straightbred X Terminal Mating System:



Rotation-Terminal Mating System:

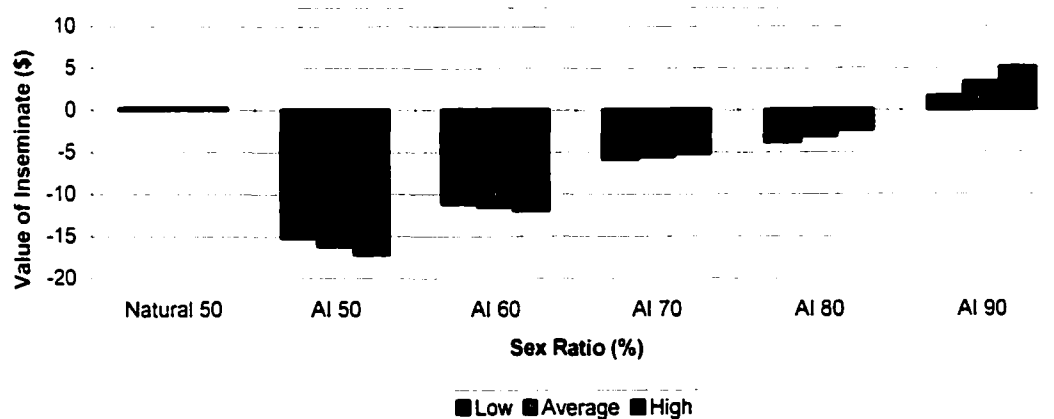


Figure 5.1. Value of inseminate (\$), given low, average, and high cattle prices, for five levels of sex control for straightbred, straightbred by terminal, and rotation-terminal mating systems using one artificial insemination period followed by natural service cleanup scenario with an 85% weaning rate and 15% replacement rate versus the natural service base scenario with an 85% weaning rate and 15% replacement rate.

Table 5.4. Production and associated revenues and expenses for a straightbred mating system using artificial insemination followed by natural service with an 80% weaning rate and 15% replacement rate versus the straightbred base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	156	161	168	176	188
Avg. weaning weight (lbs./cow)	203.94	194.56	195.39	209.60	222.70	240.34
No. of heifers (N)	105	95	92	86	78	68
Avg. weaning weight (lbs./cow)	120.01	114.24	112.87	101.94	90.42	79.35
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	156.58	157.32	156.91	156.97	157.14
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	372.53	352.13	352.07	355.80	358.22	365.73
Gross revenue from calf sales	291.49	277.87	277.47	281.31	283.77	290.76
Cash operating expenses	310.83	321.93	323.07	321.22	320.58	321.96
Non-cash operating expenses	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	19.51	(6.98)	(8.19)	(2.60)	.45	6.58
Value of inseminate (\$/cow)*	0	(26.49)	(27.70)	(22.11)	(19.06)	(12.93)

*Inseminate value equal to net receipts for AI minus net receipts for natural service.

Compared to the base scenario, the smallest decrease in gross revenues per cow was observed in the 90% sorted semen (1.8%); gross revenue from calf sales decreased .3%. Variable costs increased less than 4%, reflecting increases in animal expenses near 6% due to increased costs associated with the use of artificial insemination. Net receipts per cow decreased 66% from \$19.51/cow to \$6.58/cow when comparing the natural service and the 90% sexed inseminate scenarios, respectively; however, net receipts

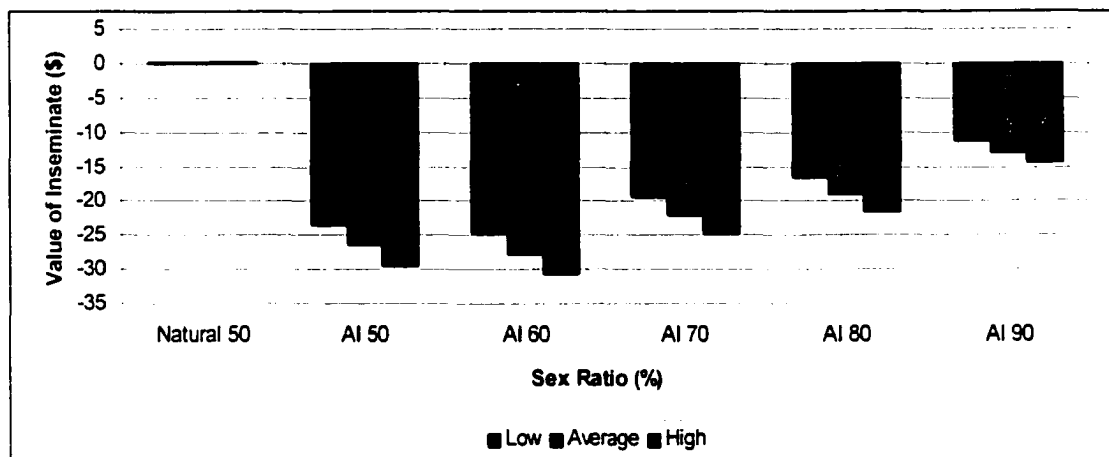
associated with artificial insemination treatments at 50, 60 and 70% sex ratios were negative. Under said production and market conditions (including high cattle prices), it is not economical to use artificial insemination; however, it is important to note that sexing does add value to the artificial inseminate but at a diminishing rate (Figure 5.2).

Artificial insemination use in the beef industry is minimal compared to its use in the dairy industry. Producers argue that the benefits of artificial insemination do not justify its added expense. However, would the use of artificial insemination with sexed sperm as the sole method of breeding in order to capture increased genetic gains and changes in the proportion of the preferred sex of calf justify the expense of an artificial insemination program? Hence, the comparison was made between a system using natural breeding versus a system using only artificial insemination.

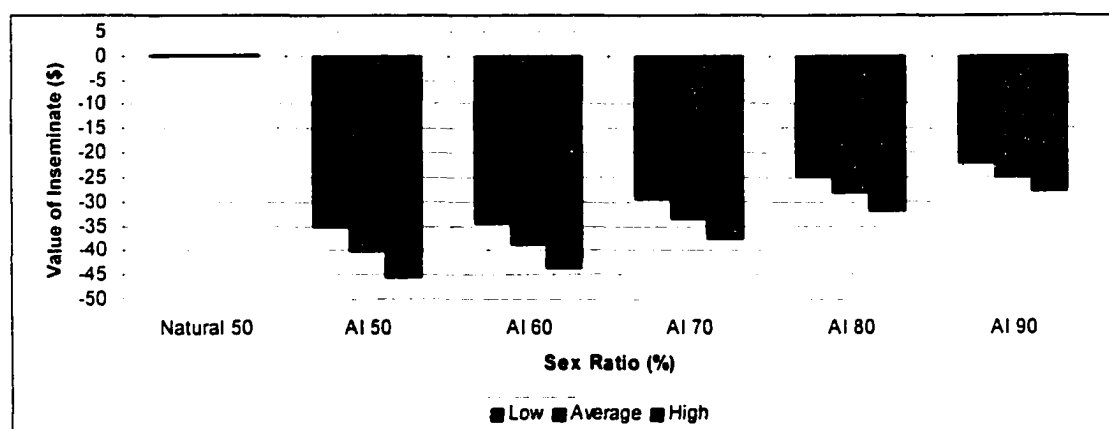
If we assume artificial insemination can produce the same weaning rates (essentially similar pregnancy and(or) calf survival rates) of 85% as the natural service scenario, the following results were obtained for the comparison between a system using natural service versus artificial insemination (Table 5.5). As the proportion of offspring of the desired sex increased from 50 to 90%, the live weight marketed at weaning per cow increased 1.4%. Average weaning weight per cow increased 9.4%. Average weaning weight per cow for steer calves increased approximately 54%.

Gross revenues increased 6.3% while gross revenue from calf sales increased 11.8%. Variable costs increased 5.3%, reflecting an 8.6% increase in animal expenses (primarily costs associated with artificial insemination). Fixed costs decreased nearly

Straightbred Mating System:



Straightbred X Terminal Mating System:



Rotation-Terminal Mating System:

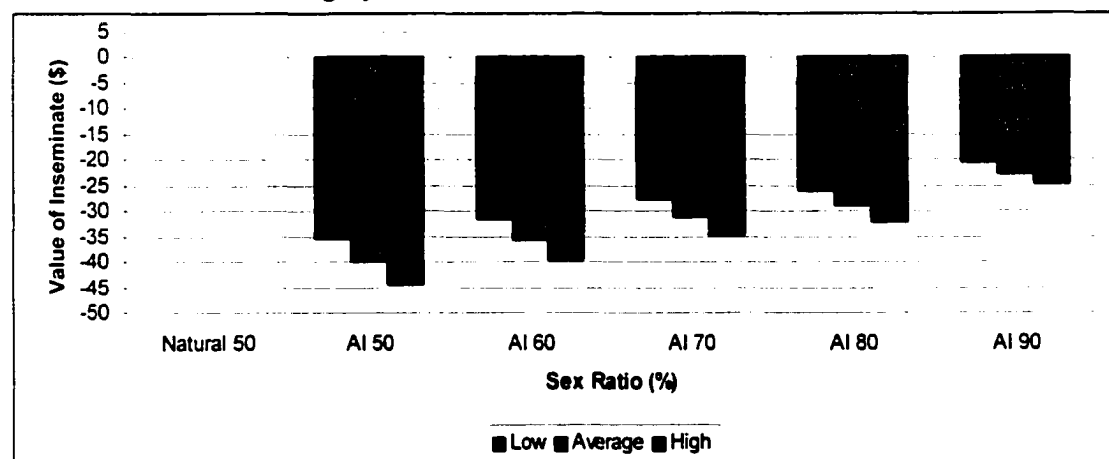


Figure 5.2. Value of inseminate (\$), given low, average, and high cattle prices, for five levels of sex control for straightbred, straightbred by terminal, and rotation-terminal mating systems using one artificial insemination period followed by natural service cleanup with an 80% weaning rate and 15% replacement rate versus the base natural service scenario with an 85% weaning rate and 15% replacement rate.

Table 5.5. Production and associated revenues and expenses for a straightbred mating system using artificial insemination with an 85% weaning rate and 15% replacement rate versus the straightbred base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	170	180	197	218	242
Avg. weaning weight (lbs./cow)	203.94	215.8	229.3	253.81	282.12	314.32
No. of heifers (N)	105	105	95	78	57	33
Avg. weaning weight (lbs./cow)	120.01	128.19	116.41	95.58	69.26	39.92
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	157.99	156.85	156.38	156.43	155.97
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	372.53	379.45	382.43	387.26	391.23	396.01
Gross revenue from calf sales	291.49	308.53	312.03	317.07	321.01	325.99
Cash operating expense	310.83	325.48	327.41	327.07	324.69	327.34
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	19.51	20.53	21.58	26.75	33.09	35.22
Value of AI (\$/cow)*	0	1.02	2.07	7.24	13.58	15.71
Value of inseminate (\$/cow)**	0	.64	1.22	4.26	7.99	9.24

*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

21% due to the elimination of the depreciation associated with live bulls. Net receipts increased 80.5% with actual values ranging from \$19.51/cow to \$35.22/cow. AI values of \$13.58/cow and \$15.71/cow for inseminates sexed for 80% and 90% the desired offspring were obtained, respectively (Figure 5.3). These are simply the values of using artificial insemination in combination with sexed sperm. These translate to inseminate

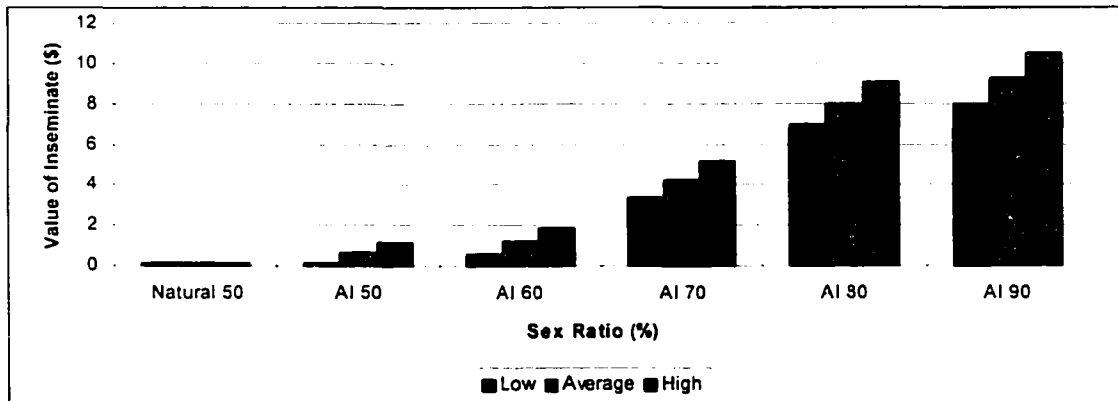
costs of \$7.99 and \$9.24 per cow for the 80% and 90% sorted AI doses, respectively. Low market prices reduce the inseminate values for 80% and 90% sexed semen to \$6.94/cow and \$8.01/cow, respectively. Conversely, high market prices increase their values to \$9.05/cow and \$10.49/cow for the 80% and 90% sexed inseminates.

As previously mentioned, pregnancy rates associated with artificial insemination tend to be lower than those associated with natural service. Assuming weaning rates of 80% for the artificial insemination treatments, the following results were obtained (Table 5.6). The live weight marketed at weaning per cow of the 90% sexed treatment decreased 3.8% from that obtained using natural service. As the proportion of the desired sex of offspring increased from 50 to 90%, the average weaning weight per cow increased 1.4%. Average weaning weight per cow for steer calves increased 42.6%.

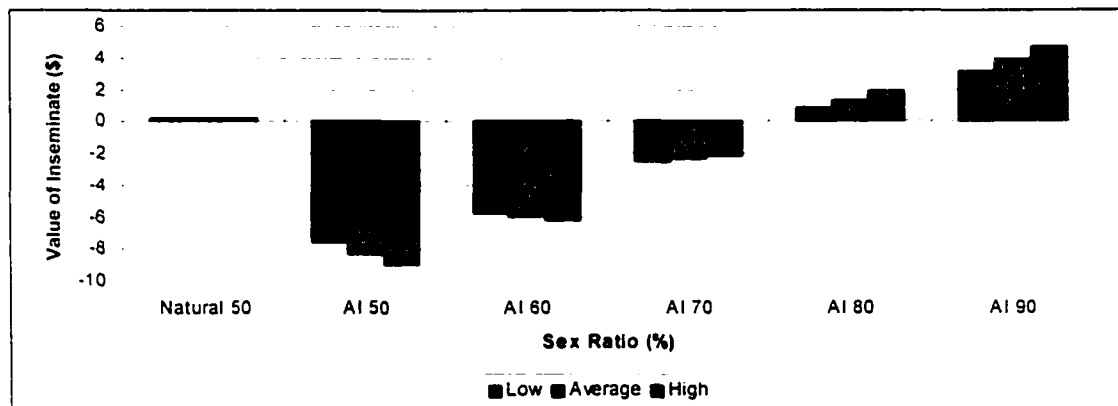
Gross revenues decreased .1%; gross revenue from calf sales increased 3.6%. Variable costs increased 5.1%, reflecting an increase in animal expenses primarily due to an 212.9% increase in breeding costs. It is important to note that it was assumed that up to three breeding opportunities per cow were necessary to achieve said weaning rates. Again, fixed costs decreased due to the elimination of live bulls and the associated depreciation. Net receipts decreased 39% when comparing the natural service scenario to the use of artificial insemination with an inseminate sexed at 90%. Net receipts for the artificial insemination scenarios at sex ratios of 50 and 60% were negative. It appears uneconomical to use artificial insemination if lowered weaning rates exist; however, it is important to note that sexing does add value to artificial inseminates (Figure 5.4).

Increases in weaning rate and replacement rate were also evaluated (Appendix P). These scenarios included a 90% weaning rate at a 15% replacement rate, 85% weaning

Straightbred Mating System:



Straightbred X Terminal Mating System:



Rotation-Terminal Mating System:

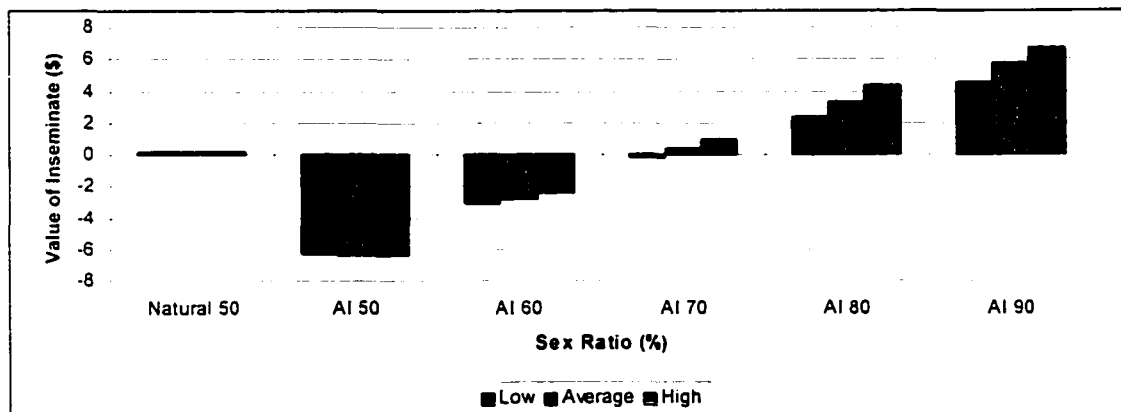


Figure 5.3. Value of artificial insemination (\$), given low, average, and high cattle prices, for five levels of sex control for straightbred, straightbred by terminal, and rotation-terminal mating systems using only artificial insemination with an 85% weaning rate and 15% replacement rate versus the natural service base scenario with an 85% weaning rate and 15% replacement rate.

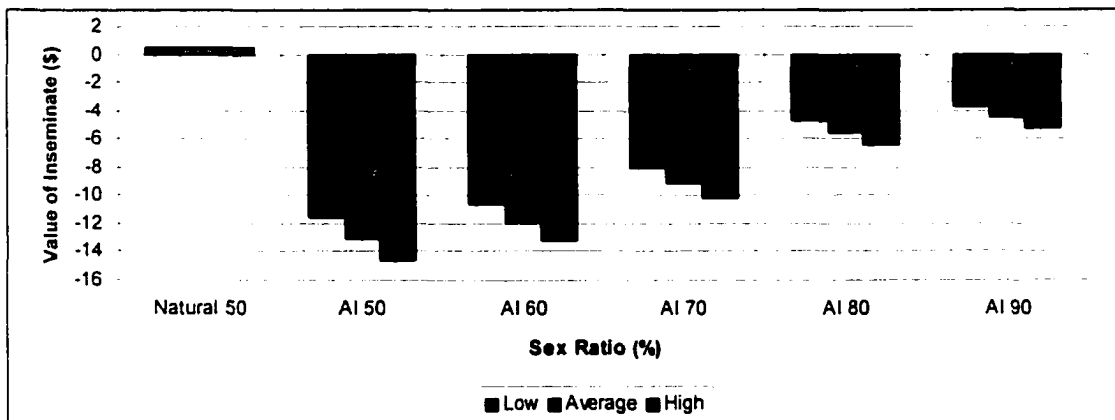
Table 5.6. Production and associated revenues and expenses for a straightbred mating system using artificial insemination with an 80% weaning rate and 15% replacement rate versus the straightbred base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	160	168	183	202	224
Avg. weaning weight (lbs./cow)	203.94	201.76	213.73	235.51	261.26	290.87
No. of heifers (N)	105	95	87	72	53	31
Avg. weaning weight (lbs./cow)	120.01	115.93	106.56	88.18	64.35	37.46
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	157.99	156.85	156.38	156.43	155.97
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	372.53	356.92	359.56	363.97	367.68	372.13
Gross revenue from calf sales	291.49	286.00	289.15	293.76	297.46	302.12
Cash operating expense	310.83	324.95	326.87	326.53	324.14	326.79
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	19.51	(1.47)	(0.75)	4.00	10.10	11.90
Value of AI (\$/cow)*:	0.00	(20.98)	(20.26)	(15.51)	(9.41)	(7.61)
Value of inseminate (\$/cow)**:	0.00	(13.11)	(11.92)	(9.12)	(5.54)	(4.48)

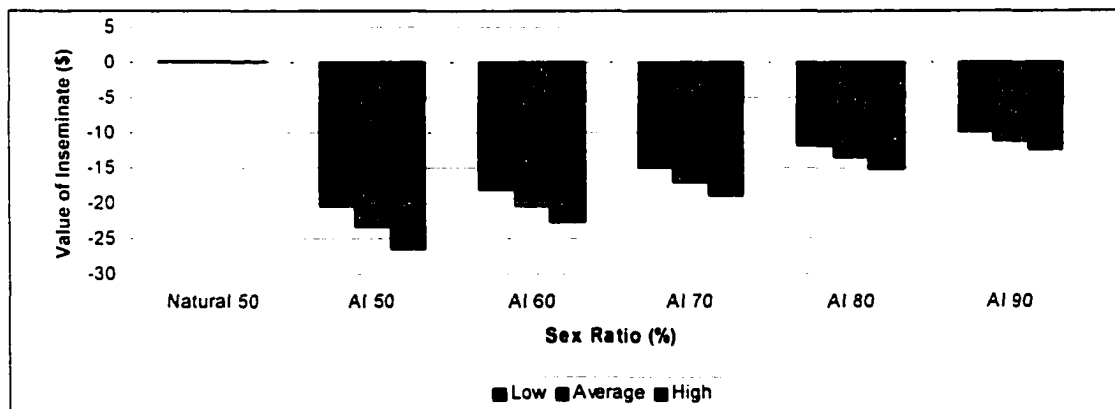
*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

Straightbred Mating System:



Straightbred X Terminal Mating System:



Rotation-Terminal Mating System:

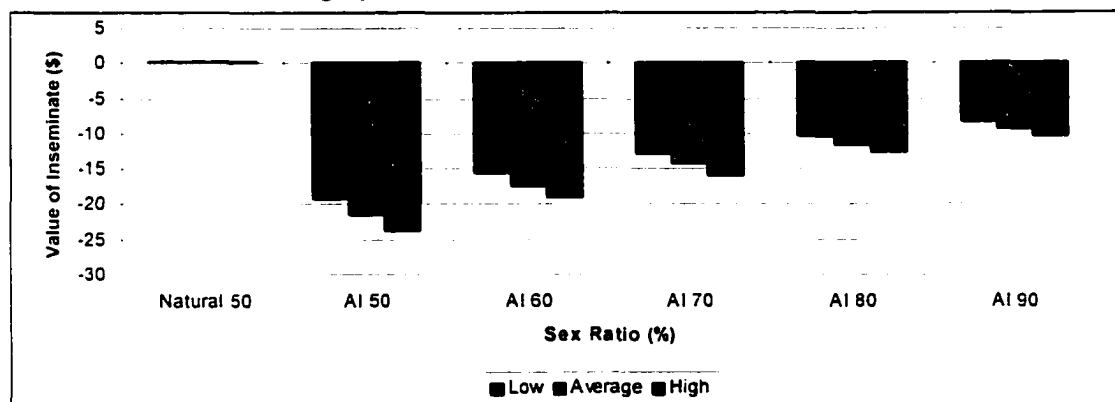


Figure 5.4. Value of artificial insemination (\$), given low, average, and high cattle prices, for five levels of sex control for straightbred, straightbred by terminal, and rotation-terminal mating systems using only artificial insemination with an 80% weaning rate and 15% replacement rate versus the base natural service scenario with an 85% weaning rate and 15% replacement rate.

rate and 20% replacement rate, and 90% weaning rate and 20% replacement rate. All assumed natural service and artificial insemination could achieve the said parameters. In a straightbred mating system using artificial insemination followed by natural service, the value of the 90% sexed inseminate was \$12.58, \$6.01, and \$8.98 for the 90%/15%, 85%/20%, and 90%/20% weaning rate/replacement rate scenarios, respectively. When a weaning rate of 90% and replacement rate of 15% was assumed for a straightbred system using artificial insemination with no natural service cleanup, the value of the inseminate sexed at 90% was \$10.89.

Straightbred by Terminal Mating System

As the proportion of calves of the preferred sex increased from 50% under natural breeding to 90% with the use of artificial insemination followed by natural service in a straightbred by terminal crossbreeding system with a weaning rate of 85% and a 15% replacement rate, the following results were obtained (Table 5.7). Average weaning weight per cow increased 4.1%. Average weaning weight for steer calves per cow increased 26.4% while average live weight marketed at weaning per cow increased .4%.

Gross revenues per cow increased 2.8% while gross revenue from calf sales alone increased 5.3%. Variable costs increased 5%. The increase in variable costs reflects increases in animal expenses due to increases in medical and breeding expenses (primarily costs associated with AI) and an increase marketing expenses associated with selling commission and yardage. Although variable costs increased, fixed costs decreased as before in that there is less bull depreciation because of fewer bulls being utilized within the system (11.9%). Net receipts per cow increased approximately 1.9%

Table 5.7. Production and associated revenues and expenses for a straightbred by terminal mating system using artificial insemination followed by natural service with an 85% weaning rate and 15% replacement rate versus the straightbred by terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate..

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	167	172	180	190	203
Avg. weaning weight (lbs./cow)	224.65	219.84	230.13	245.31	262.64	283.96
No. of heifers (N)	105	105	101	94	84	74
Avg. weaning weight (lbs./cow)	139.61	139.02	132.73	123.60	109.15	95.07
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.63	157.18	157.51	157.97	157.43
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	408.03	397.15	401.16	407.66	411.69	419.30
Gross revenue from calf sales	327.38	322.42	326.63	332.98	336.80	344.65
Cash operating expenses	312.31	322.80	325.49	324.81	323.48	327.57
Non-cash operating expenses	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	53.53	37.16	38.48	45.67	51.02	54.54
Value of inseminate (\$/cow)*	0	(16.37)	(15.05)	(7.86)	(2.51)	1.01

*Inseminate value equal to net receipts for AI minus net receipts for natural service.

when comparing the natural service and 90% sex ratio scenarios; however, it is important to note that net receipts decreased when using artificial insemination at all other inseminate sex ratios. Values of inseminates sexed for 80% and 90% were \$(2.51)/cow and \$1.01/cow, respectively. Under low market prices, values of \$(2.54)/cow for 80% and \$0.09/cow for 90% sexed inseminate were obtained. Conversely, high cattle prices

increase the values to \$(2.47)/cow and \$1.94/cow for 80% and 90% sexed inseminates, respectively (Figure 5.1).

The following results were obtained when comparing a system using one artificial insemination period followed by natural service with a weaning rate of 80% and a system using natural service with an 85% weaning rate (Table 5.8). Compared to natural service, the average weaning weight per cow for the 90% sexed treatment decreased 9.1%, the average weaning weight per cow for steer calves increased 16.8%, and the average live weight marketed at weaning per cow decreased 8.4%.

Compared to the natural service scenario, the 90% sex ratio treatment's gross revenue decreased 3.8% while gross revenue from calf sales decreased 2.9%. Variable costs increased less than 5%, reflecting a 7.5% increase in animal expense due to increased costs associated with the use of artificial insemination. Net receipts for the 90% sexed treatment decreased 46.7% compared to natural service; however, net receipts decreased as much as 75% (artificial insemination and 50% sex ratio). Under said production and market conditions (including high cattle prices), it is not economical to use artificial insemination; however, it is important to note that sexing does add value to the artificial inseminate but at a diminishing rate (Figure 5.2).

The comparison was made between a system using natural mating versus a system using only artificial insemination. If we assume artificial insemination can produce the same weaning rates (essentially same pregnancy and calf survival rates) of 85% as in the natural service scenario, the following results were obtained for the comparison between

Table 5.8. Production and associated revenues and expenses for a straightbred by terminal mating system using artificial insemination followed by natural service with an 80% weaning rate and 15% replacement rate versus the straightbred by terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	156	161	168	276	188
Avg. weaning weight (lbs./cow)	224.65	205.72	214.57	226.81	242.62	262.44
No. of heifers (N)	105	95	92	86	78	68
Avg. weaning weight (lbs./cow)	139.61	125.63	120.78	112.96	99.95	68.77
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.63	157.18	157.51	157.97	157.43
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	408.03	372.65	376.54	381.43	385.27	392.67
Gross revenue from calf sales	327.38	297.92	302.01	306.76	310.38	318.02
Cash operating expenses	312.31	322.23	324.92	324.20	322.87	326.95
Non-cash operating expenses	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	53.53	13.24	14.44	20.05	25.21	28.53
Value of inseminate (\$/cow)*	0	(40.29)	(39.09)	(33.48)	(28.32)	(25.00)

*Inseminate value equal to net receipts for AI minus net receipts for natural service.

a system using natural service versus artificial insemination (Table 5.9). Average weaning weight per cow increased 6.6%; the average weaning weight per cow for steer calves increased approximately 54%. Compared to natural service, the live weight marketed at weaning per cow for the 90% sexed treatment decreased .3%.

Gross revenues increased 4.7%; gross revenue from calf sales increased 9.1%.

Variable costs increased 6.8%, reflecting an 10.9% increase in animal expenses. The

Table 5.9. Production and associated revenues and expenses for a straightbred by terminal mating system using artificial insemination with an 85% weaning rate and 15% replacement rate versus the straightbred by terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate..

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	170	180	197	218	242
Avg. weaning weight (lbs./cow)	224.65	227.01	246.56	275.06	307.97	344.94
No. of heifers (N)	105	105	95	78	57	33
Avg. weaning weight (lbs./cow)	139.61	141.01	127.50	104.68	75.92	43.27
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.27	156.58	156.14	155.89	155.92
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	408.03	401.37	407.74	414.63	420.66	427.28
Gross revenue from calf sales	327.38	330.77	337.46	344.53	350.68	357.29
Cash operating expense	312.31	327.70	330.92	331.66	331.42	333.63
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	53.53	40.23	43.39	49.54	55.81	60.21
Value of AI (\$/cow)*	0.00	(13.30)	(10.14)	(3.99)	2.28	6.68
Value of inseminate (\$/cow)**	0.00	(8.31)	(5.96)	(2.35)	1.34	3.93

*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

animal expense included increases in feed costs (2.9%), marketing (3.3%), and breeding (~213%). Fixed costs decreased nearly 21% due to the elimination of live bulls and depreciation dollars. Compared to natural service, net receipts for the 90% sex ratio increased 12.5%. The value of artificial insemination with sexed sperm at 80% and 90% efficacies equaled \$2.28/cow and \$6.68/cow, respectively. Values per dose of \$1.34/cow

and \$3.93/cow for inseminates sexed for 80% and 90% the desired offspring were obtained, respectively. Low market prices negatively impacted the value of artificial insemination while the reverse was true of high market prices. In either case, sexing added value to artificial insemination use (Figure 5.3). Low market prices reduce the inseminate values for 80% and 90% sexed semen to \$1.47/cow and \$5.32/cow, respectively. Conversely, high market prices increase their values to \$3.10/cow and \$8.07/cow for the 80% and 90% sexed inseminates.

As previously mentioned, pregnancy rates associated with artificial insemination tend to be lower than those associated with natural service. In a straightbred by terminal system using artificial insemination as its sole method of breeding and assuming weaning rates of 80% for the artificial insemination treatments, the following results were obtained (Table 5.10). Average weaning weight per cow decreased 1.3% while the average weaning weight per cow for steer calves increased 42%. The live weight marketed at weaning per cow increased 3.6%.

Gross revenues per cow decreased compared to natural service as little as .1% (90% sex ratio) while gross revenue from calf sales increased 1.1%. Variable costs increased 6.6%, reflecting an increase in animal expenses primarily due to a 212.9% increase in breeding costs and 2.9% increase in feed expense. It is important to note here that it was assumed that up to three breeding opportunities per cow were necessary to achieve said weaning rates. Again, fixed costs decreased due to the elimination of depreciation associated with live bulls. Compared to natural service, net receipts per cow decreased as little as 35.5% (90% sex ratio). It appears uneconomical to use artificial

insemination if lowered weaning rates exist; however, it is important to note that sexing does add value to artificial insemination use (Figure 5.4).

Table 5.10. Production and associated revenues and expenses for a straightbred by terminal mating system using artificial insemination with an 80% weaning rate and 15% replacement rate versus the straightbred by terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	160	168	183	202	224
Avg. weaning weight (lbs./cow)	224.65	212.77	229.38	254.98	285.04	319.13
No. of heifers (N)	105	95	87	72	53	31
Avg. weaning weight (lbs./cow)	139.61	127.45	116.64	96.5	70.49	40.55
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.27	156.58	156.14	155.89	155.92
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	408.03	376.61	382.54	389.03	394.73	400.99
Gross revenue from calf sales	327.38	306.02	312.26	318.94	324.76	331.00
Cash operating expense	312.31	327.12	330.33	331.06	330.82	333.03
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	53.53	16.05	18.77	24.53	30.48	34.53
Value of AI (\$/cow)*	0.00	(37.48)	(34.76)	(29.00)	(23.05)	(19.00)
Value of inseminate (\$/cow)**	0.00	(23.43)	(20.45)	(17.06)	(13.56)	(11.18)

*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

Increases in weaning rate and replacement rate were also evaluated in the straightbred by terminal mating system (Appendix Q). These scenarios included a 90% weaning rate at a 15% replacement rate, 85% weaning rate and 20% replacement rate, and

90% weaning rate and 20% replacement rate. All assumed natural service and artificial insemination could achieve the said parameters. In a straightbred by terminal mating system using artificial insemination followed by natural service, the value of the 90% sexed inseminate was \$1.89, \$0.81, and \$2.78 for the 90%/15%, 85%/20%, and 90%/20% weaning rate/replacement rate scenarios, respectively. When artificial insemination was used with no natural service cleanup, the value of an inseminate sexed at 90% was \$4.89, given a weaning rate of 90% and replacement rate of 15%.

Rotation-Terminal Mating System

A rotation-terminal crossbreeding system allows cattlemen to take advantage of both hybrid vigor and breed complementarity; however, one advantage to the rotation-terminal system over the straightbred by terminal system is the ability to make use of not only individual hybrid vigor but maternal hybrid vigor as well.

The results obtained for a rota-terminal crossbreeding system using artificial insemination followed by natural service as compared to the same system using natural service were as follows (Table 5.11). Weaning rate and replacement rate were 85 and 15%, respectively. Average weaning weight per cow increased 4.9% while the average weaning weight per cow for steer calves per cow increased 27.3%. The average live weight per cow marketed at weaning increased 1.8%.

Gross revenues per cow increased 4.0% while gross revenue from calf sales increased 6.2%. Variable cost increased 5.7%. The increase in variable costs reflects increases in animal expenses due to increases in feed (2.4%), breeding (93.5%), and marketing (4.8%) expenses. Although variable costs increased, fixed costs decreased due to the use of fewer bulls and the elimination of related depreciation. Net receipts per cow

increased approximately 6.5%; however, net receipts decreased when using artificial insemination at all other sex ratios. Values of inseminates sexed for 80% and 90% were \$(3.09)/cow and \$3.30/cow, respectively. Under low market prices, inseminate values decreased to \$(3.80)/cow for 80% and \$1.60/cow for 90% sexed inseminate, respectively. Conversely, high cattle prices increase the values to \$(2.37)/cow and \$5.03/cow for 80% and 90% sexed inseminates, respectively (Figure 5.1).

Table 5.11. Production and associated revenues and expenses for a rota-terminal mating system using artificial insemination followed by natural service with an 85% weaning rate and 15% replacement rate versus the rota-terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	167	172	180	190	203
Avg. weaning weight (lbs./cow)	224.46	221.46	231.70	247.70	264.72	285.70
No. of heifers (N)	105	105	101	94	84	74
Avg. weaning weight (lbs./cow)	138.65	138.89	133.09	122.98	109.14	95.36
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	168.75	169.1	168.78	168.41	169.36
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	410.29	403.54	408.28	414.41	418.31	426.51
Gross revenue from calf sales	326.40	323.81	328.40	334.67	338.73	346.51
Cash operating expense	317.05	331.53	331.63	331.75	333.20	335.01
Non-cash operating expense	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	51.01	34.82	39.47	45.47	47.92	54.31
Value of inseminate (\$/cow)*	0	(16.19)	(11.54)	(5.54)	(3.09)	3.30

*Inseminate value equal to net receipts for AI minus net receipts for natural service.

Assuming lowered pregnancy rates associated with artificial insemination resulting in a weaning rate of 80%, the comparison was made between a system using artificial insemination followed by natural service versus a system solely using natural service (Table 5.12). Compared to the natural service scenario, the average weaning weight per cow for the 90% sexed treatment decreased 8.1% while the average weaning weight for steer calves increased 17.7%. Live weight marketed per cow decreased 6.8%.

Table 5.12. Production and associated revenues and expenses for a rota-terminal mating system using artificial insemination followed by natural service with an 80% weaning rate and 15% replacement rate versus the rota-terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	156	161	168	176	188
Avg. weaning weight (lbs./cow)	224.46	207.34	216.10	229.04	244.56	264.10
No. of heifers (N)	105	95	92	86	78	68
Avg. weaning weight (lbs./cow)	138.65	125.53	121.11	112.41	99.95	87.54
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	168.75	169.1	168.78	168.41	169.36
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	410.29	379.07	383.61	388.08	391.76	399.80
Gross revenue from calf sales	326.40	299.30	303.72	308.35	312.18	319.80
Cash operating expense	317.05	330.96	331.05	331.15	332.59	334.39
Non-cash operating expense	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	51.01	10.92	15.37	19.75	21.98	28.22
Value of inseminate (\$/cow)*	0	(40.09)	(35.64)	(31.26)	(29.03)	(22.79)

*Inseminate value equal to net receipts for AI minus net receipts for natural service.

Compared to the natural service scenario, the 90% sex ratio treatment's gross revenue decreased 2.6% while revenues associated with other artificial insemination treatments decreased. Gross revenue from calf sales decreased 2.0%. Variable costs increased 5.5%, reflecting a 8.7% increase in animal expense due to increased costs associated with the use of artificial insemination and feed. Net receipts decreased 44.7% from \$51.01/cow to \$28.22/cow when comparing the natural service and the 90% sexed inseminate scenarios, respectively; however, net receipts decreased as much as 78.6% (artificial insemination and 50% sex ratio). Under said production and market conditions (including high cattle prices), it is not economical to use artificial insemination; however, it is important to note that sexing does add value to the artificial inseminate but at a diminishing rate (Figure 5.2).

Similar to the analyses involving the straightbred and straightbred by terminal mating scenarios, the comparison was made between a rota-terminal system using natural mating versus a rota-terminal system using only artificial insemination (Table 5.13). If we assume artificial insemination can produce the same weaning rates (essentially same pregnancy and calf survival rates) of 85%, the following results were obtained for the comparison between a system using natural service versus artificial insemination. Average weaning weight per cow increased 7.2% while the average weaning weight per cow for steer calves increased 54%. The live weight marketed at weaning per cow increased 1.6%.

Gross revenues increased 5.7%; gross revenue from calf sales increased 9.8%. Variable costs increased 7.1%, reflecting an 11.2% increase in animal expenses.

Table 5.13. Production and associated revenues and expenses for a rota-terminal mating system using artificial insemination with an 85% weaning rate and 15% replacement rate versus the rota-terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate..

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	170	180	197	218	242
Avg. weaning weight (lbs./cow)	224.46	229.96	248.92	276.34	309.96	345.76
No. of heifers (N)	105	105	95	78	57	33
Avg. weaning weight (lbs./cow)	138.65	141.64	128.01	104.86	76.24	43.48
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	169.35	169.10	167.99	168.7	168.27
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	410.29	410.07	415.99	421.29	428.53	433.76
Gross revenue from calf sales	326.40	334.05	340.08	345.88	352.80	358.23
Cash operating expense	317.05	335.81	336.29	336.21	338.42	339.59
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	51.01	40.82	46.27	51.65	56.67	60.74
Value of AI (\$/cow)*	0.00	(10.19)	(4.74)	0.64	5.66	9.73
Value of inseminate (\$/cow)**	0.00	(6.37)	(1.06)	.38	3.33	5.72

*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

The animal expense included increases in feed costs (3.5%), breeding (~213%), and marketing (4.1%). Fixed costs decreased nearly 21% due to the elimination of live bulls and associated depreciation. Compared to natural service, net receipts for the 90% sex ratio increased 19.1%. Net receipts for the treatments using artificial insemination at 50 and 60% sex ratios were below those received for the natural service scenario. Inseminate values of \$3.33/cow and \$5.72/cow were obtained for inseminates sexed for

80% and 90% the desired offspring, respectively. Low market prices reduce the inseminate values for 80% and 90% sexed semen to \$2.32/cow and \$4.51/cow, respectively. Conversely, high market prices increase their values to \$4.34/cow and \$6.69/cow for the 80% and 90% sexed inseminates. The value of artificial insemination increased when sexing was applied (Figure 5.3).

As previously mentioned, pregnancy rates associated with artificial insemination tend to be lower than those associated with natural service. Assuming weaning rates of 80% for the artificial insemination treatments, the following results were obtained (Table 5.14). Compared to the natural service scenario, average weaning weight per cow for the 90% sexed treatment decreased .7% while the average weaning weight per cow for steer calves increased 42.5%. The live weight marketed at weaning per cow decreased 3.6%.

Gross revenues per cow decreased compared to natural service as little as .7% (90% sex ratio); gross revenue from calf sales increased 1.7%. Variable costs increased 6.9%, reflecting a 10.9% increase in animal expenses due to the use of artificial insemination and increases in feed. It is important to note here that it was assumed that up to three breeding opportunities per cow were necessary to achieve said weaning rates. Again, fixed costs decreased due to the elimination of live bulls and associated depreciation. Compared to natural service, net receipts decreased as little as 31.4% (90% sex ratio). It appears uneconomical to use artificial insemination if lowered weaning rates exist; however, it is important to note that sexing does add value of inseminate (Figure 5.4).

Table 5.14. Production and associated revenues and expenses for a rota-terminal mating system using artificial insemination with an 80% weaning rate and 15% replacement rate versus the rota-terminal base scenario using natural service with an 85% weaning rate and 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	170	160	168	183	202	224
Avg. weaning weight (lbs./cow)	224.46	215.59	231.61	256.19	286.89	319.91
No. of heifers (N)	105	95	87	72	53	31
Avg. weaning weight (lbs./cow)	138.65	128.03	117.11	96.67	70.78	40.75
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	169.35	169.1	167.99	168.7	168.27
No. of cull bulls (N)	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total gross revenue	410.29	385.14	390.64	395.62	402.46	407.42
Gross revenue from calf sales	326.40	309.12	314.73	320.21	326.73	331.89
Cash operating expense	317.05	335.23	335.70	335.61	337.82	338.98
Non-cash operating expense	42.19	33.44	33.44	33.44	33.44	33.44
Net receipts	51.01	16.47	21.50	26.57	31.20	35.01
Value of AI (\$/cow)*	0.00	(34.54)	(29.51)	(24.44)	(19.81)	(16.00)
Value of inseminate (\$/cow)**	0.00	(21.59)	(17.36)	(14.38)	(11.65)	(9.41)

*AI value equal to net receipts for AI minus net receipts for natural service.

**Inseminate value equal to the AI value divided by the mean number of inseminates per cow (unsexed:1.6; sexed:1.7).

As in the other mating scenarios, increases in weaning rate and replacement rate were also evaluated in the rota-terminal mating system (Appendix R). These scenarios included a 90% weaning rate at a 15% replacement rate, 85% weaning rate and 20% replacement rate, and 90% weaning rate and 20% replacement rate. All assumed natural service and artificial insemination could achieve the said parameters. In a rota-terminal

mating system using artificial insemination followed by natural service, the value of the 90% sexed inseminate was \$0.29, \$(2.24), and \$(0.02) for the 90%/15%, 85%/20%, and 90%/20% weaning rate/replacement rate scenarios, respectively. When artificial insemination was used with no natural service cleanup, the value of an inseminate sexed at 90% was \$6.81, given a weaning rate of 90% and replacement rate of 15%.

Artificial Insemination: Unsexed Versus Sexed Inseminates

Artificial insemination use in beef cattle is much less than its use in the dairy industry. It is estimated that approximately 13% of beef cattle operations (NAHMS, 1997) use artificial insemination and only about 5% of the nation's beef cowherd is inseminated each year (Taylor and Field, 1999). The majority of these are most likely yearling heifers.

One of the primary reasons beef producers do not use artificial insemination is the cost:benefit ratio. In this particular study, artificial insemination used either once in combination with natural service or as the sole method of breeding was not economical in most scenarios. In the straightbred mating system using artificial insemination as the sole method of breeding and with a weaning rate and replacement rate equal to that of natural service, net receipts for artificial insemination were greater than natural service (\$1.02). However, when comparing artificial insemination with conventional semen to that using sexed semen (Table 5.15), sexing added value to artificial insemination. Under average market prices, as much as \$19.49 was gained when using artificial insemination with a semen dose sexed at 90% compared to conventional semen. An even greater advantage was seen under more favorable market conditions. Results suggest that it is not sexing that is limiting but instead artificial insemination and its associated expense.

Table 5.15. The value of a 90% sexed semen dose relative to an unsexed semen dose.

Wean Rate	Market	Straightbred*		Straightbred X Terminal		Rotation- Terminal	
		AI+	AI-	AI+	AI-	AI+	AI-
80	Low	12.04	7.85	12.95	10.67	14.83	10.80
	Average	13.56	8.64	15.29	12.25	17.30	12.18
	High	15.09	9.44	17.64	13.83	19.76	13.55
85	Low	13.68	7.89	14.81	10.74	16.79	10.81
	Average	15.40	8.60	17.38	12.24	19.49	12.09
	High	17.15	9.33	19.91	13.75	22.21	13.12
90	Low	14.49	---	15.75	---	14.45	---
	Average	16.28	9.33	18.40	13.67	16.46	12.89
	High	18.08	---	21.05	---	18.49	---

*AI+ is artificial insemination plus natural breeding; AI- is artificial insemination only.

Discussion

For all mating systems, the number of cows needed to produce female herd replacements decreased as the proportion of calves of the desired sex increased, allowing for increased number of cows to be bred in the terminal breed group to produce male market offspring. Changes in herd structure among maternal and terminal breed groups agree with Haaland-Holmes et al. (1982) and are slightly higher in number than those reported by Hyde and Bourdon (1998).

Subsequently, the number and proportion of male calves increased as the number of offspring of the desired sex increased, resulting in increases in weaning weight per cow exposed in all mating systems when weaning rates were comparable for systems using artificial insemination versus natural service. The largest increase was observed in the straightbred system, ranging from 6.9 to 9.4% depending on whether artificial

insemination was used once followed by exposure to natural service or used as the sole method of breeding. The straightbred mating system was followed by the rota-terminal mating system (4.9 to 7.2%) and the straightbred by terminal mating system (4.1 to 6.6%). The larger increase in the straightbred system does not agree with the literature. Haaland Holmes et al. (1982) found the larger increase in a rota-terminal system (2.7) than in a straightbred system (2.4%). Scientists reported that the larger increase in the rota-terminal system was due hybrid vigor and increased number of male calves sold at weaning while the increase in the straightbred system was solely due to increased numbers of male calves sold. No genetic improvement was assumed. In this particular study, sire trend and prediction error variance were used to simulate genetic improvement due to the use of genetically superior sires associated with artificial insemination use (see Chapter 4 for a more detailed description). Using production data representing cow-calf production in Georgia, Wise and Bobst (1995) reported an increase in weighted average marketable calf weights of 2.3% for a 90% sex ratio compared to the base of 50%. Given increases in conception rates and calf weights due to selecting semen from superior bulls, the increase in average marketable calf weight was 8.3%.

Increases in the number of male calves produced also generated increases in revenue from calf sales as the proportion of offspring of the desired sex increased. Assuming comparable weaning rates between artificial insemination and natural service, the largest increases were observed in a straightbred mating system and were in the range of 8 to 11.8%, depending on whether artificial insemination was used once followed by natural service cleanup or used as the sole purpose of breeding. The straightbred mating system was followed by the rota-terminal system and then the straightbred by terminal

system with increases being in the ranges of 6.2 to 9.8% and 5.3 to 9.1%, respectively. Haaland-Holmes et al. (1982) reported changes of 7.1% and 6.3% for rota-terminal and straightbred mating systems, respectively.

Net receipts (gross revenue - production costs) were used to determine the value of artificial insemination and the use of sexed semen. The largest increases were observed in the straightbred mating system (54.2 to 80.5%) followed by the rota-terminal mating system (6.5 to 19.1%) and the straightbred by terminal system (1.9 to 12.5%). Haaland-Holmes et al. (1982) reported increases of 20% and 22% for straightbred and rota-terminal mating systems, respectively.

Given average market prices, the value an inseminate of sexed sperm targeting 90% sex ratio in favor of the preferred sex of offspring was \$9.24 to \$10.57 in a straightbred mating system, depending on whether artificial insemination was used as the sole method of breeding or used once followed by exposure to natural service. In crossbreeding systems, higher sexed inseminate values were obtained for those systems that use artificial insemination as the sole method of breeding. Inseminate values in the crossbreeding systems ranged from \$1.01 to \$3.93 and \$3.30 to \$5.72 for the straightbred by terminal and rota-terminal mating systems, respectively. Haaland-Holmes et al. (1982) reported values of \$15.98 and \$18.16 for straightbred and rota-terminal systems, respectively.

Wise and Bobst (1993) used partial budgeting to examine the economic effects of various success rates of sexed semen on a 100 head beef cow herd in a Georgia environment. Given increases in calf price along with decreases in costs of production, increases in conception rates associated with sexed semen and increases in weaning

weights due to the use of superior bulls, the value of sexed semen increased as the success rate of sexed semen increased with a low of \$31 to a high of \$44 for the 70% and 98% sex ratios, respectively. A 90% sexed semen dose was valued at \$39.57. Using similar methods to estimate the economic effects of sexed semen on cow-calf operations in Kentucky, Best (1995) obtained a breakeven value of sexed semen of \$21.41 per cow.

Conclusions and Implications

Sexed semen increases production efficiency by means of more efficient female allocation in the production of herd replacements while increasing the number of females targeted for production of male market offspring, increasing weaning weight per cow exposed. However, a technology may improve production efficiency and yet be economically infeasible.

Sexing sperm appears to be economically beneficial when weaning rates, meaning pregnancy rates and calf survival, are comparable to natural service. When weaning rates are lower (reflecting lower pregnancy rates and/or calf survival rates), the benefits in production do not outweigh the increase in variable costs associated with artificial insemination. However, the cost of sexed semen, based on the assumptions of this study, needs to be relatively close to that of an unsexed dose of sperm in a straightbred production system; however, sexed semen may not be economically viable in those systems applying crossbreeding. Besides cost and efficacy of the sexing technology, this value is dependent upon several factors, such as weaning rate (meaning pregnancy rates and calf survival) previously mentioned, mating system, and artificial insemination program. Such things can be influenced by the cow-calf producer through management

practices. However, the value of sexed semen is also dependent upon market conditions which are out of the producer's control.

Adoption of sexed semen technology will depend on individual production systems. Those currently using artificial insemination will be the first to benefit; however, under certain conditions, sexed semen provides an economic incentive to adopt artificial insemination in combination in order to take advantage of production gains due to improved genetics and(or) hybrid vigor.

This particular study only evaluates a few pieces of a greater puzzle involving sex semen utilization. An area for future research includes evaluating the use of sexed semen in the dairy industry and its impact on beef supply. The dairy industry is most likely the benefactors of said technology. Sex control will allow dairymen to produce their needed herd replacements with only a minimal number of cows while breeding the remainder of the herd with beef semen to produce male dairy-beef crosses that will compete for space at the feed bunk and on the rail.

Another research topic includes determining the value of sexed semen if a cow-calf producer retains ownership of his calves through slaughter. Selling cattle on many of today's grids may provide increased value based on potential premiums. Also, crossbreeding systems favor retained ownership to take advantage of terminal growth.

Value of sexed semen in seedstock production is another area of interest. Although many of the herd structure benefits apply, what are the potential impacts on selection intensity and genetic variability in the long term? These are just a few of the areas needing attention in order to more fully evaluate the biological and economic impacts of sexed semen.

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CHAPTER 6

CONCLUSIONS

Summary and Conclusions

In summary, pregnancy rates for sexed semen in yearling heifers were 40 to 80% of those associated with conventional frozen semen controls in the first two years and as good or better numerically in 1999, but with only 1% to 15% as many sperm per dose. In comparison, pregnancy rates for sexed semen with cows were less than half of those for conventional frozen semen in cows in the first year of cow breeding. We emphasize that there were large sire and technician effects on pregnancy rates that year for sexed semen treatments in the cows. Pregnancy rates with the more experienced technician and the more fertile bulls were nearly double those of the less experienced technician using lower fertility bulls. In the following year, pregnancy rates in cows for the sexed semen treatments improved and were 63% to 77% of those associated with frozen controls. Fertility of sorted sperm was higher for certain bulls; practical application of current technology may require identification of bulls whose sperm tolerate the stress of sorting. Further research is required into the effects of sexed semen on pregnancy rates, especially in cows.

We clearly have been able to significantly alter the sex ratio of calves in both primiparous and multiparous beef females. Altering the sex ratio will allow commercial producers to better use growth and carcass genetics in production of male market

offspring, while capitalizing on maternal genetics and environment provided by the cow from designated maternal lines. A particularly useful application will be to obtain female calves from virgin heifers; this will greatly reduce dystocia because heifer calves average about 2.3 kg less at birth than bull calves.

In the second phase of the project, increases in biological efficiency were the largest in the straightbred mating system when artificial insemination was used once followed by a period of natural service cleanup. Said improvement was achieved at sexing efficacy of 70 to 80%, suggesting that sex control does not have to be perfect before producers realize potential gains in efficiency. When artificial insemination was used alone, the largest increases were observed in the straightbred mating system for LWW but rotation-terminal mating system for all harvest production traits. These results were achieved at sex control levels of 80 and 90% for the straightbred and rotation-terminal mating systems, respectively. Sexing of an artificial insemination dose added value to the inseminate although the efficacy of sexing necessary to achieve the greatest gain in biological efficiency depended upon mating system. Potentially greater increases in efficiency, especially in production, would be achieved if artificial insemination with sexed inseminates produced similar pregnancy rates to those of artificial insemination with conventional, unsexed semen or even natural service. Results suggest that the levels of efficacy currently achieved with sexing technology make it a viable biological production option as a means to increase efficiency of production in commercial beef production.

Sexed semen increases production efficiency by means of more efficient female allocation in the production of herd replacements while increasing the number of females

targeted for production of male market offspring, increasing weaning weight per cow exposed. However, a technology may improve production efficiency and yet be economically infeasible. More efficient herd allocation into maternal and terminal breeding groups would take advantage of genetic improvement in maternal characteristics in female replacements while capitalizing on hybrid vigor and breed complementarity in the production of male market offspring. A crossbred maternal line would take advantage of maternal hybrid vigor and increased reproductive rates.

Sexing sperm appears to be economically beneficial when weaning rates (i.e. pregnancy rates and calf survival) are comparable to natural service. When weaning rates are lower (reflecting lower pregnancy rates and/or calf survival rates), the benefits in production do not outweigh the increase in variable costs associated with artificial insemination. However, the cost of sexed semen, based on the assumptions of this study, needs to be relatively close to that of an unsexed dose of sperm. Besides cost and efficacy of the sexing technology, this value is dependent upon several factors, such as weaning rate (meaning pregnancy rates and calf survival) previously mentioned, mating system, and artificial insemination program. Such things can be influenced by the cow-calf producer through management practices. However, the value of sexed semen is also dependent upon market conditions which are out of the producer's control.

When comparing artificial insemination with conventional semen to that using sexed semen, sexing added value to artificial insemination. Results suggest that it is not sexing that is limiting but instead artificial insemination and its associated expense.

Adoption of sexed semen technology will depend on individual production systems. Those currently using artificial insemination will be the first to benefit;

however, under certain conditions, sexed semen provides an economic incentive to adopt artificial insemination in combination in order to take advantage of production gains due to improved genetics and(or) hybrid vigor.

The potential benefits of commercially available sexed semen include more efficient beef production, more efficient allocation of beef genetics, and the propagation of a “value-added” product that brings with it the quality and consistency that beef consumers desire.

Further Research

This particular study only evaluates a few pieces of a greater puzzle involving sexed semen utilization. An area for future research includes evaluating the use of sexed semen in the dairy industry and its impact on beef supply. The dairy industry is most likely the benefactor of said technology. Sex control will allow dairymen to produce their needed herd replacements with only a minimal number of cows while breeding the remainder of the herd with beef semen to produce male dairy-beef crosses that will compete for space at the feed bunk and on the rail.

Another area to be addressed includes the use of sexed semen in the beef and dairy seedstock industries. For example, a seedstock producer in the beef industry may want to produce a higher proportion of female calves if he has an established market for replacement heifers. Conversely, if his production goals are to sell yearling bulls, he may want to increase the proportion of male calves.

Another research topic includes determining the value of sexed semen if a cow-calf producer retains ownership of his calves through slaughter. Selling cattle on many of

today's grids may provide increased value based on potential premiums. Also, crossbreeding systems favor retained ownership to take advantage of terminal growth.

A final area needing to be addressed includes quantifying the effects of sexed semen use in reducing dystocia among two-year-olds. Sexed semen will allow producers to obtain female calves out of virgin heifers. Heifer calves average about 2.3 kg less at birth than bull calves. This is a particularly useful application in both seedstock and commercial production sectors.

APPENDIX A


```

SUBROUTINE CONCEIVE
C
C      THIS MODULE GENERATES CALVES BORN WITHIN THE HERD.
C
C
C      ** TOP OF A BLOCK ** TOP OF A BLOCK ** TOP OF A BLOCK ** TOP OF
C      BLOCK **
C
C      INTEGER NPEGPS, NTRATS, S,T,U,V,D,X,E,F,C,B

      REAL AMTX(210), GAM12(20,20), NAM12(20,20), NAMTX(210)
      REAL OAM12(20,20), PEM12(20,20), PEMTX(210), S1012(20,20)
      REAL S1112(20,20), S112(20,20), S1212(20,20), S212(20,20)
      REAL S312(20,20), S412(20,20), S512(20,20), S612(20,20)
      REAL S712(20,20), S812(20,20), S912(20,20), SIRPEV(20,12)
C
C      COMMON / ABLOCK / NPEGPS, NTRATS, AMTX, GAM12, NAM12,
+      NAMTX, OAM12, PEM12, PEMTX, S1012, S1112, S112, S1212,
+      S212, S312, S412, S512, S612, S712, S812, S912, SIRPEV
C
C      ** BOTTOM OF A BLOCK ** BOTTOM OF A BLOCK ** BOTTOM OF A
C      BLOCK **
C
C
C      ***** TOP OF STANDARD BLOCKS ***** TOP OF STANDARD BLOCKS
*****
C
C      INCLUDE '../inc/SBLOCKS.F'
C
C      **** BOTTOM OF STANDARD BLOCKS **** BOTTOM OF STANDARD
C      BLOCKS ***
C
C      INTEGER COUNTL, LISCAL

      DETERMINE NUMBER OF NEWLY CONCEIVED CALVES

      NEEDED = NOBITS
      IF ( NEEDED .EQ. 0 ) RETURN
C
C      FIND LOCATIONS FOR NEWLY CONCEIVED ANIMALS
C
      ITSCAL = COUNTL( CVGONE, 1, N )
      IF ( NEEDED .GT. ITSCAL ) CALL BOMB ( 10 )
      CALL ICMPRS( LOCIND, 1, N, CVGONE, ITEMP1 )
      DO 10 I = 1, N
        CVGEN(I) = .FALSE.

```

```

10  CONTINUE
    DO 20 J = 1, NEEDED
        CVGEN( ITEMP1(J) ) = .TRUE.
20  CONTINUE
C
C          SET ALL NON-ZERO LOGICAL VECTORS
C
    DO 35 I = 1, N
        CVLIVE(I) = CVLIVE(I) .OR. CVGEN(I)
        CVFETS(I) = CVFETS(I) .OR. CVGEN(I)
        CVGONE(I) = CVGONE(I) .AND. .NOT. CVGEN(I)
35  CONTINUE
C
C          IDENTIFY DAMS (UPDATE DAMIND, DAMID AND FETIND)
C          ASSIGN INDIVIDUAL ID NUMBERS
C
C
    J = 0
    K = 0
    DO 40 I = 1, N
        IF ( CVGENF(I) ) THEN
            K = K + 1
            ITEMP1(K) = LOCIND(I)
            ITEMP3(K) = ID(I)
        END IF
        IF ( CVGEN(I) ) THEN
            J = J + 1
            ITEMP2(J) = LOCIND(I)
        END IF
40  CONTINUE

    DO 50 J = 1, NEEDED

        FETIND( ITEMP1(J) ) = ITEMP2(J)
        DAMIND( ITEMP2(J) ) = ITEMP1(J)
        DAMID( ITEMP2(J) ) = ITEMP3(J)
        MAXID = MAXID + 1
        ID( ITEMP2(J) ) = MAXID

50  CONTINUE

C
C
C          SAVE "NEEDED" IN LOCAL VARIABLE

```

```

C
LISCAL = NEEDED
C
C      DETERMINE SIRES
C
CALL SIREPICK
C
C      RETURN ORIGINAL VALUE TO "NEEDED"
C
NEEDED = LISCAL
C
C      ASSIGN SIRE IDS AND SIRE TYPES
C
DO 60 I = 1, N
  IF ( CVGEN(I) ) THEN
    SIREID(I) = ID( SIRIND(I) )
    SIRTYP(I) = SIRTYP( SIRIND(I) )
  END IF
60 CONTINUE
C
C      SET POINTER FOR BV SQUARE ROOT MATRIX
C
M12PNT = 222
C
C      INITIALIZE MEANS FOR BREEDING VALUES
C
DO 70 I = 1, N
  IF ( CVGEN(I) ) THEN
    BVBW(I) = ( BVBW( SIRIND(I) ) + BVBW( DAMIND(I) ) ) / 2.
    BVYW(I) = ( BVYW( SIRIND(I) ) + BVYW( DAMIND(I) ) ) / 2.
    BVMW(I) = ( BVMW( SIRIND(I) ) + BVMW( DAMIND(I) ) ) / 2.
    BVMP(I) = ( BVMP( SIRIND(I) ) + BVMP( DAMIND(I) ) ) / 2.
    BVAAP(I) = ( BVAAP( SIRIND(I) ) + BVAAP( DAMIND(I) ) ) / 2.
    BVPCYC(I) = ( BVPCYC( SIRIND(I) ) + BVPCYC( DAMIND(I) ) ) / 2.
    BVPCON(I) = ( BVPCON( SIRIND(I) ) + BVPCON( DAMIND(I) ) ) / 2.
    BVDDYS(I) = ( BVDDYS( SIRIND(I) ) + BVDDYS( DAMIND(I) ) ) / 2.
    BVMDYS(I) = ( BVMDYS( SIRIND(I) ) + BVMDYS( DAMIND(I) ) ) / 2.
    BVGL(I) = ( BVGL( SIRIND(I) ) + BVGL( DAMIND(I) ) ) / 2.
    BVMF(I) = ( BVMF( SIRIND(I) ) + BVMF( DAMIND(I) ) ) / 2.
    BVAPP(I) = ( BVAPP( SIRIND(I) ) + BVAPP( DAMIND(I) ) ) / 2.
    BVUNSD(I) = ( BVUNSD( SIRIND(I) ) + BVUNSD( DAMIND(I) ) ) / 2.
    BVPSRV(I) = ( BVPSRV( SIRIND(I) ) + BVPSRV( DAMIND(I) ) ) / 2.
    BVRM(I) = ( BVRM( SIRIND(I) ) + BVRM( DAMIND(I) ) ) / 2.
    BVIMF(I) = ( BVIMF( SIRIND(I) ) + BVIMF( DAMIND(I) ) ) / 2.
    BVFFC(I) = ( BVFFC( SIRIND(I) ) + BVFFC( DAMIND(I) ) ) / 2.
    BVYLD(I) = ( BVYLD( SIRIND(I) ) + BVYLD( DAMIND(I) ) ) / 2.
  
```

```

        BVXXXX(I) = ( BVXXXX( SIRIND(I) ) + BVXXXX( DAMIND(I) ))/ 2.
        BVZZZZ(I) = ( BVZZZZ( SIRIND(I) ) + BVZZZZ( DAMIND(I) ))/ 2.
    END IF
70  CONTINUE
C
C          DETERMINE BREED COMPOSITION
C
    K = 0
    DO 90 I = 1, N
        IF ( CVGEN(I) ) THEN
            K = K + 1
            DO 80 L = 1, 10
                TARAY1( K, L ) = BRDCMP( SIRIND(I), L )
                TARAY2( K, L ) = BRDCMP( DAMIND(I), L )
                BRDCMP( I, L ) = ( TARAY1(K,L) + TARAY2(K,L) ) / 2.
80          CONTINUE
            END IF
90  CONTINUE

C
C          SEX DETERMINATION
C

    CALL RANVN( TEMP1, NEEDED )
    CALL ICMPRS (LOCIND,1,N, CVGEN,ITEMP1)
    DO 95 J = 1, NEEDED

C
C
C          MATERNAL 50:50 FEMALES
C
    IF ( EIS14 .EQ. 1 .and.
+ SIRTYP(ITEMP1(J)) .eq. 7) THEN
        IF ( TEMP1(J) .LT. .5 ) SEX( ITEMP1(J) ) = 2
        IF ( TEMP1(J) .GE. .5 ) SEX( ITEMP1(J) ) = 1

        PRINT *, "50:50 AI MATERNAL"
    END IF

C          MATERNAL 60:40 FEMALES
C
    IF ( EIS14 .EQ. 2 .and.
+ SIRTYP(ITEMP1(J)) .eq. 7) THEN
        IF ( TEMP1(J) .LT. .6 ) SEX( ITEMP1(J) ) = 1
        IF ( TEMP1(J) .GE. .6 ) SEX( ITEMP1(J) ) = 2

```

```

PRINT *, "60:40 AI MATERNAL"
END IF
C
C      MATERNAL 70:30 FEMALES
C
IF ( EIS14 .EQ. 3 .and.
+ SIRTYP(ITEMP1(J)) .eq. 7) THEN
  IF ( TEMP1(J) .LT. .7 ) SEX( ITEMP1(J) ) = 1
  IF ( TEMP1(J) .GE. .7 ) SEX( ITEMP1(J) ) = 2

PRINT *, "70:30 AI MATERNAL"
END IF
C
C      MATERNAL 80:20 FEMALES
C
IF ( EIS14 .EQ. 4 .and.
+ SIRTYP(ITEMP1(J)) .eq. 7) THEN
  IF ( TEMP1(J) .LT. .8 ) SEX( ITEMP1(J) ) = 1
  IF ( TEMP1(J) .GE. .8 ) SEX( ITEMP1(J) ) = 2

PRINT *, " 80:20 AI MATERNAL"

END IF
C
C      MATERNAL 90:10 FEMALES
C
IF ( EIS14 .EQ. 5 .and.
+ SIRTYP(ITEMP1(J)) .eq. 7) THEN
  IF ( TEMP1(J) .LT. .9 ) SEX( ITEMP1(J) ) = 1
  IF ( TEMP1(J) .GE. .9 ) SEX( ITEMP1(J) ) = 2

PRINT *, " 90:10 AI MATERNAL"
END IF
C
C      50:50 SEX RATIO
C
IF (SIRTYP(ITEMP1(J)) .eq. 1 .or.
+ SIRTYP(ITEMP1(J)) .eq. 2 .or.
+ SIRTYP(ITEMP1(J)) .eq. 3 .or.
+ SIRTYP(ITEMP1(J)) .eq. 4 .or.
+ SIRTYP(ITEMP1(J)) .eq. 5 .or.
+ SIRTYP(ITEMP1(J)) .eq. 6) THEN
  IF ( TEMP1(J) .LT. .5 ) SEX( ITEMP1(J) ) = 2
  IF ( TEMP1(J) .GE. .5 ) SEX( ITEMP1(J) ) = 1

```

```

PRINT *, "ALL 50:50 RULE "

END IF

C
C      COWS (AI ALL) 50:50 MALES
C
  IF ( EIS14 .EQ. 1
+     .and. SIRTYP(ITEMP1(J)) .eq. 8
+     ) THEN

    IF (TEMP1(J) .LT. .5) SEX(ITEMP1(J)) = 2
    IF (TEMP1(J) .GE. .5) SEX(ITEMP1(J)) = 1
    PRINT *, "COWS 50:50 "
    END IF

C      COWS (AI ALL) 60:40 MALES
C
  IF ( EIS14 .EQ. 2
+     .and. SIRTYP(ITEMP1(J)) .eq. 8
+     ) THEN

    IF (TEMP1(J) .GE. .6) SEX(ITEMP1(J)) = 1
    IF (TEMP1(J) .LT. .6) SEX(ITEMP1(J)) = 2
    PRINT *, "COWS 60:40 "
    END IF

C      COWS (AI ALL) 70:30 MALES
C
  IF ( EIS14 .EQ. 3
+     .and. SIRTYP(ITEMP1(J)) .eq. 8
+     ) THEN

    IF (TEMP1(J) .GE. .7) SEX(ITEMP1(J)) = 1
    IF (TEMP1(J) .LT. .7) SEX(ITEMP1(J)) = 2

    PRINT *, "COWS 70:30 "
    END IF

C      COWS (AI ALL) 80:20 MALES
C
  IF ( EIS14 .EQ. 4
+     .and. SIRTYP(ITEMP1(J)) .eq. 8
+     ) THEN

    IF (TEMP1(J) .GE. .8) SEX(ITEMP1(J)) = 1

```

```

        IF (TEMP1(J) .LT. .8) SEX(ITEMP1(J)) = 2

PRINT *, "COWS 80:20 "
END IF
C
C      COWS (AI ALL) 90:10
C
      IF ( EIS14 .EQ. 5
+        .and. SIRTYP(ITEMP1(J)) .eq. 8
+        ) THEN

        IF (TEMP1(J) .GE. .9) SEX(ITEMP1(J)) = 1
        IF (TEMP1(J) .LT. .9) SEX(ITEMP1(J)) = 2

PRINT *, "COWS 90:10 "
END IF
95  CONTINUE

C
C  SEX OUTPUT
C

S = 0
T = 0
U = 0
V = 0
D = 0
X = 0
E = 0
F = 0
C = 0
B = 0
DO 151 I = 1,N
  IF (CVGEN(I) .AND. SIRTYP(I) .EQ. 7 .AND. SEX(I) .EQ. 1) THEN
    S = S + 1
  END IF
  IF (CVGEN(I) .AND. SIRTYP(I) .EQ. 7 .AND. SEX(I) .EQ. 2) THEN
    T = T + 1
  END IF
  IF (CVGEN(I) .AND. (SIRTYP(I) .EQ. 1 .or. SIRTYP(I) .EQ. 3
+    .OR. SIRTYP(I) .EQ. 5) .AND. SEX(I) .EQ. 1) THEN
    U = U + 1
  END IF
  IF (CVGEN(I) .AND. (SIRTYP(I) .EQ. 1 .or. SIRTYP(I) .EQ. 3
+    .OR. SIRTYP(I) .EQ. 5) .AND. SEX(I) .EQ. 2) THEN
    V = V + 1

```

```

      END IF
      IF (CVGEN(I) .and. SIRTYP(I) .EQ. 8 .AND. SEX(I) .EQ. 1
+    ) THEN
        B = B+1
      END IF
      IF (CVGEN(I) .and. SIRTYP(I) .EQ. 8 .AND. SEX(I) .EQ. 2
+    ) THEN
        C = C+1
      END IF
      IF (CVGEN(I) .AND. (SIRTYP(I) .EQ. 2 .or. SIRTYP(I) .EQ. 4
+    .OR. SIRTYP(I) .EQ. 6) .AND. SEX(I) .EQ. 1) THEN
        E = E+1
      END IF
      IF (CVGEN(I) .AND. (SIRTYP(I) .eq. 2 .or. SIRTYP(I) .EQ. 4
+    .or. SIRTYP(I) .eq. 6) .AND. SEX(I) .EQ. 2) THEN
        F = F+1
      END IF
151  CONTINUE

      WRITE(31,152) YEAR, DAY, S, T
152  FORMAT(// 'YR: ',I7,' DAY: ',I7,' AI MAT/HEIF: ',I7,
+    ' AI MAT/MALE: ',I7 //)
      WRITE(33,154) YEAR, DAY, U, V
154  FORMAT(// 'YR: ',I7,' DAY: ',I7,' MAT/HEIF: ',I7,
+    ' MAT/MALE: ',I7 //)
c    WRITE(35,156) YEAR, DAY, D, X
c156  FORMAT(// 'YR: ',I7,' DAY: ',I7,' AI TERM/HEIF: ',I7,
c +    ' AI TERM/MALE: ',I7 //)
      WRITE(39, 159) YEAR, DAY, B, C
159  FORMAT(// 'YR: ',I7,' DAY: ',I7,' AI TERM/HEIF: ',I7,
+    ' AI TERM/MALE: ',I7 //)
      WRITE(37, 158) YEAR, DAY, E, F
158  FORMAT(// 'YR: ',I7,' DAY: ',I7,' TERM/HEIF: ',I7,
+    ' TERM/MALE: ',I7 //)
C
C      DETERMINE NON-ADDITIVE STARTING VALUES
C
      CALL ICMPRS( LOCIND, 1, N, CVGEN, ITEMP1 )
      DO 100 K = 1, NEEDED
        DO 100 L = 1, 10
          DO 100 M = 1, 10
C
C          1) BIRTH WEIGHT
C
            J = 1
            NABW( ITEMP1(K) ) = NABW( ITEMP1(K) ) +

```



```

+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      2) YEARLING WEIGHT
C
J = 2
NAYW( ITEMP1(K) ) = NAYW( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      3) MATURE WEIGHT
C
J = 3
NAMW( ITEMP1(K) ) = NAMW( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      4) MILK PRODUCTION
C
J = 4
NAMP( ITEMP1(K) ) = NAMP( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      5) AGE AT PUBERTY
C
J = 5
NAAAP( ITEMP1(K) ) = NAAAP( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      6) PROBABILITY OF CYCLING
C
J = 6
NAPCYC( ITEMP1(K) ) = NAPCYC( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      7) PROBABILITY OF CONCEPTION
C
J = 7
NAPCON( ITEMP1(K) ) = NAPCON( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      8) DIRECT DYSTOCIA
C
J = 8
NADDYS( ITEMP1(K) ) = NADDYS( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C      9) MATERNAL DYSTOCIA
C

```

```

J = 9
NAMDYS( ITEMP1(K) ) = NAMDYS( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   10) GESTATION LENGTH
C

J = 10
NAGL( ITEMP1(K) ) = NAGL( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   11) MATURE FAT
C

J = 11
NAMF( ITEMP1(K) ) = NAMF( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   12) APPETITE
C

J = 12
NAAPP( ITEMP1(K) ) = NAAPP( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   13) UNSOUNDNESS
C

J = 13
NAUNSD( ITEMP1(K) ) = NAUNSD( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   14) PROBABILITY OF SURVIVAL
C

J = 14
NAPSRV( ITEMP1(K) ) = NAPSRV( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   15) REQUIREMENT FOR MAINTENANCE
C

J = 15
NARM( ITEMP1(K) ) = NARM( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C   16) INTRAMUSCULAR FAT
C

J = 16
NAIMF( ITEMP1(K) ) = NAIMF( ITEMP1(K) ) +
+   TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C

```

```

C          17) FAT-FREE COMPOSITION
C
      J = 17
      NAFFC( ITEMP1(K) ) = NAFFC( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C          18) YIELD GRADE
C
      J = 18
      NAYLD( ITEMP1(K) ) = NAYLD( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C          19) XXXX
C
      J = 19
      NAXXXX( ITEMP1(K) ) = NAXXXX( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
C
C          20) ZZZZ
C
      J = 20
      NAZZZZ( ITEMP1(K) ) = NAZZZZ( ITEMP1(K) ) +
+      TARAY1( K, L ) * TARAY2( K, M ) * HYVIG( J, L, M )
100 CONTINUE
C
C          GENERATE BVS, NAVS, PE AND TE EFFECTS
C
      IF ( MNGEN .EQ. 1 ) THEN
        MAXP = TVBLEN / NTRATS
        IF ( NEEDED .LE. MAXP ) THEN
          DO 110 I = 1, N
            CVGET(I) = CVGEN(I)
110      CONTINUE
          RCOUNT = NEEDED
          CALL BVGEN
          CALL NAVGEN
          CALL PEGEN
          CALL TEGEN
        ELSE
          CALL ICMPRS( LOCIND, 1, N, CVGEN, ITEMP1 )
          NLEFT = NEEDED
          NSTART = ITEMP1(1)
          CHCNT = 0
120      DO 130 I = 1, N
            CVGET(I) = .FALSE.
130      CONTINUE

```

```

IF ( NLEFT .GT. MAXP ) THEN
  CIICNT = CIICNT + MAXP
  NLAST = ITEMP1(CIICNT)
  OFFSET = NLAST - NSTART + 1
  DO 140 I = NSTART, NSTART + OFFSET - 1
    CVGET(I) = CVGEN(I)
140   CONTINUE
  RCOUNT = MAXP
  CALL BVGEN
  CALL NAVGEN
  CALL PEGEN
  CALL TEGEN
  NLEFT = NLEFT - MAXP
  NSTART = ITEMP1(CIICNT + 1)
  GO TO 120
ELSE
  NLAST = ITEMP1(NEEDED)
  OFFSET = NLAST - NSTART + 1
  DO 150 I = NSTART, NSTART + OFFSET - 1
    CVGET(I) = CVGEN(I)
150   CONTINUE
  RCOUNT = MAXP
  CALL BVGEN
  CALL NAVGEN
  CALL PEGEN
  CALL TEGEN
END IF
END IF
END IF
C
C      ADD UP COMPONENTS OF POTENTIALS AND ADJUST FOR SEX
C
DO 170 I = 1, N
  IF ( CVGEN(I) ) THEN
C
C      1) HEIFERS
C
    IF ( SEX(I) .EQ. 1 ) THEN
      POAAP(I) = BVAAP(I) + NAAAP(I) + PEAAP(I)
      POBW(I) = BVBW(I) + NABW(I) + PEBW(I)
      POAPP(I) = BVAPP(I) + NAAPP(I) + PEAPP(I)
      PODDYS(I) = BVDDYS(I) + NADDYS(I) + PEDDYS(I)
      POGL(I) = BVGL(I) + NAGL(I) + PEGL(I)
      POMDYS(I) = BVMDYS(I) + NAMDYS(I) + PEMDYS(I) + TEMDYS(I)
      POMF(I) = BVMF(I) + NAMF(I) + PEMF(I)
      POMP(I) = BVMP(I) + PEMP(I) + TEMP(I)
    
```

```

POMW(I) = BVMW(I) + NAMW(I) + PEMW(I)
POPCON(I) = BVPCON(I) + ( NAPCON(I) + PEPCON(I) +
+   TEPCON(I) ) * ( 1. - BVPCON(I) )
POPCYC(I) = BVPCYC(I) + ( NAPCYC(I) + PEPCYC(I) +
+   TEPCYC(I) ) * ( 1. - BVPCYC(I) )
POUNSD(I) = BVUNSD(I) + NAUNSD(I) + PEUNSD(I)
POYW(I) = BVYW(I) + NAYW(I) + PEYW(I)
POPSRV(I) = BVPSRV(I) + ( NAPSRV(I) + PEPSRV(I) ) *
+   ( 1. - BVPSRV(I) )
PORM(I) = BVRM(I) + NARM(I) + PERM(I)
POIMF(I) = BVIMF(I) + NAIMF(I) + PEIMF(I)
POFFC(I) = BVFFC(I) + NAFFC(I) + PEFFC(I)
POYLD(I) = BVYLD(I) + NAYLD(I) + PEYLD(I)
POXXXX(I) = BVXXXX(I) + NAXXXX(I) + PEXXXX(I)
POZZZZ(I) = BVZZZZ(I) + NAZZZZ(I) + PEZZZZ(I)
END IF

C
C           2) BULLS
C

IF ( SEX(I) .EQ. 2 ) THEN
  POBW(I) = ( BVBW(I) + NABW(I) ) * BABW + PEBW(I)
  POAPP(I) = BVAPP(I) + NAAPP(I) + PEAPP(I)
  PODDYS(I) = ( BVDDYS(I) + NADDYS(I) ) * BADDYS + PEDDYS(I)
  POGL(I) = ( BVGL(I) + NAGL(I) ) * BAGL + PEGL(I)
  POMF(I) = ( BVMF(I) + NAMF(I) ) * BAMF + PEMF(I)
  POMW(I) = ( BVMW(I) + NAMW(I) ) * BAMW + PEMW(I)
  POUNSD(I) = ( BVUNSD(I) + NAUNSD(I) ) * BAUNSD + PEUNSD(I)
  POYW(I) = ( BVYW(I) + NAYW(I) ) * BAYW + PEYW(I)
  POPSRV(I) = BVPSRV(I) + ( NAPSRV(I) + PEPSRV(I) +
+   BAPSRV ) * ( 1. - BVPSRV(I) )
  PORM(I) = ( BVRM(I) + NARM(I) ) * BARM + PERM(I)
  POIMF(I) = ( BVIMF(I) + NAIMF(I) ) * BAIMF + PEIMF(I)
  POFFC(I) = ( BVFFC(I) + NAFFC(I) ) * BAFFC + PEFFC(I)
  POYLD(I) = ( BVYLD(I) + NAYLD(I) ) * BAYLD + PEYLD(I)
  POXXXX(I) = BVXXXX(I) + NAXXXX(I) + PEXXXX(I)
  POZZZZ(I) = BVZZZZ(I) + NAZZZZ(I) + PEZZZZ(I)
END IF

C
C           BOUND POTENTIALS
C

IF ( POBW(I) .LT. 0. ) POBW(I) = 0.
IF ( POYW(I) .LT. 0. ) POYW(I) = 0.
IF ( POMW(I) .LT. 0. ) POMW(I) = 0.
IF ( POMP(I) .LT. 0. ) POMP(I) = 0.
IF ( POAAP(I) .LT. 0. ) POAAP(I) = 0.
IF ( POPCYC(I) .LT. 0. ) POPCYC(I) = 0.

```

```

IF ( POPCYC(I) .GT. 1. ) POPCYC(I) = 1.
IF ( POPCON(I) .LT. 0. ) POPCON(I) = 0.
IF ( POPCON(I) .GT. 1. ) POPCON(I) = 1.
IF ( PODDYS(I) .LT. 0. ) PODDYS(I) = 0.
IF ( POMDYS(I) .LT. 0. ) POMDYS(I) = 0.
IF ( POGL(I) .LT. 0. ) POGL(I) = 0.
IF ( POMF(I) .LT. .04 ) POMF(I) = .04
IF ( POAPP(I) .LT. 0. ) POAPP(I) = 0.
IF ( POUNSD(I) .LT. 0. ) POUNSD(I) = 0.
IF ( POPSRV(I) .LT. 0. ) POPSRV(I) = 0.
IF ( POPSRV(I) .GT. 1. ) POPSRV(I) = 1.
IF ( PORM(I) .LT. 0. ) PORM(I) = 0.
IF ( POIMF(I) .LT. 0. ) POIMF(I) = 0.
IF ( POFFC(I) .LT. 0. ) POFFC(I) = 0.
IF ( POYLD(I) .LT. 0. ) POYLD(I) = 0.
IF ( POXXXX(I) .LT. 0. ) POXXXX(I) = 0.
IF ( POZZZZ(I) .LT. 0. ) POZZZZ(I) = 0.
C
C      TRANSFER FETAL GESTATION LENGTH TO DAMS' RECORDS
C
      GLF( DAMIND(I) ) = INT( POGL(I) + .5 )
      END IF
170 CONTINUE
C
C      DETERMINE AGE OF DAM AT CALVING
C
      DO 175 I = 1, N

      CVVIRG(I) = CVVIRG(I) .OR. ( CVGEN(I) .AND. SEX(I) .EQ. 1 )

      IF ( CVGEN(I) ) THEN
        ITEMP1(I) = DOA(I) - DOG(I) + GLF(I)
        TEMP1(I) = REAL( ITEMP1(I) )
        TEMP2(I) = TEMP1(I) / 30.4375
        ITEMP2(I) = INT( TEMP2(I) )
        ITEMP3(I) = ( ITEMP2(I) - 8 ) / 12 + 1
        DAMAGE( FETIND(I) ) = ITEMP3(I)
      END IF
175 CONTINUE
C
C      DETERMINE ACTUAL BIRTH WEIGHTS
C
      DO 190 I = 1, N
        IF ( CVGEN(I) ) THEN
          DO 180 J = 1, 15
            IF ( DAMAGE(I) .EQ. J ) BW(I) = POBW(I) * BWCF(J)
          
```

```

180    CONTINUE
C
C        SET YEAR OF BIRTH
C
        YOB(I) = YEAR
        ITEMPI(I) = INT( POGL(I) + .5 ) + DAY + STEP
+      - ( STEP / 2 + 1 )
        TEMP1(I) = REAL( ITEMPI(I) )
        IF ( TEMP1(I) - HAFSTP .GT. REAL( NDIY ) )
+      YOB(I) = YEAR + 1
C
C        TRANSFER FETAL BIRTH WEIGHTS TO DAMS' RECORDS
C
        BWF( DAMIND(I) ) = BW(I)
        END IF
        CV2(I) = CVGENF(I) .AND. ( CVNWFN(I) .OR. CVNEWI(I) )
190    CONTINUE
C
C        DETERMINE CONCEPTUS WEIGHTS FOR FETUSES IN NEW
FOUNDATION
C        COWS AND NEWLY IMPORTED COWS.
C
        NOBITS = COUNTL( CV2, 1, N )
        IF ( NOBITS .GT. 0 ) THEN
            DO 200 I = 1, N
                IF ( CV2(I) ) CCW(I) = .0000001 *
+      DOG(I) ** ( LOG( 16600000. * BWF(I) ) /
+      LOG( POGL( FETIND(I) ) ) )
                CVGET(I) = CVGEN(I)
200    CONTINUE
            ELSE
                DO 210 I = 1, N
                    CVGET(I) = CVGEN(I)
210    CONTINUE
            END IF
C
C        COMPUTE INFLECTION WEIGHTS
C
        RCOUNT = NEEDED
        CALL INFLECT
C
C        COMPUTE BVWW
C
        CALL WWBVGEN
C
C        COMPUTE WEIGHTS, FILL AND FAT

```

```

C
  CALL INGROW
C
C  USED BY M. ENNS, ALONG WITH OUTPUT CODE TO DETERMINE
C  WHICH CALVES WERE TWO BREED OR THREE BREED CROSSES
C  ALL ORIGINAL COWS WERE PUREBRED, SOME OF WHICH WERE
C  BRED TO THEIR SIRES OF THEIR OWN BREED BUT WHICH
C  WERE THEN CONSIDERED TO BE TWO BREED CROSSES
C
  DO 250 I = 1, N
    IF ( CVGEN(I) ) THEN
      IF ( YOB(DAMIND(I)) .LT. 2 .OR. CVIMP(DAMIND(I)) )
+    THEN
        GEN(I) = 1
      ELSE
        GEN(I) = 2
      END IF
    END IF
  250 CONTINUE

C
C      ZERO CVGENF
C
  DO 220 I = 1, N
    CVGENF(I) = .FALSE.
  220 CONTINUE
  RETURN
  END

```


APPENDIX B

```

SUBROUTINE BREED
C
C      THIS MODULE DETERMINES WHETHER A FEMALE IS ELIGIBLE
C      FOR BREEDING ON THE CURRENT DAY -- UPDATES CVBRD
C      AND SIRGRP.
C
C      THIS MODULE WILL NEED TO BE RECOMPILED PERIODICALLY
C      AS BREEDING SEASONS AND ASSOCIATED RULES CHANGE
C
C      INTEGER COUNTL, HBRED, MBRED, TBRED
C
C      ***** TOP OF STANDARD BLOCKS ***** TOP OF STANDARD BLOCKS
C      ***
C
C      INCLUDE './inc/SBLOCKS.F'
C
C      **** BOTTOM OF STANDARD BLOCKS **** BOTTOM OF STANDARD
C      BLOCKS
C
C      INITIALIZE CVBRD, CVTERM AND BRDGRP AND DETERMINE
C      FEMALES
C      TO BE BRED
C
C      DO 10 I = 1, N
C          CVBRD(I) = .FALSE.
C          CVTERM(I) = .FALSE.
C          CV3(I) = .FALSE.
C          CV4(I) = .FALSE.
C          CVTERM(I) = SIRTYP(I) .eq. 8 .or. SIRTYP(I) .eq. 6
C      + .or. SIRTYP(I) .eq. 4 .or. SIRTYP(I) .eq. 2
C      c      CVTERM(I) = BRDCMP(I,3) .GT. .1
C      c      CVTERM(I) = BRDCMP(I,1) .LT. .99 .AND. BRDCMP(I,2)
C      c      + .LT. .99 .AND. BRDCMP(I,3) .LT. .99 .AND. BRDCMP(I,4)
C      c      + .LT. .99 .AND. BRDCMP(I,5) .LT. .99
C          BRDGRP(I) = 0
C      c      CVTERM(I) = BRDCMP(I,4) .LT. .49 .OR. ( BRDCMP(I,4) .GT. .51
C      c      + .AND. BRDCMP(I,4) .LT. .99 ) .OR. GEN(I) .EQ. 2
C          CV2(I) = CV1(I) .AND. .NOT. CVCULL(I) .AND. SEX(I)
C      + .EQ. 1 .AND. .NOT. CVCALF(I) .AND. .NOT. CVTERM(I)
C      10 CONTINUE
C
C      THE FOLLOWING CODE USED IN PRESENCE OF IMPORT GROUPS

```

```

C
  CV3(I) = CV2(I)

C
C THIS IS FOR STRAIGHTBRED POPULATIONS. YEARLING HEIFERS AND A
C   FEW
C   YOUNG
C COWS ARE IN BRDGRP1 AND ALL OTHERS IN TWO.
C
  IF (EIS12 .EQ. 0 .and.
+   EIS14 .ge. 1 ) THEN

    IF (YEAR .ge. cutoff-7) then

      SPCOD3 = int(TSIZ1-((1. + ERS31)*EIS11*1./ERS31))
      END IF

      IF (YEAR .lt. cutoff-7) then
        SPCOD3 = 80
      END IF

      IF (SPCOD3 .lt. 0) SPCOD3=0
      ITSCAL = COUNTL (CV2,1,N)
      IF (ITSCAL .EQ. 0) RETURN
      CALL ICMPRS (LOCIND, 1, N, CV2, ITEMP1)
      CALL ICMPRS (MOA, 1, N, CV2, ITEMP2)
      CALL ISORT (ITEMP2, ITEMP1, ITSCAL, -2)
      DO 41 K = 1, SPCOD3
        BRDGRP(ITEMP1(K)) = 2
41    CONTINUE
      DO 43 K = SPCOD3+1,ITSCAL
        BRDGRP(ITEMP1(K)) = 1
43    CONTINUE
      END IF

C      THE FOLLOWING IS SIMILAR TO THE ABOVE CODE WHERE
C      THERE ARE
C      2 BRD GRPS: HEIFERS+YOUNG COWS. AND OLD COWS
C      (TERMINAL).
C      CODE IS TO BE USED FOR A STRAIGHTBRED X TERMINAL
C      MATING.
C
    IF ( EIS12 .EQ. 1 ) THEN

      IF (YEAR .GE. CUTOFF - 7) THEN

```

```

SPCOD3 = int(TSIZ1 - ((1.+ERS31) * (EIS11 * (1./ERS31))))
END IF

IF (YEAR .LT. CUTOFF -7 ) THEN
SPCOD3 = 80
END IF

IF (SPCOD3 .lt. 0) SPCOD3 = 0
ITSCAL = COUNTL( CV2, 1, N )
IF ( ITSCAL .EQ. 0 ) RETURN
CALL ICMPRS( LOCIND, 1, N, CV2, ITEMP1 )
CALL ICMPRS( MOA, 1, N, CV2, ITEMP2 )
CALL ISORT( ITEMP2, ITEMP1, ITSCAL, -2 )
DO 21 K = 1, SPCOD3
  BRDGRP( ITEMP1(K) ) = 2
21 CONTINUE
DO 23 K = SPCOD3 + 1, ITSCAL
  BRDGRP( ITEMP1(K) ) = 1
23 CONTINUE
END IF
C      THE FOLLOWING ASSIGNS FIVE BREED GRPS FOR A ROTA-
C      TERMINAL
C      MATING SYSTEM: HXA HEIFERS, AXH HEIFERS, YOUNG HXA
C      COWS,
C      YOUNG AXH COWS, AND TERMINAL COWS.

IF ( EIS12 .EQ. 2 ) THEN

IF (YEAR .GE. CUTOFF - 7) THEN
SPCOD3 = int(TSIZ1 - ((1.+ERS31) * (EIS11 * (1./ERS31))))
END IF

IF (YEAR .LT. CUTOFF -7 ) THEN
SPCOD3 = 80
END IF

IF (SPCOD3 .lt. 0) SPCOD3 = 0
ITSCAL = COUNTL( CV2, 1, N )
IF ( ITSCAL .EQ. 0 ) RETURN
CALL ICMPRS( LOCIND, 1, N, CV2, ITEMP1 )
CALL ICMPRS( MOA, 1, N, CV2, ITEMP2 )
CALL ISORT( ITEMP2, ITEMP1, ITSCAL, -2 )

```

```

DO 25 K = 1, SPCOD3
  BRDGRP( ITEMP1(K) ) = 3
25 CONTINUE
DO 27 K = SPCOD3 + 1, ITSCAL
  IF (BRDCMP(ITEMP1(K),1) .gt. .5) BRDGRP(ITEMP1(K)) = 1
  IF (BRDCMP(ITEMP1(K),2) .gt. .5) BRDGRP(ITEMP1(K)) = 2
27 CONTINUE
END IF

```

```

IF (EIS12 .le. 1) THEN
DO 100 I = 1,N
  CV5(I) = BRDGRP(I) .eq. 1 .and. YOA(I) .eq. 1
  CV6(I) = BRDGRP(I) .eq. 1 .and. YOA(I) .gt. 1
  CV7(I) = BRDGRP(I) .eq.2
100 CONTINUE
END IF

```

```

IF (EIS12 .eq. 2) THEN
DO 101 I = 1,N
  CV5(I) = BRDGRP(I) .eq. 1
  CV6(I) = BRDGRP(I) .eq. 2
  CV7(I) = BRDGRP(I) .eq. 3
101 CONTINUE
END IF

```

```

HBRED = COUNTL(CV5,1,N)
MBRED = COUNTL(CV6,1,N)
TBRED = COUNTL(CV7,1,N)
WRITE(25,102) YEAR, HBRED,MBRED,TBRED
102 FORMAT(// 'YR: ',I7, ' HEIFERS: ',I7,
+ ' MAT: ',I7, ' TERM: ',I7 //)

```

```

C
C      THIS COMPLETES THE CODE THAT ENABLES RANDOM
C      MATING TO BE PERFORMED
C
C
C      THE FOLLOWING CODE CHANGES THE MATGRP ARRAY SO THAT
C      WE CAN SIMULATE SIRE TREND IN NATURALLY MATED SIRES.
C      SPCOD1 REFERS TO DIFFERENT BREEDING SCENARIOS:
C      1 = GRADE BULLS, NO SIRE SELECTION
C      2 = GRADE BULLS
C      3 = BETTER BULLS
C      4 = AI (HEIFERS ONLY)
C      5 = FULL AI
C

```

```

IF ( YEAR .GE. CUTOFF-7 ) THEN
  IF ( EIS12 .eq. 0 .and. SPCOD1 .LE. 2 ) THEN
    CONTINUE
  ELSE IF ( EIS12 .eq. 0 .and. SPCOD1 .EQ. 3 ) THEN
    MATGRP(1,1) = 16
    MATGRP(1,2) = 16
    MATGRP(2,1) = 13
    MATGRP(2,2) = 13
  ELSE IF ( EIS12 .eq. 0 .and. SPCOD1 .EQ. 4 ) THEN
    MATGRP(1,1) = 20
    MATGRP(1,2) = 12
    MATGRP(2,1) = 13
    MATGRP(2,2) = 13
  ELSE IF ( EIS12 .eq. 0 .and. SPCOD1 .EQ. 5 ) THEN
    MATGRP(1,1) = 20
    MATGRP(1,2) = 12
    MATGRP(2,1) = 17
    MATGRP(2,2) = 9
  END IF

```

```

IF ( EIS12 .eq. 1 .and. SPCOD1 .LE. 2 ) THEN
  CONTINUE
ELSE IF ( EIS12 .eq. 1 .and. SPCOD1 .EQ. 3 ) THEN
  MATGRP(1,1) = 16
  MATGRP(1,2) = 16
  MATGRP(2,1) = 15
  MATGRP(2,2) = 15
ELSE IF ( EIS12 .eq. 1 .and. SPCOD1 .EQ. 4 ) THEN
  MATGRP(1,1) = 20
  MATGRP(1,2) = 12
  MATGRP(2,1) = 15
  MATGRP(2,1) = 15
ELSE IF ( EIS12 .eq. 1 .and. SPCOD1 .EQ. 5 ) THEN
  MATGRP(1,1) = 20
  MATGRP(1,2) = 12
  MATGRP(2,1) = 19
  MATGRP(2,2) = 11
END IF

```

```

IF ( EIS12 .eq. 2 .and. SPCOD1 .LE. 2 ) THEN
  CONTINUE
ELSE IF ( EIS12 .eq. 2 .and. SPCOD1 .EQ. 3 ) THEN
  MATGRP(1,1) = 14
  MATGRP(1,2) = 14
  MATGRP(2,1) = 16
  MATGRP(2,2) = 16

```

```

    MATGRP(3,1) = 15
    MATGRP(3,2) = 15
ELSE IF ( EIS12 .eq. 2 .and. SPCOD1 .EQ. 4) THEN
    MATGRP(1,1) = 18
    MATGRP(1,2) = 10
    MATGRP(2,1) = 20
    MATGRP(2,2) = 12
    MATGRP(3,1) = 15
    MATGRP(3,2) = 15
ELSE IF ( EIS12 .eq. 2 .and. SPCOD1 .EQ. 5) THEN
    MATGRP(1,1) = 18
    MATGRP(1,2) = 10
    MATGRP(2,1) = 20
    MATGRP(2,2) = 12
    MATGRP(3,1) = 19
    MATGRP(3,2) = 11
END IF
END IF

```

```

C
C      LOOP THROUGH SEASONS AND BREED GROUPS WITHIN
C      SEASONS
C      AND UPDATE CVBRD
C
DO 50 J = 1, NOBS
  IF ( ( DAY .GE. BSSTRT(J) .AND. DAY .LE. BSEND(J) ) .OR.
+ ( ( BSSTRT(J) .GT. BSEND(J) ) .AND. ( DAY .GE. BSSTRT(J)
+ .OR. DAY .LE. BSEND(J) ) ) ) THEN
    DO 40 I = 1, NOBGPS
      IF ( MATGRP(I,J) .NE. 0 ) THEN
        DO 30 K = 1, N
          CVBRD(K) = CVBRD(K) .OR. BRDGRP(K) .EQ. I
          IF ( BRDGRP(K) .EQ. I ) SIRGRP(K) = MATGRP(I,J)
30      CONTINUE
        END IF
40    CONTINUE
      END IF
50  CONTINUE
  RETURN
END

```

APPENDIX C


```

SUBROUTINE REPLACE
C
C      THIS MODULE DETERMINES: 1) WHICH YEARLING HEIFERS (OF
C      THOSE
C      NOT ALREADY CULLED IN CULL) WILL BE KEPT AS
C      REPLACEMENTS; AND
C      2) WHICH HEIFER CALVES WILL BE KEPT AS POSSIBLE
REPLACEMENTS.
C
C
C      ***** TOP OF STANDARD BLOCKS ***** TOP OF STANDARD BLOCKS
C
INCLUDE './inc/SBLOCKS.F'
C
C      **** BOTTOM OF STANDARD BLOCKS **** BOTTOM OF STANDARD
C      BLOCKS ****
C
INTEGER COUNTL, aculls, aicount, nscount, COWS
C
C      INITIALIZE VARIABLES
C
DO 10 I = 1, N
  CV2(I) = .FALSE.
  CV3(I) = .FALSE.
  CV4(I) = .FALSE.
  IF ( CV1(I) ) THEN
C
C      ESTABLISH GENERAL CRITERIA FOR ALL YEARLING
C      REPLACEMENTS
C
  CV2(I) = SEX(I) .EQ. 1 .AND. MOA(I) .GT. 12 .AND. MOA(I)
+    .LE. 24 .AND. .NOT. CVCULL(I) .and. .NOT. CVTERM(I)
C
C      WRITE RULES TO DETERMINE YEARLING HEIFERS TO ENTER
C      COWHERD
C
C      IN THIS EXAMPLE, PREGNANT HEIFERS ARE CHOSEN BY WEIGHT
C      UNTIL WINTER FED HERD SIZE IS MAINTAINED
C
C
C      FIRST DETERMINE NUMBER OF COWS KEPT IN CULL GROUP 1
C
  CV3(I) = CVCG1(I) .AND. .NOT. CVCULL(I) .AND.
+    MOA(I) .GT. 24
C
C      COUNT AVAILABLE YEARLINGS FROM CULL GROUP 1

```

```

C          AND DETERMINE NUMBER OF REPLACEMENTS REQUIRED
C
      CV4(I) = CV2(I) .AND. CVCG1(I)
      END IF
10  CONTINUE
      HCOUNT = COUNTL( CV4, 1, N )
      IF ( HCOUNT .EQ. 0 ) GO TO 39
      NEEDED = TSIZ1 - COUNTL( CV3, 1, N )
      EIS11 = NEEDED

      COWS = COUNTL( CV3, 1, N )
      write (24.8000) YEAR,COWS,HCOUNT,NEEDED
8000  format (// 'YEAR: ',I7,' Cows: ', I7,' Heifers: ',
      + I7,' Needed: ',I7 //)

if( eis3 .eq. 1 ) then
C
C          CHOOSE YEARLING REPLACEMENTS BY CONCEPTION DATE
C
      IF ( NEEDED .LT. HCOUNT ) THEN
        CALL ICMPRS( LOCIND, 1, N, CV4, ITEMP1 )
        CALL ICMPRS( DOG, 1, N, CV4, ITEMP2 )
        CALL ISORT( ITEMP2, ITEMP1, HCOUNT, -2 )
        DO 20 K = NEEDED + 1, HCOUNT
          CVNWCL( ITEMP1(K) ) = .TRUE.
          CVCULL( ITEMP1(K) ) = .TRUE.
20      CONTINUE
        END IF
      end if
      if ( eis3 .eq. 2 ) then
c
c          choose all available yearling replacements and cull cows
c          by descending age within ascending sire type.
c
      if ( needed .lt. hcount ) then
        aculls = hcount - needed
        do 24 j = 1, nstyps
          do 21 i = 1, n
            cv5(i) = cv3(i) .and. sirtyp(i) .eq. j
21      continue
            liscal = countl( cv5, 1, n )
            if ( liscal .lt. aculls ) then
              call icmprs( locind, 1, n, cv5, itemp1 )
              do 22 k = 1, liscal
                cvcull( itemp1(k) ) = .true.
                cvnwcl( itemp1(k) ) = .true.

```

```

        cvscul( itemp1(k) ) = .true.
22      continue
        aculls = aculls - liscal
      else
        call icmprs( locind, 1, n, cv5, itemp1 )
        call icmprs( moa, 1, n, cv5, itemp2 )
        call isort( itemp2, itemp1, liscal, -2 )
        do 23 k = 1, aculls
          cvcull( itemp1(k) ) = .true.
          cvnwcl( itemp1(k) ) = .true.
          cvscul( itemp1(k) ) = .true.
23      continue
          go to 39
        end if
24      continue
      end if
      end if
      if ( eis3 .eq. 3 ) then
c
c        choose all available ai daughters and cull cows by
c        descending age within ascending sire type.
c
        if ( needed .lt. hcount ) then
          do 25 i = 1, n
            cv6(i) = cv4(i) .and. ( sirtyp(i) .eq. 7 .or. sirtyp(i)
+            .eq. 8 )
25      continue
            aicount = countl( cv6, 1, n )
            aculls = aicount - needed
            if ( aculls .ge. 1 ) then
              do 29 j = 1, nstyps
                do 26 i = 1, n
                  cv5(i) = cv3(i) .and. sirtyp(i) .eq. j
26      continue
                liscal = countl( cv5, 1, n )
                if ( liscal .lt. aculls ) then
                  call icmprs( locind, 1, n, cv5, itemp1 )
                  do 27 k = 1, liscal
                    cvcull( itemp1(k) ) = .true.
                    cvnwcl( itemp1(k) ) = .true.
                    cvscul( itemp1(k) ) = .true.
27      continue
                    aculls = aculls - liscal
                  else
                    call icmprs( locind, 1, n, cv5, itemp1 )
                    call icmprs( moa, 1, n, cv5, itemp2 )

```

```

        call isort( itemp2, itemp1, liscal, -2 )
        do 28 k = 1, aculls
            cvcull( itemp1(k) ) = .true.
            cvnwcl( itemp1(k) ) = .true.
            cvscul( itemp1(k) ) = .true.
28      continue
        go to 30
    end if
29  continue
end if
30  if ( aculls .ge. 0 ) then
    do 31 i = 1, n
        cvcull(i) = cvcull(i) .or. ( cv4(i) .and. .not.
+      cv6(i) )
        cvnwcl(i) = cvnwcl(i) .or. ( cv4(i) .and. .not.
+      cv6(i) )
31    continue
    end if
    if ( aculls .lt. 0 ) then
        needed = needed - aicount
        do 32 i = 1, n
            cv7(i) = cv4(i) .and. .not. cv6(i)
32        continue
        nscount = countl( cv7, 1, n )
        CALL ICMPRS( LOCIND, 1, N, CV7, ITEMPI )
        CALL ICMPRS( DOG, 1, N, CV7, ITEMPI )
        CALL ISORT( ITEMPI, ITEMPI, nscount, -2 )
        DO 33 K = NEEDED + 1, nscount
            CVNWCL( ITEMPI(K) ) = .TRUE.
            CVCULL( ITEMPI(K) ) = .TRUE.
33        CONTINUE
    end if
end if
end if
39  CONTINUE
C
C      IN THIS EXAMPLE, 10% OF WEANLING HEIFERS ARE CULLED.
C      THE HEAVIEST HEIFERS
C      AT WEANING ARE KEPT FOR BREEDING.
C
DO 40 I = 1, N
    CV2(I) = CV1(I) .AND. CVNEWN(I) .AND. SEX(I) .EQ. 1
+  .AND. .NOT. CVCULL(I)
    CV4(I) = CV2(I) .AND. CVCG1(I)
40  CONTINUE
HCOUNT = COUNTL( CV4, 1, N )

```

```

ITSCAL = INT( .9 * HCOUNT + .5 )
IF ( HCOUNT .GT. ITSCAL ) THEN
  CALL ICMPRS( LOCIND, 1, N, CV4, ITEMP1 )
  CALL RCMPRS( W, 1, N, CV4, TEMP1 )
  CALL RSORT ( TEMP1, ITEMP1, HCOUNT, -2 )
  DO 50 K = ITSCAL + 1, HCOUNT
    CVNWCL( ITEMP1(K) ) = .TRUE.
    CVCULL( ITEMP1(K) ) = .TRUE.
50  CONTINUE
  END IF
  RETURN
END

```

APPENDIX D

```

SUBROUTINE CULL
C
C      THIS MODULE DETERMINES ANIMALS TO BE CULLED ( I.E.
C      NOT TO BE KEPT FOR BREEDING ).
C
C      ***** TOP OF STANDARD BLOCKS ***** TOP OF STANDARD BLOCKS
C      *****
C
C      INCLUDE './inc/SBLOCKS.F'
C
C      **** BOTTOM OF STANDARD BLOCKS **** BOTTOM OF STANDARD
C      BLOCKS ***
C
C      INTEGER COUNTL
C
C      DETERMINE (ON JANUARY 1) COWS, HEIFERS AND SIRES TO
C      BE
C      CULLED FOR UNSOUNDNESS IN THE FOLLOWING YEAR. SET
C      CVUNSD.
C
C      DO 10 I = 1, N
C      CV2(I) = CV1(I) .AND. .NOT. CVCULL(I) .AND. ( SEX(I)
+      .EQ. 1 .OR. CVSIRE(I) ) .AND. .NOT. CVCALF(I)
C
C      IF (BRDCMP(I,3) .gt. 0.1) CVTERM(I) = .TRUE.
C      IF (SIRTYP(I) .eq. 8 .or. SIRTYP(I) .eq. 6 .or.
+      SIRTYP(I) .eq. 4 .or. SIRTYP(I) .eq. 2)
+      CVTERM(I) = .TRUE.
C
10  CONTINUE
C      OFFSET = COUNTL( CV2, 1, N )
C      IF ( OFFSET .EQ. 0 ) GO TO 50
C      IF ( DAY .EQ. 1 ) THEN
C      CALL ICMPRS( LOCIND, 1, N, CV2, ITEMP1 )
C      DO 30 K = 1, OFFSET
C      IF( YOA( ITEMP1(K) ) .EQ. 0 ) TEMP2(K) = CULLF(1) *
+      POUNSD( ITEMP1(K) )
C      IF( YOA( ITEMP1(K) ) .GE. 1 ) THEN
C      DO 20 J = 1, 15
C      IF ( YOA( ITEMP1(K) ) .EQ. J ) TEMP2(K) = CULLF(J)
+      * POUNSD( ITEMP1(K) )
C      20  CONTINUE
C      END IF

```

```

30  CONTINUE
    CALL RANVN( TEMP1, OFFSET )
    DO 40 K = 1, OFFSET
        IF ( TEMP1(K) .LT. TEMP2(K) ) CVUNSD( ITEMP1(K) ) = .TRUE.
40  CONTINUE
    END IF
C
C      WRITE RULES TO DETERMINE CULL GROUPS (SET CVCG
C      VECTORS)
C
C      IN THIS EXAMPLE, THERE IS JUST ONE GENERAL CULL GROUP
C
50  DO 60 I = 1, N
    CVCG1(I) = CV1(I) .AND. SEX(I) .EQ. 1
C
C      WRITE RULES TO CULL ANIMALS ON DATES OTHER THAN THE
C      GENERAL CULLING (WEANING) DATES.
C
C      IN THIS EXAMPLE, NONPREGNANT, (COMPLETELY) DRY COWS
C      AND
C      NONPREGNANT, DRY, UNSOUND COWS ARE CULLED
C
    CV2(I) = CVCG1(I) .AND. CVUNSD(I) .AND. .NOT. CVP(I)
    CV3(I) = .NOT. CVL(I) .AND. MOA(I) .GT. 18
    CVNWCL(I) = CVNWCL(I) .OR. ( CV2(I) .AND. CV3(I) .AND.
+    .NOT. CVCULL(I) )
C
C      UNSOUND AND OLD SIRES ARE CULLED AT THE END OF
C      THEIR
C      BREEDING SEASONS AND SO ARE NATURAL SERVICE HEIFER
C      BULLS THAT ARE TWO YEARS OLD.
C
c    CV3(I) = CV1(I) .AND. CVSIRE(I) .AND. .NOT. CVCULL(I) .AND.
c +    ( CVUNSD(I) .OR. YOA(I) .GE. MXSAGE .OR. (( SIRTYP(I) .EQ.
C      2
c +    .OR. SIRTYP(I) .EQ. 4 .OR. SIRTYP(I) .EQ. 6 ) .AND. YOA(I)
c +    .GE. 2 ))
C
C
60  CONTINUE
c  NOBITS = COUNTL( CV3, 1, N )
c  IF ( NOBITS .GT. 0 ) THEN
c    CALL ICMPRS( LOCIND, 1, N, CV3, ITEMP1 )
c    DO 80 J = 1, NOBS
c      IF ( DAY + STPMN1 .EQ. BSEND(J) ) THEN
c        DO 70 K = 1, NOBGPS

```



```

c          DO 70 L = 1, NOBITS
c          CVNWCL( ITEMP1(L) ) = CVNWCL( ITEMP1(L) ) .OR.
c +          ( CV3( ITEMP1(L) ) .AND.
c +          SIRGRP( ITEMP1(L) ) .EQ. MATGRP(K,J) )
c70      CONTINUE
c      END IF
c80      CONTINUE
c      END IF
C
C
C      DO 90 I = 1, N
C
C          CULL MALES THAT WERE NOT ALREADY CULLED AT
C          WEANING,
C          E.G., IMPORTED STEERS
C
C          CVNWCL(I) = CVNWCL(I) .OR. ( CV1(I) .AND. SEX(I) .GE. 2
+          .AND. .NOT. CVSIRE(I) .AND. .NOT. CVCALF(I) .AND. .NOT.
+          CVCULL(I) )
C
C          RULES TO CULL ANIMALS ON REGULAR CULLING (WEANING)
C          DATES. THESE RULES ARE ONLY VALID
C          IF THERE IS ONE WEANING DATE
C
C          CV2(I) = CV1(I) .AND. .NOT. CVCULL(I) .AND.
+          WNDAY(I) .EQ. DAY + STPMN1
C          CVNWCL(I) = CVNWCL(I)
C
C          CULL OLD SIRES AND 2-YR-OLD NATURAL SERVICE
C          HEIFER BULLS
C
+          .OR. ( CVSIRE(I) .AND. CVSIM(I) .AND. CV2(I) .AND.
+          ( CVUNSD(I) .OR. YOA(I) .GE. MXSAGE .OR. (( SIRTYP(I) .EQ.
+          1
+          .OR. SIRTYP(I) .EQ. 3 .OR. SIRTYP(I) .EQ. 5 ) .AND. YOA(I)
+          .GE. 2 ) ) )
C
C          CULL OPEN FEMALES FROM THE BREEDING HERD
C
+          .OR. ( CVCG1(I) .AND. CV2(I) .AND. MOA(I) .GT. 12
+          .AND. .NOT. CVP(I) )
C
C          CULL UNSOUND ANIMALS
C
+          .OR. ( CV2(I) .AND. CVUNSD(I) )
C

```

```

C          CULL NONBREEDING MALES
C
+ .OR. ( CV2(I) .AND. .NOT. CVCALF(I) .AND. .NOT. CVSIRE(I)
+ .AND. SEX(I) .NE. 1 )
C
C          CULL OLD COWS
C
+ .OR. ( CV2(I) .AND. SEX(I) .EQ. 1 .AND.
+ YOA(I) .GE. MXDAGE )
C
C          CULL TERMINAL FEMALES
C
+ .OR. ( CV2(I) .AND. SEX(I) .EQ. 1 .AND. CVTERM(I) )
C
C          THIS ONE WILL CULL ALL HEIFERS SO WE CAN BUY
C          REPLACEMENTS
C
+ .OR. ( CV2(I) .AND. CVNEWN(I) .AND. SEX(I) .EQ. 1 )
C
C          CVCULL(I) = CVCULL(I) .OR. CVNWCL(I)
C
C          "CULL" AI SIRES EACH YEAR
C
IF ( CVSIRE(I) .AND. .NOT. CVSIM(I)
+ .AND. WNDAY(1) .EQ. DAY + STPMN1 ) THEN
    CVLIVE(I) = .FALSE.
END IF
C
C          WRITE RULES TO DETERMINE THE NEXT GENERAL CULLING
C          DATE FOR
C          OPEN ANIMALS THAT WERE NOT CULLED.
C
C          IN THIS EXAMPLE, THERE IS ONLY ONE CALVING SEASON, SO
C          WE
C          WILL CHECK AGAIN AT THE SAME TIME NEXT YEAR, I.E.
C          WEANING DATES WILL NOT BE CHANGED.
C
90 CONTINUE
C
C          DIAGNOSTICS
C
c          this stuff is for ai run diagnostics (9/96)
c

```

```

if ( dbcode .eq. 23 ) then
  eis15 = 2
  do 100 i = 1, n
    if ( cvsire(i) .and. cvnwcl(i) ) then
      eis16 = i
      call document
    end if
100  continue
  end if
C
  RETURN
END

```

APPENDIX E

```

SUBROUTINE DISPOSE
C
C      THIS MODULE DETERMINES THE STATUS OF ANIMALS AS THEY
C      MOVE FROM ONE ENTERPRISE TO ANOTHER. ANIMALS THAT
C      ARE REMOVED FROM THE COW CALF ENTERPRISE (CVCULL AND
C      CVNWCL)
C      CAN BE SOLD (CVSELL), PUT IN THE STOCKER ENTERPRISE
C      (CVPAST) OR FED ( CVFEED). CATTLE IN THE
C      STOCKER ENTERPRISE CAN BE SOLD OR FED. WHILE FED
C      CATTLE
C      CAN ONLY BE SOLD. ANIMALS THAT ARE SOLD ARE
C      SUBSEQUENTLY
C      REMOVED FROM THE SIMULATION. THE CATEGORY CODE
C      (CATCD)
C      SORTS ANIMALS INTO CATEGORIES AS THEY MOVE
C      FROM ONE ENTERPRISE TO THE NEXT. CARE MUST BE TAKEN
C      TO INSURE THAT ALL ANIMALS ARE CATEGORIZED AND
C      ASSIGNED
C      TO BE SOLD, PASTURED OR FED AT THE COMPLETION OF EACH
C      ENTERPRISE PERIOD.
C
C      THE CV1 CONDITIONAL CANNOT BE USED IN THIS SUBROUTINE
C      AS NEWLY IMPORTED ANIMALS NEED TO BE SORTED AND THEY
C      AREN'T ACTUALLY PRESENT UNTIL THE FOLLOWING STEP
C      THIS PRESENTS NO PROBLEMS AS THE TRIGGERS FOR THE
C      CATEGORIZATION OF ANIMAL FLOW THROUGH ENTERPRISE
C      REQUIRE THE ANIMAL TO BE EITHER CV1 OR AN IMPORT
C
C      ***** TOP OF STANDARD BLOCKS ***** TOP OF STANDARD BLOCKS
C      *****
C      INCLUDE './inc/SBLOCKS.F'
C
C      **** BOTTOM OF STANDARD BLOCKS **** BOTTOM OF STANDARD
C      BLOCKS ***
C
C      INTEGER COUNTL, IMINC, IMAXC,PAST,FEEDER
C
C      REAL RMAXC
C
C      DO 10 I = 1, N
C
C          SET CVTERM, DAYS ON PASTURE (DAYPA), DAYS ON FEED
C          (DAYFD)
C

```

```

c    IF ( BRDCMP(I,3) .GT. 0.1 ) CVTERM(I) = .TRUE.
      IF (SIRTYP(I) .eq. 8 .or. SIRTYP(I) .eq. 6 .or.
+       SIRTYP(I) .eq. 4 .or. SIRTYP(I) .eq. 2)
+       CVTERM(I) = .TRUE.

```

```

C
      IF ( CVPAST(I) ) THEN
        DAYPA(I) = DAYPA(I) + STEP
      ELSE
        DAYPA(I) = 0
      ENDIF
      IF ( CVFEED(I) ) THEN
        DAYFD(I) = DAYFD(I) + STEP
      ELSE
        DAYFD(I) = 0
      END IF
      CV2(I) = CVLIVE(I) .AND. SEX(I) .EQ. 1 .AND. .NOT.
+ CVFETS(I)
      CV3(I) = CVLIVE(I) .AND. SEX(I) .GT. 1 .AND. .NOT.
        CVFETS(I)

```

```

C
C      CATCD DESCRIPTION
C      1  COWS, OVER 2
C      2  SIRES
C      3  COWS, 2 YEARS OLD
C      4  YEARLING BRED FEMALES
C      5  MATERNAL WEANLING FEMALES
C      6  PATERNAL WEANLING FEMALES
C      7  MATERNAL WEANLING MALES
C      8  PATERNAL WEANLING MALES
C      9  MATERNAL YEARLING FEMALES
C     10  PATERNAL YEARLING FEMALES
C     11  MATERNAL YEARLING MALES
C     12  PATERNAL YEARLING MALES
C     13  FAT MATERNAL FEMALES
C     14  FAT PATERNAL FEMALES
C     15  FAT MATERNAL MALES
C     16  FAT PATERNAL MALES
C     17  BRED FEMALES FROM BREEDING HERD
C     18  OPEN FEMALES FROM BREEDING HERD
C     19  NURSING CALVES IN BREEDING HERD
C     20  BRED COWS CULLED FOR REASONS OTHER THAN AGE OR
          SOUNDNESS

```

```

C
C      SET DISPOSAL CODES FOR CATEGORIES OF CATTLE AND

```

```

C      DETERMINE SUBSEQUENT PHASE AS ANIMALS ARE
C      TRANSFERED FROM ONE ENTERPRISE TO ANOTHER
C
C
C      DIRECT CATTLE FLOW FROM BREEDING HERD
C
      IF ( CVNWCL(I) ) THEN
      IF ( CV2(I) .AND. .NOT. CVSCUL(I) .AND.
+      YOA(I) .GT. 2 ) THEN
      CATCD(I) = 1
      CVSELL(I) = .TRUE.
      ELSE IF ( CVSIRE(I) ) THEN
      CATCD(I) = 2
      CVSELL(I) = .TRUE.
      ELSE IF ( CV2(I) .AND. YOA(I) .EQ. 2 .AND. CVCLVD(I)
+      .AND. .NOT. CVSCUL(I) ) THEN
      CATCD(I) = 3
      CVSELL(I) = .TRUE.
      ELSE IF ( CV2(I) .AND. YOA(I) .GE. 2 .AND. CVCLVD(I)
+      .AND. CVSCUL(I) ) THEN
      CATCD(I) = 20
      CVSELL(I) = .TRUE.
      ELSE IF ( CV2(I) .AND. YOA(I) .GE. 1 .AND. .NOT.
+      CVCLVD(I) .AND. CVP(I) ) THEN
      CATCD(I) = 4
      CVSELL(I) = .TRUE.
C
C      SIMULATE ABORTION OF PREGNANT HEIFERS THAT ARE
C      CULLED.
C      THE COMMENTS ON THE FOLLOWING CODE SHOULD BE
REMOVED
C      IF BRED HEIFERS ARE TO
C      BE PLACED IN THE FEEDLOT. IF THIS IS THE CASE
C      CATCD SHOULD BE SET TO 9 RATHER THAN 4.
C
C      CATCD(I) = 9
C      CVLIVE( FETIND(I) ) = .FALSE.
C      CVP(I) = .FALSE.
C      CVPAST(I) = .TRUE.
C      CVFEED(I) = .TRUE.
      ELSE IF ( CV2(I) .AND. YOA(I) .LT. 1 .AND. .NOT.
+      CVTERM(I) ) THEN
      CATCD(I) = 5
C      CVFEED(I) = .TRUE.
C      CVPAST(I) = .TRUE.
      CVSELL(I) = .TRUE.

```

```

ELSE IF ( CV2(I) .AND. YOA(I) .LT. 1 ) THEN
  CATCD(I) = 6
  CVPAST(I) = .TRUE.
C   CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
ELSE IF ( CV3(I) .AND. YOA(I) .LT. 1 .AND. .NOT.
+   CVTERM(I) ) THEN
  CATCD(I) = 7
  CVPAST(I) = .TRUE.
c   CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
ELSE IF ( CV3(I) .AND. YOA(I) .LT. 1 ) THEN
  CATCD(I) = 8
  CVPAST(I) = .TRUE.
c   CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
ELSE IF ( CV2(I) .AND. .NOT. CVTERM(I) .AND. .NOT.
+   CVP(I) ) THEN
  CATCD(I) = 9
  CVFEED(I) = .TRUE.
C   CVSELL(I) = .TRUE.
ELSE IF ( CV2(I) ) THEN
  CATCD(I) = 10
C   CVPAST(I) = .TRUE.
  CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
ELSE IF ( CV3(I) .AND. .NOT. CVTERM(I) ) THEN
  CATCD(I) = 11
C   CVPAST(I) = .TRUE.
  CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
ELSE IF ( CV3(I) ) THEN
  CATCD(I) = 12
C   CVPAST(I) = .TRUE.
  CVFEED(I) = .TRUE.
c   CVSELL(I) = .TRUE.
END IF

```

```

IF (EIS12 .eq. 0) THEN
DO 101 J = 1,N

```

```

  CV5(J) = CVPAST(J) .and. CATCD(J) .eq. 7
  CV7(J) = CVFEED(J) .and. .not. CVPAST(J)

```



```

101    CONTINUE
      PAST = COUNTL(CV5,1,N)
      FEEDER = COUNTL(CV7,1,N)

c      IF (DAY .eq. 291) THEN
102    WRITE(58,102) YEAR, DAY, PAST, FEEDER
      FORMAT(//'YR: ',I7,' DAY: ',I7,' PASTURE: ',
+         I7,' FED: ',I7///)
c      END IF

      END IF

C
C      DIRECT FLOW FOR IMPORTS
C
      ELSE IF ( CVNEWS(I) .OR. CVNEWI(I) ) THEN
        IF ( CV2(I) .AND. YOA(I) .GT. 2 )
+          THEN
          CATCD(I) = 1
        ELSE IF ( CVSIRE(I) ) THEN
          CATCD(I) = 2
        ELSE IF ( CV2(I) .AND. YOA(I) .EQ. 2 .AND. CVCLVD(I)
+          ) THEN
          CATCD(I) = 3
        ELSE IF ( CV2(I) .AND. YOA(I) .GE. 1 .AND. .NOT.
+          CVCLVD(I) .AND. CVP(I) ) THEN
          CATCD(I) = 4
        ELSE IF ( CV2(I) .AND. YOA(I) .LT. 1 .AND. .NOT.
+          CVTERM(I) ) THEN
          CATCD(I) = 5
        ELSE IF ( CV2(I) .AND. YOA(I) .LT. 1 ) THEN
          CATCD(I) = 6
          CVPAST(I) = .TRUE.
          CVCULL(I) = .TRUE.
        ELSE IF ( CV3(I) .AND. YOA(I) .LT. 1 .AND. .NOT.
+          CVTERM(I) ) THEN
          CATCD(I) = 7
          CVPAST(I) = .TRUE.
          CVCULL(I) = .TRUE.
        ELSE IF ( CV3(I) .AND. YOA(I) .LT. 1 ) THEN
          CATCD(I) = 8
          CVPAST(I) = .TRUE.
          CVCULL(I) = .TRUE.
        ELSE IF ( CV2(I) .AND. .NOT. CVTERM(I) .AND. YOA(I)
+          .EQ. 1 ) THEN

```

```

      CATCD(I) = 9
    ELSE IF ( CV2(I) .AND. YOA(I) .EQ. 1 ) THEN
      CATCD(I) = 10
      CVPAST(I) = .TRUE.
      CVCULL(I) = .TRUE.
    ELSE IF ( CV3(I) .AND. .NOT. CVTERM(I) ) THEN
      CATCD(I) = 11
      CVPAST(I) = .TRUE.
      CVCULL(I) = .TRUE.
    ELSE IF ( CV3(I) ) THEN
      CATCD(I) = 12
      CVPAST(I) = .TRUE.
      CVCULL(I) = .TRUE.
    END IF

```

C
C
C

DIRECT FLOW FOR STOCKER PROGRAM

```

    ELSE IF ( CVPAST(I) .AND. DAYPA(I) .GE. TDAYPA )
+    THEN
      IF ( CV2(I) .AND. .NOT. CVTERM(I) ) THEN
        CATCD(I) = 9
        CVFEED(I) = .TRUE.
        CVCULL(I) = .TRUE.
      ELSE IF ( CV2(I) ) THEN
        CATCD(I) = 10
        CVFEED(I) = .TRUE.
        CVCULL(I) = .TRUE.
      ELSE IF ( CV3(I) .AND. .NOT. CVTERM(I) ) THEN
        CATCD(I) = 11
        CVFEED(I) = .TRUE.
        CVCULL(I) = .TRUE.
      ELSE IF ( CV3(I) ) THEN
        CATCD(I) = 12
        CVFEED(I) = .TRUE.
        CVCULL(I) = .TRUE.
      END IF
    END IF

```

C
C
C

OVERIDE PREVIOUS FLOW WITH 'GOODBYE MATILDA' CODE

```

    IF ( CVUNSD(I) .AND. CVNWCL(I) )
+    CVSELL(I) = .TRUE.

```

C
C
C

TAKE INVENTORY OF BREEDING HERD

```

      IF ( ( DAY .EQ. 1 .AND. YEAR - CUTOFF .EQ. 0 .OR.
+       DAY + STPMN1 .EQ. NDIY ) .AND.
+       .NOT. CVCULL(I) ) THEN
      IF ( CV2(I) .AND. ( CVCLVD(I) .OR. CVP(I) ) )
+       CATCD(I) = 17
      IF ( CV2(I) .AND. .NOT. ( CVCALF(I) .OR.
+       CVP(I) .OR. CVCLVD(I) ) ) CATCD(I) = 18
      IF ( CVCALF(I) ) CATCD(I) = 19
      END IF

C
C       ASSIGN ANIMALS TO PENS IN THE FEEDLOT
C
      CV6(I) = ( CVNWCL(I) .OR. CVNEWI(I) ) .AND. CVFEED(I)
+       .OR. (CVPAST(I) .AND. CVFEED(I))
10  CONTINUE
      NOBITS = COUNTL( CV6, 1, N )
      IF ( NOBITS .GT. 0 ) CALL PENSORT

C
C       CALCULATE AVERAGES FOR PENS WHEN ANIMALS GET CLOSE
C       TO FINISHING CRITERIA AND SELL THEM WHEN FIRST
C       CRITERION IS MET.
C
      DO 80 I = 1, N
      CV2(I) = CVLIVE(I) .AND. SEX(I) .EQ. 1 .AND. .NOT. CVFETS(I)
      CV3(I) = CVLIVE(I) .AND. SEX(I) .GT. 1 .AND. .NOT. CVFETS(I)
      CV4(I) = CV1(I) .AND. CVFEED(I) .AND. .NOT. ( CVNWCL(I) .OR.
+       CVNEWI(I) .OR. CVPAST(I) )
80  CONTINUE
      NOBITS = COUNTL( CV4, 1, N )
      IF ( NOBITS .EQ. 0 ) RETURN
      DO 100 I = 1, N
      IF ( CV4(I) ) THEN
      CARWT(I) = ( EBW(I) - 30.26 ) / 1.362
      CARFAT(I) = .007 + 1.0815 * PCFEB(I)
      DRSPCT(I) = CARWT(I) / W(I)
      QLTGRD(I) = 2.5 + 23. * CARFAT(I) * POIMF(I)
      YLDGRD(I) = -1.7 + 15. * CARFAT(I)
      END IF
100 CONTINUE

C
C
C

```

```

C
C
C      DETERMINE IF CATTLE MEET THE QUALITY TARGET OR
C      YIELD THRESHOLD IF GRDYLD IS 1 OR PCFEB TARGET
C      IF GRDYLD IS 0. SET CATCODES 13-16 FOR FAT
C      CATTLE REACHING SELLING TARGETS
C
IF ( GRDYLD .EQ. 1 ) THEN
  RVAR1 = RMAXC( QLTGRD, 1, N, CV4 )
  RVAR2 = RMAXC( YLDGRD, 1, N, CV4 )
  IF ( RVAR1 .GE. TSQLT .OR. RVAR2 .GE. TSYLD ) THEN
    IVAR1 = IMINC( PEN, 1, N, CV4 )
    IVAR2 = IMAXC( PEN, 1, N, CV4 )
    DO 110 J = IVAR1, IVAR2
      IVAR3 = 0
      RVAR4 = 0.
      RVAR5 = 0.
      DO 120 I = 1, N
        IF ( CV4(I) .AND. PEN(I) .EQ. J ) THEN
          IVAR3 = IVAR3 + 1
          RVAR4 = RVAR4 + QLTGRD(I)
          RVAR5 = RVAR5 + YLDGRD(I)
        END IF
120      CONTINUE
        IF ( IVAR3 .GT. 0 ) THEN
          IF ( RVAR4 / REAL( IVAR3 ) .GE. TSQLT .OR.
+          RVAR5 / REAL( IVAR3 ) .GE. TSYLD ) THEN
            DO 130 I = 1, N
              IF ( CV4(I) .AND. PEN(I) .EQ. J ) THEN
                CVSELL(I) = .TRUE.
                IF ( CV2(I) .AND. .NOT. CVTERM(I) ) THEN
                  CATCD(I) = 13
                ELSE IF ( CV2(I) .AND. CVTERM(I) ) THEN
                  CATCD(I) = 14
                ELSE IF ( CV3(I) .AND. .NOT. CVTERM(I) )
+                THEN
                  CATCD(I) = 15
                ELSE IF ( CV3(I) .AND. CVTERM(I) ) THEN
                  CATCD(I) = 16
                END IF
              END IF
130            CONTINUE
            END IF
          END IF
110        CONTINUE

```

```

      END IF
    ELSE
      RVAR1 = RMAXC( PCFEB, 1, N, CV4 )
      IF ( RVAR1 .GE. TSEBF ) THEN
        IVAR1 = IMINC( PEN, 1, N, CV4 )
        IVAR2 = IMAXC( PEN, 1, N, CV4 )
        DO 140 J = IVAR1, IVAR2
          IVAR3 = 0
          RVAR4 = 0.
          DO 150 I = 1, N
            IF ( CV4(I) .AND. PEN(I) .EQ. J ) THEN
              IVAR3 = IVAR3 + 1
              RVAR4 = RVAR4 + PCFEB(I)
            END IF
150          CONTINUE
            IF ( IVAR3 .GT. 0 ) THEN
              IF ( RVAR4 / REAL( IVAR3 ) .GE. TSEBF ) THEN
                DO 160 I = 1, N
                  IF ( CV4(I) .AND. PEN(I) .EQ. J ) THEN
                    CVSELL(I) = .TRUE.
                    IF ( CV2(I) .AND. .NOT. CVTERM(I) ) THEN
                      CATCD(I) = 13
                    ELSE IF ( CV2(I) .AND. CVTERM(I) ) THEN
                      CATCD(I) = 14
                    ELSE IF ( CV3(I) .AND. .NOT. CVTERM(I) )
+                      THEN
                      CATCD(I) = 15
                    ELSE IF ( CV3(I) .AND. CVTERM(I) ) THEN
                      CATCD(I) = 16
                    END IF
                  END IF
160          CONTINUE
                END IF
              END IF
140          CONTINUE
            END IF
          END IF
        END IF
      IF (EIS12 .eq. 0) THEN
c      DO 101 J = 1,N
c
c      CV5(J) = CVPAST(J) .and. .not. CVFEED(J)
c      CV7(J) = CVFEED(J) .and. .not. CVPAST(J)
c
c
c101    CONTINUE

```

```

c      PAST = COUNTL(CV5,1,N)
c      FEEDER = COUNTL(CV7,1,N)
c
c      WRITE(20,102) YEAR, DAY, PAST, FEEDER
c102    FORMAT(//'YR: ',I7,' DAY: ',I7,' PASTURE: ',
c  +    I7,' FED: ',I7//)
c
c      END IF

```

```

RETURN
END

```

APPENDIX F

TAPE1 -- GENERAL SIMULATION AND OUTPUT PARAMETERS

GENERAL PARAMETERS:

N	NEWHRD	NEWHFL	MINSPC	CUTOFF	DBCODE	SPCOD1	SPCOD2	SPCOD3
2150	1	0	400	12	23	5	21	0

TIMESTEP VARIABLES:

STEP	NSTEPS
10	962

RANDOM NUMBER GENERATION PARAMETERS:

CLSEED	SEED	U01BLN	N01BLN	TVBLEN	MTXSIZ	NTRATS	NRTRTS	MNGEN
1	224543	65533	65532	65532	20	20	4	1

ITERATION PARAMETERS:

NOGRPS	NOFITS	NOTITS
2	5	500

TOLEANCES:

IWTOL	DIGTOL	CPTOL	MERTOL	INTOL
1.00	.0050	.0050	.0050	.0500

SUMMARY CODES: (2 LINES OF 25 CODES EACH -- BLANKS ACCEPTABLE -- END WITH 99)

1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5
1	2	3	4	99																				
99																								

OUTPUT CODES: (2 LINES OF 25 CODES EACH -- BLANKS ACCEPTABLE -- END WITH 99)

1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	20	1	2	3	4	5
11	15	99																						
99																								

TITLE FOR RUN:

|<-FIRST CHARACTER LAST CHARACTER->|
 SPCOD1:5;EIS14=5;EIS12=0; straight 2ai

TAPE2 -- GENERAL MANAGEMENT VARIABLES

BREEDING VARIABLES:

NOBS	NOBGPS																		
2	2																		

BSSTRT	BSEND	MATGRP	(BY SEASON (J), BREED GROUP (I))																
151	170	8 5 0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	214	8 5																	

CALVING, WEANING AND CASTRATION VARIABLES:

NOCS	CFCM(1)	(2)	(3)	(4)
1	1.6851	1.6851	1.6851	1.6851

CSSTRT	CSEND	WNDAY	CSDATE	(BY SEASON)
1	365	300	150	

FINISHING CRITERIA FOR ANIMALS ON FEED AND PASTURE:

TDAYPA	PENSIZ	GRDYLD	TSQLT	TSYLD	TSEBF
305	50	1	10.000	4.000	0.280

IMPORTATION POLICY AND CULLING AGES:

IMPPOL	MXDAGE	MXSAGE
0	12	4

TARGET SIZES FOR CULL GROUPS:

1	2	3	4	5	6	7	8	9	10
400									

TAPE3 -- SUPPLEMENTATION VARIABLES

GENERAL VARIABLES:

ALLFIX NOFGPS NFGAPA

0 11 1

DIGESTIBILITY AND CRUDE PROTEIN CONTENTS:

	MILK	ESUP	PSUP	CREEP	RAT3	RAT2	RAT1	HFOR
DIG:		.900	.900	.650	.850	.750	.650	.570
CP:	.258	.096	.440	.120	.120	.120	.120	.160

MILK ENERGY VALUES:

DEMILK	MEMILK
5.88	5.59

MAXIMUM FEED LEVELS (BY FEED GROUP, FEED):

	GROUP	ESUP	PSUP	CREEP	RAT3	RAT2	RAT1	HFOR
FIXMAX:	(1)							2.00
	(2)		10.00					0.00
	(3)					30.00		0.00
	(4)				30.00			0.00
	(5)	0.50						6.80
	(6)	.00						0.00
	(7)							0.00
	(8)							0.00
	(9)							0.00
	(10)	.00						0.00
	(11)	.00						0.00
VARPR:	(1)	.00	.00	.00	.00	.00	.00	0.00
	(2)	0.00	.00	.00	.00	.00	.00	0.00
	(3)	.00		.00	.00	.00	.00	0.00
	(4)	.00		.00	.00	.00	.00	0.00
	(5)	.00		.00	.00	.00	.00	1.00
	(6)	0.07		.00	.00	.00	.00	.93
	(7)	0.00						1.00
	(8)	0.00						1.00
	(9)	0.00						1.00
	(10)	.50						.50
	(11)	.07						.93

FEEDING PERIODS (BY FEED GROUP, FEED):

	GROUP	ESUP	PSUP	CREEP	RAT3	RAT2	RAT1	HFOR	GFOR
FPSTRT:	(1)	0	0	0	0	0	0	0	1
	(2)	0	1	0	0	0	0	0	0
	(3)	0	0	0	0	1	0	0	0
	(4)	0	0	0	1	0	0	0	0
	(5)	1	0	0	0	0	0	1	1
	(6)	0	0	0	0	0	1	1	1
	(7)	0						1	1
	(8)	0						1	1
	(9)	0						1	1
	(10)	1						1	1
	(11)	0						131	131

FPEND:	(1)	0	0	0	0	0	0	0	365
	(2)	0	365	0	0	0	0	0	0
	(3)	0	0	0	0	365	0	0	0
	(4)	0	0	0	365	0	0	0	0
	(5)	365	0	0	0	0	0	365	365
	(6)	0	0	0	0	0	365	365	365
	(7)	0						365	365
	(8)	0						365	365
	(9)	0						365	365
	(10)	365						365	365
	(11)	0						300	300

TARGET EMPTY BODY FAT BY (FEED GROUP, MONTH) :

GROUP	1	2	3	4	5	6	7	8	9	10	11	12	F/F
(1)	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	0
(2)	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	0
(3)	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	0
(4)	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	.300	0
(5)	.08	.08	.09	.09	.09	.07	.07	.07	.07	.07	.07	.07	1
(6)	.09	.09	.10	.10	.11	.08	.08	.08	.08	.08	.08	.08	1
(7)	.14	.14	.15	.15	.15	.08	.08	.08	.08	.11	.12	.13	1
(8)	.15	.16	.17	.17	.17	.08	.08	.08	.08	.11	.12	.13	1
(9)	.15	.16	.17	.17	.17	.08	.08	.08	.08	.11	.12	.13	1
(10)	.14	.15	.16	.17	.17	.08	.08	.08	.08	.11	.12	.13	1
(11)	.08	.08	.09	.09	.09	.06	.06	.06	.06	.07	.07	.07	1

TAPE4 -- FOUNDATION HERD PARAMETERS

NUMBERS OF HERDS AND GROUPS WITHIN HERDS:

NOHRDS	NFNGPS
1	2

HERD PARAMETERS (BY HERD):

HERD	ASDATE	FNDOA
(1)	1	286

DAY OF GESTATION, DAY AFTER CALVING, CONDITION, SERVICE SIRES, AND GENETIC LAG (BY GROUP):

GROUP	FNDOG	FNDAC	FNCON	FSSGRP	GLAG
(1)	204	286	1.00	1	2.00
(2)			1.00		2.00

AGE DISTRIBUTION (BY GROUP, AGE):

GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1)	0	70	70	60	50	40	30	20	20	20	10	10			
(2)	180														

DAM SIDE BREED COMPOSITION (FNBED) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.00									
(2)	1.00									

SIRE SIDE BREED COMPOSITION (FNBCS) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.00									
(2)	1.00									

GENETIC STARTING (BREEDING) VALUES (BY GROUP):

GROUP	FVBW	FVYW	FVMW	FVMP	FVAAP	FVPCYC	FVPCON	FVDDYS	FVMDYS
(1)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(2)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00

GROUP	FVGL	FVMF	FVAPP	FVUNSD	FVPSRV	FVRM	FVIME	FVFFC	FVYLD
(1)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(2)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00

GROUP	FVXXXX	FVZZZZ
(1)	1.00	1.00
(2)	1.00	1.00

TAPE4 -- FOUNDATION HERD PARAMETERS

NUMBERS OF HERDS AND GROUPS WITHIN HERDS:

NCHRDS	NFNGPS
1	4

HERD PARAMETERS (BY HERD):

HERD	ASDATE	FNDOA
(1)	1	286

DAY OF GESTATION, DAY AFTER CALVING, CONDITION, SERVICE SIRE, AND GENETIC LAG (BY GROUP):

GROUP	FNDOG	FNDAC	FNCON	FSSGRP	GLAG
(1)	204	286	1.00	2	2.00
(2)	204	286	1.00	1	2.00
(3)			1.00		2.00
(4)			1.00		2.00

AGE DISTRIBUTION (BY GROUP, AGE):

GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1)	0	35	35	30	25	20	15	10	10	10	5	5			
(2)	0	35	35	30	25	20	15	10	10	10	5	5			
(3)	90														
(4)	90														

DAM SIDE BREED COMPOSITION (FNBCD) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	.38	.62								
(2)	.62	.38								
(3)		1.00								
(4)	1.00									

SIRE SIDE BREED COMPOSITION (FNBCS) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.00									
(2)		1.00								
(3)	1.00									
(4)		1.00								

GENETIC STARTING (BREEDING) VALUES (BY GROUP):

GROUP	FVBW	FVYW	FVMW	FVMP	FVAAP	FVPCYC	FVPCON	FVDDYS	FVMDYS
(1)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(2)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(3)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(4)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00

GROUP	FVGL	FVMF	FVAPP	FVUNSD	FVPSRV	FVRM	FVIME	FVFEC	FVYLD
(1)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(2)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(3)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(4)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00

GROUP	FVXXXX	FVZZZZ
(1)	1.00	1.00
(2)	1.00	1.00
(3)	1.00	1.00
(4)	1.00	1.00

TAPES -- SIRE PARAMETERS

7
12
11

NUMBER OF SIRE GROUPS AND PREDICTION ERROR GROUPS:

NOSGPS	NPEGPS	STREND	NSTYPS
20	3	1	8

SIRE GROUP PARAMETERS (BY GROUP):

GROUP	NSPSG	SGPEG	SGSIM	SIRYOA	SIRDOA	SIRCON	SSDATE	SGPTYP
(1)	13	2	1	4	286	1.00	0	2
(2)	13	2	1	3	286	1.00	0	1
(3)	13	2	1	2	286	1.00	0	2
(4)	13	2	1	1	286	1.00	0	1
(5)	13	2	1	1	426	1.00	0	2
(6)	13	2	1	1	426	1.00	0	1
(7)	13	2	1	1	426	1.00	0	2
(8)	13	2	1	1	426	1.00	0	1
(9)	7	2	1	1	426	1.00	0	4
(10)	7	2	1	1	426	1.00	0	3
(11)	7	2	1	1	426	1.00	0	4
(12)	7	2	1	1	426	1.00	0	3
(13)	13	2	1	1	426	1.00	0	6
(14)	13	2	1	1	426	1.00	0	5
(15)	13	2	1	1	426	1.00	0	6
(16)	13	2	1	1	426	1.00	0	5
(17)	5	3	0	6	426	1.00	0	8
(18)	6	3	0	6	426	1.00	0	7
(19)	5	3	0	6	426	1.00	0	8
(20)	6	3	0	6	426	1.00	0	7

DAM SIDE BREED COMPOSITION (SBCD) (BY SIRE GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.000									
(2)		1.000								
(3)			1.000							
(4)	1.000									
(5)	1.000									
(6)		1.000								
(7)			1.000							
(8)	1.000									
(9)	1.000									
(10)		1.000								
(11)			1.000							
(12)	1.000									
(13)	1.000									
(14)		1.000								
(15)			1.000							
(16)	1.000									
(17)	1.000									
(18)		1.000								
(19)			1.000							
(20)	1.000									

SIRE SIDE BREED COMPOSITION (SBCS) (BY SIRE GROUP, BREED) :

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.000									
(2)		1.000								
(3)			1.000							
(4)	1.000									
(5)	1.000									
(6)		1.000								
(7)			1.000							
(8)	1.000									
(9)	1.000									
(10)		1.000								
(11)			1.000							
(12)	1.000									
(13)	1.000									
(14)		1.000								
(15)			1.000							
(16)	1.000									
(17)	1.000									
(18)		1.000								
(19)			1.000							
(20)	1.000									

GENETIC STARTING (BREEDING) VALUES (BY SIRE GROUP) :

GROUP	SVBW	SVYW	SVMW	SVMP	SVAAP	SVPCYC	SVPCON	SVDDYS	SVMDYS
(1)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(2)	30.4	250.3	549.5	8.5	365.0	.950	.850	1.00	1.00
(3)	43.0	357.0	815.0	9.9	365.0	.950	.850	1.00	1.00
(4)	30.3	270.3	469.0	9.0	365.0	.950	.850	1.00	1.00
(5)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(6)	30.4	250.3	549.5	8.5	365.0	.950	.850	1.00	1.00
(7)	43.0	357.0	815.0	9.9	365.0	.950	.850	1.00	1.00
(8)	30.3	270.3	469.0	9.0	365.0	.950	.850	1.00	1.00
(9)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(10)	30.4	250.3	549.5	8.5	365.0	.950	.850	1.00	1.00
(11)	43.0	357.0	815.0	9.9	365.0	.950	.850	1.00	1.00
(12)	30.3	270.3	469.0	9.0	365.0	.950	.850	1.00	1.00
(13)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(14)	30.4	250.3	549.5	8.5	365.0	.950	.850	1.00	1.00
(15)	43.0	357.0	815.0	9.9	365.0	.950	.850	1.00	1.00
(16)	30.3	270.3	469.0	9.0	365.0	.950	.850	1.00	1.00
(17)	34.6	308.9	536.0	9.4	365.0	.950	.850	1.00	1.00
(18)	30.4	250.3	549.5	8.5	365.0	.950	.850	1.00	1.00
(19)	43.0	357.0	815.0	9.9	365.0	.950	.850	1.00	1.00
(20)	30.3	270.3	469.0	9.0	365.0	.950	.850	1.00	1.00

GROUP	SVGL	SVMF	SVAPP	SVUNSD	SVPSRV	SVRM	SVIMF	SVFFC	SVYLD
(1)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(2)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(3)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(4)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(5)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(6)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(7)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(8)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(9)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(10)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(11)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(12)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(13)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(14)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(15)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(16)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(17)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(18)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(19)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00
(20)	283.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00

GROUP	SVXXXX	SVZZZZ
(1)	1.00	1.00
(2)	1.00	1.00
(3)	1.00	1.00
(4)	1.00	1.00
(5)	1.00	1.00
(6)	1.00	1.00
(7)	1.00	1.00
(8)	1.00	1.00
(9)	1.00	1.00
(10)	1.00	1.00
(11)	1.00	1.00
(12)	1.00	1.00
(13)	1.00	1.00
(14)	1.00	1.00
(15)	1.00	1.00
(16)	1.00	1.00
(17)	1.00	1.00
(18)	1.00	1.00
(19)	1.00	1.00
(20)	1.00	1.00

PREDICTION ERROR VARIANCES (BY PE GROUP (J), TRAIT (I)):

GROUP	BW	YW	MW	MP	AAP	PCYC	PCON	DDYS	MDYS	GL
(1)	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12
(2)	2.79	117.0	540.0	2.16	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12 BIF ACC = .4
(3)	.0775	3.25	15.0	.06	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12 BIF ACC = .9

GROUP	MF	APP	UNSD	PSRV	RM	IMF	FFC	YLD	XXXX	ZZZZ
(1)	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12
(2)	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12
(3)	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12	1.E-12

SIRE TRENDS (BY SIRE TYPE):

TYPE	STBW	STYW	STMW	STMP	STAAP	STPCYC	STPCON	STDDYS	STMDYS
(1)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(2)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(3)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(4)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(5)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(6)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(7)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00
(8)	0.0	1.3	0.0	.00	0.0	.000	.000	0.00	0.00

TYPE	STGL	STMF	STAPP	STUNSD	STPSRV	STRM	STMF	STFFC	STYLD
(1)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(2)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(3)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(4)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(5)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(6)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(7)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00
(8)	000.0	.000	0.00	0.00	.000	0.00	0.00	0.00	0.00

TYPE	STXXXX	STZZZZ
(1)	0.00	0.00
(2)	0.00	0.00
(3)	0.00	0.00
(4)	0.00	0.00
(5)	0.00	0.00
(6)	0.00	0.00
(7)	0.00	0.00
(8)	0.00	0.00

GENETIC LEADS (BY SIRE TYPE):

TYPE	GLEAD
(1)	0.00
(2)	0.00
(3)	2.75
(4)	2.75
(5)	3.50
(6)	3.50
(7)	5.50
(8)	5.50

TAPE6 -- IMPORTED REPLACEMENT PARAMETERS

NUMBER OF IMPORT GROUPS:

NIMGPS
1

IMPORT GROUP PARAMETERS (BY GROUP):

GROUP	IMDATE	IMPYOA	IMPDOA	IMPDOG	IMPDAC	IMPSEX	IMPCON	ISSGRP	
(1)	330	1	221	0	0	1	1.00	8	HF

DAM SIDE BREED COMPOSITION (IMBCD) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.00									

SIRE SIDE BREED COMPOSITION (IMBCS) (BY GROUP, BREED):

GROUP	1	2	3	4	5	6	7	8	9	10
(1)	1.00									

GENETIC STARTING (BREEDING) VALUES (BY GROUP):

GROUP	IVBW	IVYW	IVMW	IVMP	IYAAP	IVPCYC	IVPCON	IVDDYS	IVMDYS
(1)	36.3	274.8	518.4	9.0	365.0	.950	.850	1.00	1.00

GROUP	IVGL	IVMF	IVAPP	IVUNSD	IVPSRV	IVRM	IVIMF	IVFFC	IVYLD
(1)	363.0	.170	1.00	1.00	.998	1.40	1.00	1.00	1.00

GROUP	IVXXXX	IVZZZZ
(1)	1.00	1.00

TAPE7 -- VARIANCE/COVARIANCE MATRICES AND HYBRID VIGOR

NUMBER OF TRAITS:

NTRATS NTRTTS (ALREADY READ FROM TAPE1)

20 4

ADDITIVE VARIANCE/COVARIANCE MATRIX (AMTX)
LOWER DIAGONAL ONLY:

ROW	1	2	3	4	5	6	7	8	9	10
(1)	7.75	25.0	325.0	60.8	500.0	1500.0	0.0	0.0	0.0	6.00
(2)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(3)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0
(4)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(5)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(6)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(7)	0.0	0.0	0.0	0.0	0.0	2.E-5	0.0	0.0	0.0	0.0
(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0
(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(10)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(11)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12
(13)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(14)	0.0	0.0	0.0	0.0	0.0	0.0	00.50	0.0	0.0	0.0
(15)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(16)	0.0	0.0	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(17)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(18)	.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(19)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5
(20)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(21)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5

NON-ADDITIVE VARIANCE/COVARIANCE MATRIX (NAMTX)
LOWER DIAGONAL ONLY:

ROW	1	2	3	4	5	6	7	8	9	10
(1)	1.E-12	0.0	1.E-12	0.0	0.0	1.E-12	0.0	0.0	0.0	1.E-12
(2)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(3)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0
(4)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(5)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(6)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(7)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0
(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(10)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(11)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12
(13)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(14)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(15)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(16)	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(17)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(18)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(19)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12
(20)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(21)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12

"PERMANENT" ENVIRONMENTAL VARIANCE/COVARIANCE MATRIX (PEMTX)
LOWER DIAGONAL ONLY:

ROW	1	2	3	4	5	6	7	8	9	10
(1)	16.75	26.6	675.0	31.0	534.0	1400.0	0.0	0.0	0.0	1.9
(2)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(3)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0
(4)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(5)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(6)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(7)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(8)	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0
(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(10)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(11)	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0
(12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12
(13)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(14)	0.0	0.0	0.0	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0
(15)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(16)	0.0	0.0	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(17)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(18)	1.E-12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(19)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12
(20)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(21)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.E-12

TEMPORARY ENVIRONMENTAL VARIANCE/COVARIANCE MATRIX (TEMTX)
LOWER DIAGONAL ONLY:

ROW	1	2	3	4	5	6	7	8	9	10
(1)	1.E-12	0.0	1.E-12	0.0	0.0	1.E-12	0.0	0.0	0.0	1.E-12

HYBRID VIGOR MATRIX (HYVIG) (BY TRAIT, BREED OF SIRE, BREED OF DAM):

TRAIT / (BREED OF SIRE)		BREED OF DAM									
		1	2	3	4	5	6	7	8	9	10
BW	(1)	0.0	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(2)	1.6	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(3)	1.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BW	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
YW	(1)	0.0	18.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(2)	18.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(3)	18.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YW	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
MW	(1)	0.0	13.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW	(2)	13.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW	(3)	13.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MW (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MW (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
MP (1)	0.0	.04	.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (2)	.04	0.0	.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (3)	.04	.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MP (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
AAP (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AAP (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
PCYC (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCYC (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
PCON (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PCON (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
DDYS (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DDYS (10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1	2	3	4	5	6	7	8	9	10
MDYS (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS (2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS (3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MDYS	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MDYS	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
GL	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GL	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
MF	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MF	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
APP	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
APP	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
UNSD	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UNSD	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
PSRV	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PSRV	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1	2	3	4	5	6	7	8	9	10
RM	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RM	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RM	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(1)	1	2	3	4	5	6	7	8	9	10
IMF	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMF	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(1)	1	2	3	4	5	6	7	8	9	10
FFC	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FFC	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(1)	1	2	3	4	5	6	7	8	9	10
YLD	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YLD	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(1)	1	2	3	4	5	6	7	8	9	10
XXXX	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XXXX	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(1)	1	2	3	4	5	6	7	8	9	10
ZZZZ	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(4)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(6)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(7)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(8)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZZZZ	(10)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TAPE8 -- MISCELLANEOUS VARIABLES

MIN DYSTOCIA, INFLECTION AGE, EMPTY BODY PROPORTIONS, "STANDARD" VARIABLES:

MINDYS	IDOA	EBPBW	EBPYW	EBPMW	SDOPL	SMF	SWORK	SDC	SPGCF
.025	205	.960	.920	.820	60	.170	1.000	1.070	1.200

BULL ADJUSTMENTS:

BABW	BAYW	BAMW	BADDYS	BAGL	BAMF	BADC	BAUNSD	BAPSRV
1.070	1.220	1.700	0.200	1.0043	.900	1.000	1.200	0.000
BARM	BAIMF	BAFFC	BAYLD					
1.150	1.000	1.000	1.000					

STEER ADJUSTMENTS:

SAYW	SAMW	SAMF	SADC	SAUNSD	SAPSRV
1.110	1.150	.950	1.000	.800	0.000

DEATH CORRECTION FACTORS:

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CFDMO	1.2	1.2	1.1	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.2
CFEPMO	1.5	1.5	1.2	1.0	1.0	1.0	1.1	1.2	1.0	1.0	1.2	1.3

DEATH CORRECTION FACTORS BY MONTH OF AGE:

	1	2	3	4	5	6	7	8	9	10	11	12
CFDAGE	10.0	5.0	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

AGE OF DAM ADJUSTMENT AND CULLING FACTORS:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BWCF	.90	.93	.96	.98	1.00	1.00	1.00	1.00	1.00	1.00	.97	.97	.97	.97	.97
CULLF	.010	.015	.025	.030	.030	.030	.030	.040	.040	.050	.070	.100	.100	.200	.300

INTERCEPTS FOR DYSTOCIA EQUATIONS (CFDYS):

1	2	3	4
-.2038	-.2038	-.7227	-.2230

EXPERIMENTAL REAL, INTEGER AND LOGICAL SCALAR VARIABLES:

ERS1	ERS2	ERS3	ERS4	ERS5	ERS6	ERS7	ERS8
1.250	.180	2.500	1.000	.850	.600	1.200	1.200
ERS9	ERS10	ERS11	ERS12	ERS13	ERS14	ERS15	ERS16
0.00	0.40	0.60	5.00	0.84	0.86	0.92	0.85
ERS17	ERS18	ERS19	ERS20	ERS21	ERS22	ERS23	ERS24
0.87	0.90	1.33	1.33	0.97	1.04	0.00	0.00
ERS25	ERS26	ERS27	ERS28	ERS29	ERS30	ERS31	ERS32
0.00	0.00	0.00	0.00	0.00	0.00	0.90	1.20
EIS1	EIS2	EIS3	EIS4	EIS5	EIS6	EIS7	EIS8
380	550	1	0	0	0	0	0
EIS9	EIS10	EIS11	EIS12	EIS13	EIS14	EIS15	EIS16
0	0	0	0	0	5	0	0

ELS1	ELS2	ELS3	ELS4	ELS5	ELS6	ELS7	ELS8
F	F	F	F	F	F	F	F
ELS9	ELS10	ELS11	ELS12	ELS13	ELS14	ELS15	ELS16
F	F	F	F	F	F	F	F

APPENDIX G

Simulated live weight at weaning (LWW) for maternal calves.

Management Scenario	Maternal Outputs (AI):					
	No. Male Calves	Avg. LWW, kg	Total LWW, kg	No. Female Calves	Avg. LWW, kg	Total LWW, kg
NATURAL						
Straightbred	-	-	-	-	-	-
Straight X Terminal	-	-	-	-	-	-
Rota-Terminal	-	-	-	-	-	-
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	54	225.0	12147.8	58	214.8	12459.6
60%	36	223.5	8044.6	59	213.7	12605.9
70%	23	222.8	5123.9	60	213.3	12798.0
80%	16	222.4	3559.0	72	212.5	15301.4
90%	8	221.7	1773.4	78	213.2	16626.5
Straightbred X Terminal:						
50%	52	224.2	11659.4	56	213.3	11947.0
60%	36	224.6	8084.9	61	213.8	13040.6
70%	26	223.2	5802.2	65	214.0	13912.6
80%	17	222.9	3789.6	72	214.2	15423.8
90%	7	212.8	1489.6	80	212.8	17024.0
Rota-Terminal:						
50%	55	228.2	12549.9	58	217.5	12616.2
60%	37	227.9	8432.3	59	216.7	12787.7
70%	26	228.1	5930.6	65	216.3	14060.8
80%	16	226.3	3621.1	69	216.1	14912.3
90%	9	226.1	2034.9	80	215.3	17222.4
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	117	219.3	25653.4	122	208.3	25412.6
60%	85	218.1	18538.5	141	207.4	29240.6
70%	57	215.4	12277.8	138	206.7	28519.1
80%	32	215.7	6902.4	136	206.1	28032.3
90%	14	215.0	3010.6	135	205.8	27788.4
Straightbred X Terminal:						
50%	120	220.3	26440.8	128	209.8	26854.4
60%	83	217.4	18047.5	133	207.3	27573.6
70%	56	216.6	12128.5	136	206.8	28124.8
80%	32	215.3	6888.3	138	206.3	28469.4
90%	13	213.3	2773.2	136	205.8	27988.8
Rota-Terminal:						
50%	124	224.5	27843.0	129	212.5	27407.3
60%	85	221.1	18790.1	133	210.2	27953.9
70%	53	219.4	11626.1	137	208.6	28578.2
80%	32	218.0	6976.6	134	208.7	27960.4
90%	13	219.7	2855.6	131	207.8	27216.6

-Continued

Simulated live weight at weaning (LWW) for maternal calves, continued.

Maternal Outputs (Natural):						
Management Scenario	No. Male Calves	Avg. LWW, kg	Total LWW,kg	No. Female Calves	Avg. LWW, kg	Total LWW, kg
NATURAL						
Straightbred	102	213.44	21770.9	109	202.68	22092.12
Straight X Terminal	102	215.22	21952.4	107	203.26	21748.82
Rota-Terminal	102	217.18	22152.4	110	205.24	22576.4
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	56	204.86	11472.2	59	193.72	11429.48
60%	56	204.38	11445.3	58	193.08	11198.64
70%	47	202.68	9525.96	50	193.1	9655
80%	47	203.2	9550.4	48	192.8	9254.4
90%	42	203.6	8551.2	44	193.78	8526.32
Straightbred X Terminal:						
50%	55	204.74	11260.7	57	193.72	11042.04
60%	53	203.9	10806.7	54	193.7	10459.8
70%	49	205.4	10064.6	50	193.8	9690
80%	44	204.84	9012.96	46	194.02	8924.92
90%	40	203.66	8146.4	43	192.98	8298.14
Rota-Terminal:						
50%	55	208.72	11479.6	58	196.56	11400.48
60%	55	208.24	11453.2	55	196.54	10809.7
70%	49	206.94	10140.1	52	195.86	10184.72
80%	44	207.14	9114.16	46	197.02	9062.92
90%	42	208.24	8746.08	43	197.14	8477.02
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-
Straightbred X Terminal:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-
Rota-Terminal:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-

Simulated live weight at weaning (LWW) for terminal calves.

Management Scenario	Terminal Outputs (AI):					
	No. Male Calves	Avg. LWW, kg	Total LWW, kg	No. Female Calves	Avg. LWW, kg	Total LWW, kg
NATURAL						
Straightbred	-	-	-	-	-	-
Straight X Terminal	-	-	-	-	-	-
Rota-Terminal	-	-	-	-	-	-
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	28	244.8	6855.0	28	232.2	6501.6
60%	33	245.0	8084.3	24	231.3	5551.2
70%	47	245.9	11558.2	22	232.0	5103.1
80%	55	245.1	13479.4	15	231.0	3464.7
90%	65	245.8	15978.3	7	232.5	1627.4
Straightbred X Terminal:						
50%	26	268.8	6989.8	29	254.6	7382.8
60%	33	270.7	8933.1	23	256.0	5887.5
70%	41	269.9	11065.9	21	256.4	5385.2
80%	54	270.7	14615.6	15	257.8	3866.7
90%	62	271.3	16823.1	7	257.7	1803.8
Rota-Terminal:						
50%	27	269.3	7270.6	28	255.4	7151.8
60%	34	271.2	9219.4	24	257.2	6172.8
70%	44	271.9	11965.4	18	256.3	4613.0
80%	58	272.5	15803.8	15	257.6	3863.7
90%	63	272.3	17157.4	8	257.8	2062.2
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	51	236.5	12062.5	53	222.4	11788.3
60%	68	235.9	16038.5	48	223.5	10727.0
70%	102	237.1	24188.3	46	223.8	10296.6
80%	138	236.5	32634.2	37	222.4	8229.5
90%	175	236.3	41356.0	20	223.1	4462.8
Straightbred X Terminal:						
50%	46	258.3	11883.6	49	246.0	12056.0
60%	74	259.8	19223.7	50	246.3	12317.0
70%	103	260.1	26794.4	47	247.1	11611.8
80%	134	260.0	34834.6	38	246.6	9370.0
90%	171	260.1	44480.5	20	246.5	4930.0
Rota-Terminal:						
50%	45	260.7	11731.5	45	247.0	11115.9
60%	73	261.7	19104.1	52	247.2	12852.3
70%	104	261.0	27146.1	46	247.3	11377.6
80%	138	261.5	36089.8	37	247.4	9153.1
90%	176	260.5	45855.0	21	247.4	5195.4

-Continued

Simulated live weight at weaning (LWW) for terminal calves. continued.

Management Scenario	Terminal Outputs (Natural):					
	No. Male Calves	Avg. LWW, kg	Total LWW, kg	No. Female Calves	Avg. LWW, kg	Total LWW, kg
NATURAL						
Straightbred	64	220.7	14124.8	68	207.68	14122.2
Straight X Terminal	63	257.72	16236.4	69	243.92	16830.5
Rota-Terminal	62	255.94	15868.3	67	242	16214
ARTIFICIAL INSEMINATION: NATURAL						
Straightbred:						
50%	30	221.4	6642	31	207.56	6434.36
60%	41	207.74	8517.34	37	219.46	8120.02
70%	46	221.54	10190.8	48	208.68	10016.6
80%	45	221.54	9969.3	48	208.52	10009
90%	48	221.82	10647.4	51	209.56	10687.6
Straightbred X Terminal:						
50%	30	245.1	7353	32	232.12	7427.84
60%	39	244.76	9545.64	40	232.28	9291.2
70%	42	246.54	10354.7	45	234.1	10534.5
80%	47	246.36	11578.9	49	232.46	11390.5
90%	50	246.58	12329	51	232.92	11878.9
Rota-Terminal:						
50%	30	244.32	7329.6	30	230.06	6901.8
60%	39	245.2	9562.8	38	231.46	8795.48
70%	42	248.3	10428.6	44	233	10252
80%	46	247.12	11367.5	47	231.92	10900.2
90%	48	246.58	11835.8	51	233	11883
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-
Straightbred X Terminal:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-
Rota-Terminal:						
50%	-	-	-	-	-	-
60%	-	-	-	-	-	-
70%	-	-	-	-	-	-
80%	-	-	-	-	-	-
90%	-	-	-	-	-	-

Simulated live weight at weaning (LWW) cull cows and heifers.

Management Scenario	Cull cow output:			Cull heifer output:		
	No. Cull Cows	Avg. LWW.kg	Total LWW. kg	No. Cull Heifers	Avg. LWW. kg	Total LWW. kg
NATURAL						
Straightbred	62	492.2	30518.9	22	384.8	8466.5
Straight X Term	62	489.6	30355.2	21	379.6	7972.0
Rota-Terminal	62	511.4	31708.0	25	394.1	9853.0
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	69	473.4	32666.0	19	384.1	7298.3
60%	70	475.6	33294.8	19	390.5	7419.1
70%	68	474.4	32260.6	17	389.3	6617.4
80%	69	474.6	32747.4	24	388.1	9313.9
90%	68	478.1	32513.5	27	393.0	10612.1
Straightbred X Terminal:						
50%	68	476.6	32407.4	18	383.7	6905.9
60%	68	475.2	32315.0	20	386.4	7728.4
70%	68	476.2	32383.0	20	386.7	7734.4
80%	68	477.6	32476.8	24	388.7	9329.8
90%	68	476.0	32366.6	28	388.4	10876.3
Rota-Terminal:						
50%	68	510.2	34693.6	21	398.6	8370.2
60%	69	511.3	35276.9	18	398.5	7173.0
70%	68	510.3	34699.0	21	395.4	8303.8
80%	66	509.2	33605.9	22	400.8	8817.2
90%	69	512.0	35330.8	25	402.7	10068.5
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	76	477.7	36302.2	15	394.0	5909.4
60%	86	474.2	40782.9	17	393.7	6693.2
70%	86	472.8	40660.8	14	392.5	5494.4
80%	86	473.0	40674.6	14	393.1	5503.1
90%	85	471.6	40082.6	13	393.0	5109.5
Straightbred X Terminal:						
50%	74	475.5	35185.5	22	393.4	8654.8
60%	85	473.4	40239.0	11	391.9	4310.9
70%	83	472.1	39182.6	16	391.4	6261.8
80%	87	471.3	41004.8	13	396.0	5147.7
90%	85	471.4	40069.0	14	395.3	5533.9
Rota-Terminal:						
50%	75	512.0	38401.5	21	404.3	8490.7
60%	85	511.3	43457.1	12	405.5	4866.2
70%	84	507.9	42665.3	15	400.4	6006.3
80%	85	510.1	43355.1	12	399.7	4796.2
90%	82	508.7	41716.7	13	404.7	5260.6

APPENDIX H

Simulated live weight (LW) for maternal fed animals at harvest.

Management Scenario	No. Fed Steers	Avg. L.W. kg	Total L.W. kg	No. Fed Heifers	Avg. L.W. kg	Total L.W. kg
NATURAL						
Straightbred	102	465.5	47479.0	5	452.0	2260.2
Straight X Terminal	101	469.1	47375.1	5	448.3	2241.4
Rota-Terminal	102	482.9	49259.9	5	461.3	2306.6
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	109	469.2	51138.4	7	439.4	3075.8
60%	90	473.0	42566.4	7	445.6	3119.3
70%	70	464.7	32529.0	7	441.8	3092.9
80%	61	464.7	28344.3	7	439.4	3075.7
90%	49	457.7	22426.3	8	448.4	3587.4
Straightbred X Terminal:						
50%	105	466.8	49011.9	7	438.6	3069.9
60%	90	469.0	42208.2	7	443.3	3102.8
70%	73	472.5	34492.5	7	445.6	3119.1
80%	59	467.6	27588.4	7	439.0	3073.1
90%	46	468.1	21533.5	7	443.8	3106.3
Rota-Terminal:						
50%	109	484.3	52786.5	7	457.5	3202.6
60%	91	484.5	44091.3	7	465.2	3256.1
70%	74	486.2	35975.8	8	472.9	3783.0
80%	59	484.4	28577.2	7	469.9	3289.6
90%	50	487.4	24371.0	8	471.9	3775.0
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	114	476.4	54311.9	10	446.9	4469.2
60%	83	480.9	39911.4	13	443.5	5765.5
70%	57	476.0	27130.9	13	451.2	5865.9
80%	31	482.6	14960.6	14	441.4	6179.9
90%	14	469.7	6576.4	13	452.7	5885.1
Straightbred X Terminal:						
50%	118	476.2	56196.3	11	446.8	4915.0
60%	81	477.6	38684.0	13	451.4	5868.7
70%	54	474.0	25593.8	13	445.4	5789.9
80%	31	473.2	14668.6	12	442.3	5307.8
90%	13	474.6	6170.3	13	450.6	5857.3
Rota-Terminal:						
50%	122	499.8	60980.5	10	470.1	4700.8
60%	84	495.8	41645.5	12	474.8	5697.6
70%	53	499.7	26482.0	13	474.6	6169.5
80%	31	501.8	15554.6	14	470.5	6587.3
90%	13	495.5	6441.8	13	468.8	6094.1

*Percent relative to the baseline where the baseline is the straightbred, natural breeding management scenario.

Simulated live weight (LW) for terminal fed animals at harvest.

Management Scenario	No. Fed Steers	Avg. LW, kg	Total LW, kg	No. Fed Heifers	Avg. LW, kg	Total LW, kg
NATURAL						
Straightbred	61	473.8	28899.4	65	412.8	26833.3
Straight X Terminal	60	594.5	35667.6	65	516.0	33538.7
Rota-Terminal	59	592.2	34942.2	65	511.7	33259.2
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	56	499.7	27982.1	57	438.7	25005.9
60%	69	504.9	34835.3	61	440.2	26849.8
70%	91	500.7	45563.7	67	436.3	29233.4
80%	98	507.0	49686.0	60	433.0	25980.0
90%	112	500.4	56040.3	56	431.3	24152.8
Straightbred X Terminal:						
50%	54	592.3	31985.3	60	520.2	31209.6
60%	59	590.0	34807.6	61	514.8	31404.0
70%	82	596.1	48880.2	64	519.3	33232.6
80%	100	598.3	59834.0	61	512.1	31235.7
90%	111	597.9	66362.5	55	513.3	28233.7
Rota-Terminal:						
50%	56	583.6	32680.5	56	518.3	29025.9
60%	71	591.3	41979.5	60	514.9	30896.4
70%	82	598.4	49068.8	60	519.4	31165.2
80%	101	592.5	59840.5	59	513.0	30269.4
90%	109	603.8	65816.4	57	516.1	29417.7
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	51	504.7	25738.7	52	442.2	22992.3
60%	69	510.8	35245.2	48	445.4	21377.3
70%	101	508.7	51374.7	45	449.6	20230.2
80%	138	506.8	69938.4	35	445.6	15594.6
90%	171	510.2	87240.8	21	445.0	9344.6
Straightbred X Terminal:						
50%	44	604.5	26596.2	48	535.4	25699.2
60%	74	596.4	44136.6	50	521.0	26049.0
70%	101	605.5	61155.5	46	532.9	24515.2
80%	134	607.3	81375.5	37	526.0	19463.5
90%	169	601.8	101711.0	19	522.8	9934.0
Rota-Terminal:						
50%	44	604.3	26589.2	45	526.5	23691.6
60%	71	600.5	42636.9	51	523.0	26672.0
70%	102	601.4	61340.8	44	534.5	23516.2
80%	137	607.1	83175.4	37	531.8	19675.1
90%	175	606.4	106113.0	21	529.1	11111.1

APPENDIX I

Simulated carcass weight (CW) for maternal fed animals at harvest.

Management Scenario	No. Fed Males	Avg. CW, kg	Total CW, kg	No. Fed Females	Avg. CW, kg	Total CW, kg
NATURAL						
Straightbred	102	293.3	29918.6	5	284.3	1421.5
Straight X Terminal	101	295.8	29873.8	5	281.5	1407.5
Rota-Terminal	102	305.4	31154.9	5	290.5	1452.4
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	109	295.8	32240.0	7	275.3	1927.0
60%	90	298.6	26872.2	7	279.6	1957.5
70%	70	292.7	20491.8	7	276.9	1938.0
80%	61	292.8	17859.6	7	275.1	1926.0
90%	49	287.8	14103.2	8	281.5	2252.2
Straightbred X Terminal:						
50%	105	294.1	30884.7	7	274.6	1921.9
60%	90	295.7	26616.6	7	277.9	1945.6
70%	73	298.2	21767.1	7	279.5	1956.4
80%	59	294.8	17392.0	7	274.8	1923.7
90%	46	295.2	13580.1	7	278.2	1947.4
Rota-Terminal:						
50%	109	306.3	33388.9	7	287.6	2013.1
60%	91	306.5	27889.7	7	293.2	2052.4
70%	74	307.7	22769.8	8	298.6	2388.5
80%	59	306.5	18085.9	7	296.4	2074.8
90%	50	308.6	15432.0	8	297.8	2382.1
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	114	300.7	34277.5	10	280.5	2804.8
60%	83	303.8	25218.7	13	278.0	3613.5
70%	57	300.4	17123.9	13	283.5	3685.2
80%	31	305.1	9458.7	14	276.5	3871.3
90%	14	295.9	4143.2	13	284.6	3699.5
Straightbred X Terminal:						
50%	118	300.6	35473.2	11	280.3	3083.3
60%	81	301.5	24424.7	13	283.6	3686.5
70%	54	299.0	16146.0	13	279.3	3631.4
80%	31	298.4	9251.6	12	277.2	3325.9
90%	13	299.4	3891.9	13	283.1	3680.0
Rota-Terminal:						
50%	122	317.0	38676.4	10	296.4	2963.8
60%	84	314.2	26396.2	12	299.8	3597.6
70%	53	317.0	16798.9	13	299.6	3895.3
80%	31	318.4	9871.6	14	296.7	4154.4
90%	13	313.9	4080.4	13	295.5	3841.2

Simulated carcass weight (CW) for terminal fed animals at harvest.

Management Scenario	No. Fed Males	Avg. CW. kg	Total CW. kg	No. Fed Females	Avg. CW. kg	Total CW. kg
NATURAL						
Straightbred	61	299.1	18243.9	65	257.3	16725.8
Straight X Terminal	60	382.1	22927.2	65	328.1	21329.1
Rota-Terminal	59	380.7	22460.1	65	325.3	21143.2
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	56	316.7	17733.0	57	274.9	15671.6
60%	69	320.5	22113.1	61	276.0	16838.4
70%	91	317.4	28883.4	67	273.4	18316.5
80%	98	321.8	31540.3	60	271.0	16262.4
90%	112	317.0	35504.0	56	269.8	15109.9
Straightbred X Terminal:						
50%	54	380.4	20542.7	60	331.0	19857.6
60%	59	378.7	22345.7	61	327.3	19964.1
70%	82	383.0	31407.6	64	330.4	21145.6
80%	100	384.7	38470.0	61	325.5	19854.3
90%	111	384.3	42655.1	55	326.4	17952.0
Rota-Terminal:						
50%	56	374.4	20967.5	56	329.8	18467.7
60%	71	379.8	26968.6	60	327.5	19647.6
70%	82	384.7	31545.4	60	330.6	19838.4
80%	101	380.5	38434.5	59	326.2	19243.4
90%	109	388.6	42357.4	57	328.4	18717.7
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	51	320.0	16321.0	52	277.2	14416.5
60%	69	324.4	22383.6	48	279.5	13416.0
70%	101	322.8	32604.8	45	282.5	12711.6
80%	138	321.5	44367.0	35	279.7	9788.8
90%	171	323.9	55386.9	21	279.2	5864.0
Straightbred X Terminal:						
50%	44	388.9	17111.6	48	341.5	16393.9
60%	74	383.2	28353.8	50	331.4	16571.0
70%	101	389.6	39347.6	46	339.8	15631.7
80%	134	390.8	52372.6	37	335.0	12393.5
90%	169	387.0	65403.0	19	332.7	6320.9
Rota-Terminal:						
50%	44	388.8	17108.1	45	335.3	15090.3
60%	71	386.2	27417.4	51	333.0	16984.0
70%	102	386.7	39447.5	44	341.1	15006.6
80%	137	390.7	53531.4	37	339.1	12545.2
90%	175	390.2	68292.0	21	337.2	7080.4

Simulated carcass weight (CW) for cull cows and heifers at harvest.

Management Scenario	Cull cow output:			Cull heifer output:		
	No. Cull Cows	Avg. CW, kg	Total CW, kg	No. Cull Heifers	Avg. CW, kg	Total CW, kg
NATURAL						
Straightbred	62	275.6	17087.8	22	210.6	4633.6
Straight X Terminal	62	273.6	16963.2	21	207.3	4353.9
Rota-Terminal	62	287.0	17792.8	25	216.2	5403.8
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	69	264.0	18218.8	19	210.1	3991.7
60%	70	265.4	18579.4	19	214.0	4065.6
70%	68	264.6	17991.4	17	213.4	3628.1
80%	69	264.7	18265.0	24	212.6	5101.9
90%	68	267.0	18152.6	27	215.7	5823.9
Straightbred X Terminal:						
50%	68	265.8	18073.7	18	209.9	3777.3
60%	68	264.9	18015.2	20	211.7	4233.4
70%	68	265.5	18056.7	20	211.8	4235.6
80%	68	266.3	18109.1	24	213.0	5110.8
90%	68	265.3	18041.8	28	212.9	5960.9
Rota-Terminal:						
50%	68	286.2	19464.3	21	219.0	4598.4
60%	69	286.7	19784.4	18	219.1	3942.9
70%	68	286.2	19464.3	21	217.1	4558.1
80%	66	285.6	18847.6	22	220.4	4849.0
90%	69	287.4	19827.8	25	221.6	5540.0
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	76	266.7	20267.7	15	216.1	3241.7
60%	86	264.6	22753.9	17	216.0	3672.7
70%	86	263.7	22679.9	14	215.3	3014.1
80%	86	263.8	22683.4	14	215.6	3019.0
90%	85	262.9	22343.1	13	215.5	2801.8
Straightbred X Terminal:						
50%	74	265.1	19620.4	22	215.9	4750.5
60%	85	263.9	22430.7	11	214.8	2362.4
70%	83	263.1	21833.2	16	214.4	3430.2
80%	87	262.5	22840.1	13	217.4	2826.5
90%	85	262.6	22317.6	14	216.8	3035.3
Rota-Terminal:						
50%	75	287.4	21556.5	21	222.4	4670.0
60%	85	287.0	24391.6	12	223.3	2679.5
70%	84	285.0	23935.8	15	220.0	3300.6
80%	85	286.2	24322.8	12	219.7	2635.9
90%	82	285.3	23396.2	13	222.7	2895.4

APPENDIX J

Simulated empty body weight (EBW) for maternal fed animals at harvest.

Management Scenario	No Fed Steers	Avg EBW, kg	Total EBW, kg	No Fed Heifers	Avg EBW, kg	Total EBW, kg
NATURAL						
Straightbred	102	429.8	43839.6	5	417.4	2087.2
Straight X Terminal	101	433.1	43747.1	5	413.7	2068.3
Rota-Terminal	102	446.3	45520.6	5	425.9	2129.5
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	109	433.1	47212.3	7	405.2	2836.1
60%	90	436.9	39322.8	7	411.1	2878.0
70%	70	429.0	30027.2	7	407.3	2851.2
80%	61	429.0	26170.2	7	405.0	2835.0
90%	49	422.2	20688.8	8	413.7	3309.6
Straightbred X Terminal:						
50%	105	430.9	45246.6	7	404.2	2829.4
60%	90	433.1	38977.2	7	408.8	2861.7
70%	73	436.4	31855.7	7	410.9	2876.6
80%	59	431.7	25471.5	7	404.6	2831.9
90%	46	432.3	19887.6	7	409.2	2864.1
Rota-Terminal:						
50%	109	447.5	48773.1	7	422.0	2953.7
60%	91	447.7	40740.7	7	429.6	3007.3
70%	74	449.3	33251.2	8	436.9	3495.2
80%	59	447.8	26417.8	7	434.0	3038.1
90%	50	450.7	22533.0	8	435.8	3486.6
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	114	439.8	50139.5	10	412.3	4122.8
60%	83	444.1	36860.3	13	408.9	5315.4
70%	57	439.5	25049.2	13	416.4	5413.2
80%	31	445.8	13819.8	14	406.9	5696.0
90%	14	433.4	6067.0	13	417.8	5431.9
Straightbred X Terminal:						
50%	118	439.7	51887.0	11	412.0	4532.4
60%	81	441.0	35717.8	13	416.5	5414.5
70%	54	437.5	23626.1	13	410.7	5339.6
80%	31	436.7	13538.9	12	407.7	4892.4
90%	13	438.0	5694.3	13	415.8	5405.7
Rota-Terminal:						
50%	122	462.1	56373.8	10	433.9	4339.0
60%	84	458.3	38497.2	12	438.6	5263.2
70%	53	462.0	24483.9	13	438.4	5698.9
80%	31	464.0	14383.4	14	434.4	6081.9
90%	13	457.7	5950.6	13	432.8	5625.9

Simulated empty body weight (EBW) for terminal fed animals at harvest.

Management Scenario	No. Fed Steers	Avg. EBW, kg	Total EBW, kg	No. Fed Heifers	Avg. EBW, kg	Total EBW, kg
NATURAL						
Straightbred	61	299.1	18243.9	65	257.3	16725.8
Straight X Terminal	60	382.1	22927.2	65	328.1	21329.1
Rota-Terminal	59	380.7	22460.1	65	325.3	21143.2
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	56	316.7	17733.0	57	274.9	15671.6
60%	69	320.5	22113.1	61	276.0	16838.4
70%	91	317.4	28883.4	67	273.4	18316.5
80%	98	321.8	31540.3	60	271.0	16262.4
90%	112	317.0	35504.0	56	269.8	15109.9
Straightbred X Terminal:						
50%	54	380.4	20542.7	60	331.0	19857.6
60%	59	378.7	22345.7	61	327.3	19964.1
70%	82	383.0	31407.6	64	330.4	21145.6
80%	100	384.7	38470.0	61	325.5	19854.3
90%	111	384.3	42655.1	55	326.4	17952.0
Rota-Terminal:						
50%	56	374.4	20967.5	56	329.8	18467.7
60%	71	379.8	26968.6	60	327.5	19647.6
70%	82	384.7	31545.4	60	330.6	19838.4
80%	101	380.5	38434.5	59	326.2	19243.4
90%	109	388.6	42357.4	57	328.4	18717.7
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	51	320.0	16321.0	52	277.2	14416.5
60%	69	324.4	22383.6	48	279.5	13416.0
70%	101	322.8	32604.8	45	282.5	12711.6
80%	138	321.5	44367.0	35	279.7	9788.8
90%	171	323.9	55386.9	21	279.2	5864.0
Straightbred X Terminal:						
50%	44	388.9	17111.6	48	341.5	16393.9
60%	74	383.2	28353.8	50	331.4	16571.0
70%	101	389.6	39347.6	46	339.8	15631.7
80%	134	390.8	52372.6	37	335.0	12393.5
90%	169	387.0	65403.0	19	332.7	6320.9
Rota-Terminal:						
50%	44	388.8	17108.1	45	335.3	15090.3
60%	71	386.2	27417.4	51	333.0	16984.0
70%	102	386.7	39447.5	44	341.1	15006.6
80%	137	390.7	53531.4	37	339.1	12545.2
90%	175	390.2	68292.0	21	337.2	7080.4

Simulated empty body weight (EBW) for cull cows and heifers at harvest.

Management Scenario	Cull cow output:			Cull heifer output:		
	No. Cull Cows	Avg. EBW, kg	Total EBW, kg	No. Cull Heifers	Avg. EBW, kg	Total EBW, kg
NATURAL						
Straightbred	62	405.6	25149.7	22	317.1	6976.6
Straight X Terminal	62	402.9	24979.8	21	312.6	6565.4
Rota-Terminal	62	421.1	26109.4	25	324.7	8116.5
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	69	389.9	26901.7	19	316.4	6011.6
60%	70	391.8	27423.2	19	321.7	6112.3
70%	68	390.6	26562.2	17	320.9	5456.0
80%	69	390.8	26965.2	24	319.8	7675.2
90%	68	393.8	26781.1	27	324.0	8749.1
Straightbred X Terminal:						
50%	68	392.3	26673.7	18	316.1	5689.4
60%	68	391.1	26594.8	20	318.6	6371.2
70%	68	391.9	26650.6	20	318.7	6374.0
80%	68	393.0	26722.6	24	320.3	7687.2
90%	68	391.6	26630.2	28	320.2	8966.2
Rota-Terminal:						
50%	68	420.1	28568.2	21	328.5	6898.5
60%	69	420.8	29033.8	18	328.6	5914.8
70%	68	420.1	28568.2	21	325.9	6843.5
80%	66	419.2	27667.2	22	330.5	7270.1
90%	69	421.6	29093.2	25	332.1	8302.0
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	76	393.5	29904.5	15	324.6	4869.0
60%	86	390.6	33593.3	17	324.5	5516.5
70%	86	389.4	33491.8	14	323.5	4528.7
80%	86	389.5	33497.0	14	324.0	4535.4
90%	85	388.3	33003.8	13	323.8	4209.4
Straightbred X Terminal:						
50%	74	391.4	28962.1	22	324.4	7135.9
60%	85	389.7	33122.8	11	322.8	3550.4
70%	83	388.5	32248.8	16	322.3	5156.2
80%	87	387.8	33740.3	13	326.4	4242.9
90%	85	387.9	32968.1	14	325.6	4557.8
Rota-Terminal:						
50%	75	421.7	31629.0	21	333.1	6995.9
60%	85	421.1	35793.5	12	334.4	4012.6
70%	84	418.4	35142.2	15	330.0	4949.4
80%	85	420.0	35700.0	12	329.4	3953.3
90%	82	418.9	34346.5	13	333.6	4336.8

APPENDIX K

Simulated fat free weight (FFW) for maternal fed animals at harvest.

Management Scenario	No. Fed Steers	Avg. FFW, kg	Total FFW, kg	No. Fed Heifers	Avg. FFW, kg	Total FFW, kg
NATURAL						
Straightbred	102	322.4	32879.7	5	313.1	1565.4
Straight X Terminal	101	324.9	32810.4	5	310.2	1551.2
Rota-Terminal	102	334.7	34140.4	5	319.4	1597.1
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	109	324.9	35409.2	7	303.9	2127.1
60%	90	327.7	29492.1	7	308.4	2158.5
70%	70	321.7	22520.4	7	305.5	2138.4
80%	61	321.8	19627.7	7	303.8	2126.3
90%	49	316.7	15516.6	8	310.3	2482.2
Straightbred X Terminal:						
50%	105	323.2	33935.0	7	303.2	2122.1
60%	90	324.8	29232.9	7	306.6	2146.3
70%	73	327.3	23891.8	7	308.2	2157.4
80%	59	323.8	19103.6	7	303.4	2123.9
90%	46	324.3	14915.7	7	306.9	2148.1
Rota-Terminal:						
50%	109	335.6	36579.9	7	316.5	2215.3
60%	91	335.8	30555.5	7	322.2	2255.5
70%	74	337.0	24938.4	8	327.7	2621.4
80%	59	335.8	19813.4	7	325.5	2278.6
90%	50	338.0	16899.8	8	326.9	2614.9
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	114	329.9	37604.6	10	309.2	3092.1
60%	83	333.1	27645.2	13	306.7	3986.6
70%	57	329.6	18786.9	13	312.3	4059.9
80%	31	334.4	10364.9	14	305.1	4272.0
90%	14	325.0	4550.3	13	313.4	4073.9
Straightbred X Terminal:						
50%	118	329.8	38915.2	11	309.0	3399.3
60%	81	330.7	26788.3	13	312.4	4060.9
70%	54	328.1	17719.6	13	308.1	4004.7
80%	31	327.6	10154.2	12	305.8	3669.3
90%	13	328.5	4270.7	13	311.9	4054.2
Rota-Terminal:						
50%	122	346.6	42280.3	10	325.4	3254.3
60%	84	343.7	28872.9	12	329.0	3947.4
70%	53	346.5	18362.9	13	328.8	4274.2
80%	31	348.0	10787.5	14	325.8	4561.4
90%	13	343.3	4463.0	13	324.6	4219.4

Simulated fat free weight (FFW) for terminal fed animals at harvest.

Management Scenario	No. Fed Steers	Avg. FFW, kg	Total FFW, kg	No. Fed Heifers	Avg. FFW, kg	Total FFW, kg
NATURAL						
Straightbred	61	328.2	20022.0	65	285.5	18560.1
Straight X Terminal	60	413.0	24781.5	65	357.9	23263.5
Rota-Terminal	59	411.6	24282.6	65	355.0	23072.4
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	56	346.2	19384.7	57	303.6	17302.6
60%	69	350.1	24154.8	61	304.7	18585.5
70%	91	346.9	31569.7	67	305.5	20467.8
80%	98	351.5	34445.0	60	299.6	17973.0
90%	112	346.5	38809.7	56	298.4	16707.6
Straightbred X Terminal:						
50%	54	411.3	22209.4	60	360.8	21645.9
60%	59	409.6	24164.9	61	357.0	21779.7
70%	82	414.0	33946.8	64	360.2	23051.5
80%	100	415.7	41565.0	61	355.2	21664.5
90%	111	415.2	46090.5	55	356.1	19585.5
Rota-Terminal:						
50%	56	405.2	22689.2	56	359.6	20134.8
60%	71	410.7	29159.7	60	357.2	21431.7
70%	82	415.7	34087.0	60	360.4	21625.2
80%	101	411.5	41556.5	59	355.8	20994.9
90%	109	419.7	45742.4	57	358.2	20414.8
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	51	349.6	17829.1	52	305.9	15905.8
60%	69	354.0	24429.1	48	308.2	14793.1
70%	101	352.5	35601.0	45	311.3	14006.3
80%	138	351.1	48452.5	35	308.4	10793.5
90%	171	353.5	60454.5	21	307.9	6466.6
Straightbred X Terminal:						
50%	44	420.0	18479.3	48	371.6	17835.8
60%	74	414.1	30642.7	50	361.2	18062.3
70%	101	420.7	42488.2	46	369.9	17013.3
80%	134	421.9	56539.3	37	364.9	13499.8
90%	169	418.0	70645.4	19	362.5	6887.9
Rota-Terminal:						
50%	44	419.9	18474.7	45	365.3	16436.3
60%	71	417.1	29616.6	51	362.9	18506.1
70%	102	417.7	42609.0	44	371.1	16327.7
80%	137	421.9	57794.8	37	369.1	13655.2
90%	175	421.3	73728.4	21	367.1	7709.3

Simulated fat free weight (FFW) for cull cows and heifers at harvest.

Management Scenario	Cull cow output:			Cull heifer output:		
	No. Cull Cows	Avg. FFW. kg	Total FFW. kg	No. Cull Heifers	Avg. FFW. kg	Total FFW. kg
NATURAL						
Straightbred	62	345.2	21402.4	22	269.9	5937.1
Straight X Terminal	62	342.9	21257.9	21	266.1	5587.3
Rota-Terminal	62	358.4	22218.9	25	276.3	6907.3
ARTIFICIAL INSEMINATION:NATURAL						
Straightbred:						
50%	69	331.8	22893.5	19	269.3	5115.9
60%	70	333.4	23337.3	19	273.8	5201.6
70%	68	332.4	22604.6	17	273.1	4643.0
80%	69	332.6	22947.3	24	272.2	6531.6
90%	68	335.2	22790.9	27	275.8	7445.5
Straightbred X Terminal:						
50%	68	333.8	22699.1	18	269.0	4841.6
60%	68	332.8	22632.4	20	271.1	5421.8
70%	68	333.5	22679.4	20	271.2	5424.2
80%	68	334.4	22741.0	24	272.6	6541.9
90%	68	333.3	22662.4	28	272.5	7630.3
Rota-Terminal:						
50%	68	357.5	24311.4	21	279.6	5870.6
60%	69	358.1	24707.5	18	279.6	5033.5
70%	68	357.5	24311.4	21	277.3	5823.7
80%	66	356.7	23544.8	22	281.2	6186.8
90%	69	358.8	24758.6	25	282.6	7065.0
ARTIFICIAL INSEMINATION						
Straightbred:						
50%	76	334.9	25448.6	15	276.2	4143.5
60%	86	332.4	28588.1	17	276.2	4694.6
70%	86	331.4	28501.3	14	275.3	3853.9
80%	86	331.5	28505.6	14	275.7	3859.7
90%	85	330.4	28086.6	13	275.6	3582.2
Straightbred X Terminal:						
50%	74	333.1	24646.4	22	276.0	6072.7
60%	85	331.6	28187.7	11	274.7	3021.4
70%	83	330.7	27444.0	16	274.2	4387.8
80%	87	330.0	28712.6	13	277.8	3610.8
90%	85	330.1	28056.0	14	277.1	3878.7
Rota-Terminal:						
50%	75	358.9	26916.0	21	283.5	5953.5
60%	85	358.4	30460.6	12	284.6	3414.7
70%	84	356.0	29905.7	15	280.8	4212.0
80%	85	357.4	30380.7	12	280.4	3364.2
90%	82	356.5	29228.9	13	283.9	3690.6

APPENDIX L

Differences in Nutritional Intake.

COWCALF	Energy Suppl.	%	Protein Suppl.	%	Harvested Forage	%	Grazed Forage	%
NATURA								
L								
Straight	39252.2	100.0	3797.0	100.0	3247245.0	100.0	4405692.0	100.0
SXT	27303.3	69.6	3794.1	99.9	3268607.0	100.7	4376467.0	99.3
ROTA-TERM	38275.8	97.5	3381.9	89.1	3413826.0	105.1	4551654.0	103.3
AI:NATURAL								
STRAIGHT								
50	23871.3	60.8	3675.0	96.8	3223608.0	99.3	4307902.0	97.8
60	24060.3	61.3	3913.7	103.1	3224329.0	99.3	4318658.0	98.0
70	23693.8	60.4	3864.0	101.8	3186753.0	98.1	4272186.0	97.0
80	23844.7	60.7	3060.3	80.6	3251283.0	100.1	4346555.0	98.7
90	23959.0	61.0	3104.6	81.8	3273717.0	100.8	4376435.0	99.3
SXT								
50	17435.9	44.4	3393.9	89.4	3236568.0	99.7	4296793.0	97.5
60	18904.5	48.2	3955.2	104.2	3241821.0	99.8	4310237.0	97.8
70	18911.8	48.2	3608.0	95.0	3254387.0	100.2	4323871.0	98.1
80	18852.9	48.0	3017.8	79.5	3293881.0	101.4	4383761.0	99.5
90	18867.4	48.1	3667.3	96.6	3318447.0	102.2	4400606.0	99.9
ROTA-TERM								
50	17486.5	44.5	3680.8	96.9	3414293.0	105.1	4485040.0	101.8
60	21017.8	53.5	3493.2	92.0	3425861.0	105.5	4501341.0	102.2
70	21019.8	53.6	3455.2	91.0	3423684.0	105.4	4510412.0	102.4
80	20684.2	52.7	3690.0	97.2	3442846.0	106.0	4529460.0	102.8
90	20666.3	52.7	3565.1	93.9	3491539.0	107.5	4584220.0	104.1
AI								
STRAIGHT								
50	-	-	3577.1	94.2	3245274.0	99.9	4279924.0	97.1
60	-	-	3184.2	83.9	3321662.0	102.3	4354821.0	98.8
70	-	-	3335.6	87.8	3297855.0	101.6	4316166.0	98.0
80	-	-	2667.3	70.2	3309316.0	101.9	4334413.0	98.4
90	-	-	3142.2	82.8	3319241.0	102.2	4339948.0	98.5
SXT								
50	-	-	3326.9	87.6	3294107.0	101.4	4348294.0	98.7
60	-	-	3943.1	103.8	3299485.0	101.6	4311932.0	97.9
70	-	-	3815.8	100.5	3324611.0	102.4	4350239.0	98.7
80	-	-	3639.8	95.9	3349378.0	103.1	4371294.0	99.2
90	-	-	4058.3	106.9	3354424.0	103.3	4371313.0	99.2
ROTA-TERM								
50	-	-	3456.1	91.0	3473687.0	107.0	4528740.0	102.8
60	-	-	3382.4	89.1	3485616.0	107.3	4518902.0	102.6
70	-	-	3249.3	85.6	3496093.0	107.7	4512993.0	102.4
80	-	-	3632.1	95.7	3505885.0	108.0	4498922.0	102.1
90	-	-	3720.8	98.0	3518390.0	108.4	4542084.0	103.1

Differences in weaning weight.

Mating System Scenario	Terminal		Maternal		Cull Cow Wt., kg
	Average Steer Wt., kg	Average Heifer Wt., kg	Average Steer Wt., kg	Average Heifer Wt., kg	
NATURAL					
Straightbred	220.7	207.7	213.4	202.7	492.2
Straight X Term	257.7	243.9	215.2	203.3	489.6
Rota-Terminal	255.9	242.0	217.2	205.2	511.4
ARTIFICIAL INSEMINATION:NATURAL					
Straightbred:					
50% (2)	232.7	219.3	214.7	204.2	473.4
60%	224.3	224.1	211.8	203.5	475.6
70%	233.9	216.0	209.3	204.1	474.4
80%	234.5	213.9	208.1	204.6	474.6
90%	235.6	212.3	206.5	206.2	478.1
Straightbred X Terminal:					
50%	256.1	242.8	214.2	203.4	476.6
60%	256.6	240.9	212.3	204.4	475.2
70%	258.1	241.2	211.6	205.2	476.2
80%	259.4	238.4	209.9	206.3	477.6
90%	260.3	235.9	205.0	205.9	476.0
Rota-Terminal:					
50%	256.1	242.3	218.5	207.0	510.2
60%	257.3	241.4	216.1	207.0	511.3
70%	260.4	239.8	214.3	207.2	510.3
80%	261.3	238.1	212.3	208.5	509.2
90%	261.2	236.4	211.4	208.9	512.0
ARTIFICIAL INSEMINATION					
Straightbred:					
50% (2)	236.5	222.4	219.3	208.3	477.7
60%	235.9	223.5	218.1	207.4	474.2
70%	237.1	223.8	215.4	206.7	472.8
80%	236.5	222.4	215.7	206.1	473.0
90%	236.3	223.1	215.0	205.8	471.6
Straightbred X Terminal:					
50%	258.3	246.0	220.3	209.8	475.5
60%	259.8	246.3	217.4	207.3	473.4
70%	260.1	247.1	216.6	206.8	472.1
80%	260.0	246.6	215.3	206.3	471.3
90%	260.1	246.5	213.3	205.8	471.4
Rota-Terminal:					
50%	260.7	247.0	224.5	212.5	512.0
60%	261.7	247.2	221.1	210.2	511.3
70%	261.0	247.3	219.4	208.6	507.9
80%	261.5	247.4	218.0	208.7	510.1
90%	260.5	247.4	219.7	207.8	508.7

APPENDIX M

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred Natural Service (Heifers chosen at weaning)
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	4.80	170	445.89	189.50	75,801
Heifer Calves	cwt.	84.98	4.57	105	388.53	101.99	40,795
Cull Cows	cwt.	44.89	10.85	60	487.23	73.08	29,234
Cull Bulls	cwt.	48.34	16.45	4	795.19	7.95	3,181
Total Gross Revenues From Production				339		\$372.53	\$149,011

2. DIRECT CASH OPERATING EXPENSES

Animal Expense	194.95	77,982
Machine & Equipment Expense	16.22	6,486
Labor Expense	5.38	2,150
Land Expense	34.96	13,983
Finance Expense	59.33	23,731
Total Direct Cash Operating Expenses	\$310.83	\$124,332

3. NET CASH RECEIPTS FROM OPERATIONS

\$61.70 \$24,680

4. Non-Cash Operating Expense

\$42.19 16,875

5. Total Operating Expenses

\$353.02 141,207

6. NET RECEIPTS

\$19.51 \$7,805

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf Page 1.

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	480 lbs.
Heifers	457 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	64	70.00	11.20	4,480
Grass Hay	ton	756	65.00	122.85	49,140
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	28	243.00	17.01	6,804
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$161.06	\$64,424

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	14	22.50	0.79	315
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	0.00	0.00	0
Labor	each	400	0.00	0.00	0
A.I. Service	each	400	0.00	0.00	0
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$14.39	\$5,755

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	149,011	0.02	7.45	2,980
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$10.57	\$4,227

Total Animal Expense

\$194.95 \$77,982

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,360	1.75	14.70	5,880
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.96	\$13,983

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	3,500	1.00	8.75	3,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$42.19	\$16,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred AI/Natural 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	106.05	5.12	203	542.94	275.54	110,217
Heifer Calves	cwt.	98.10	4.87	74	458.03	84.74	33,894
Cull Cows	cwt.	53.25	10.54	60	561.41	84.21	33,685
Cull Bulls	cwt.	55.88	16.45	2	919.23	4.60	1,838
Total Gross Revenues From Production				339		\$449.09	\$179,635

2. DIRECT CASH OPERATING EXPENSES

Animal Expense		207.94	83,175
Machine & Equipment Expense		16.22	6,486
Labor Expense		5.38	2,150
Land Expense		34.86	13,944
Finance Expense		59.33	23,731
Total Direct Cash Operating Expenses		\$323.71	\$129,485

3. NET CASH RECEIPTS FROM OPERATIONS

\$125.37 \$50,149

4. Non-Cash Operating Expense

\$37.19 14,875

5. Total Operating Expenses

\$360.90 144,360

6. NET RECEIPTS

\$88.19 \$35,274

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal)

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1.

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	512 lbs.
Heifers	467 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Alfalfa Hay	ton	65	70.00	11.29	4,517
Grass Hay	ton	762	65.00	123.85	49,541
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	23	243.00	13.91	5,563
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$159.05	\$63,620

Livestock Medical and Breeding

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	6	22.50	0.34	135
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	3.60	3.60	1,440
A.I. Service	each	400	5.00	5.00	2,000
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$27.85	\$11,139

Livestock Supplies

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	179,635	0.02	8.98	3,593
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$12.10	\$4,839
Total Animal Expense				\$207.94	\$83,175

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,338	1.75	14.60	5,841
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.86	\$13,944

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	1,500	1.00	3.75	1,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$37.19	\$14,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred AI 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.20	242	482.75	292.06	116,826
Heifer Calves	cwt.	84.98	4.84	33	411.25	33.93	13,571
Cull Cows	cwt.	44.89	10.40	60	466.76	70.01	28,006
Cull Bulls	cwt.	48.34	16.45	0	795.19	0.00	0
Total Gross Revenues From Production				335		\$396.01	\$158,403

2. DIRECT CASH OPERATING EXPENSES

Animal Expense		211.69	84,676
Machine & Equipment Expense		16.22	6,486
Labor Expense		5.38	2,150
Land Expense		34.74	13,895
Finance Expense		59.33	23,731
Total Direct Cash Operating Expenses		\$327.34	\$130,938

3. NET CASH RECEIPTS FROM OPERATIONS

\$68.66 \$27,465

4. Non-Cash Operating Expense

\$33.44 13,375

5. Total Operating Expenses

\$360.78 144,313

6. NET RECEIPTS

\$35.22 \$14,090

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1.

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	520 lbs.
Heifers	484 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	65	70.00	11.45	4,579
Grass Hay	ton	773	65.00	125.57	50,229
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	23	243.00	14.08	5,631
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$161.10	\$64,439

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	0	22.50	0.00	0
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	4.91	4.91	1,964
A.I. Service	each	400	6.81	6.81	2,724
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$30.63	\$12,252

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	158,403	0.02	7.92	3,168
Brand Inspection	hd.	335	1.35	1.13	452
Health Inspection	hd.	335	0.25	0.21	84
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.02	\$4,408

Total Animal Expense**\$211.69 \$84,676**

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,310	1.75	14.48	5,792
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.74	\$13,895

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	0	1.00	0.00	0
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$33.44	\$13,375

APPENDIX N

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred by Terminal Natural Service
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.29	170	491.16	208.74	83,497
Heifer Calves	cwt.	84.98	5.32	105	451.98	118.64	47,458
Cull Cows	cwt.	44.89	10.80	60	484.62	72.69	29,077
Cull Bulls	cwt.	48.34	16.45	4	795.19	7.95	3,181
Total Gross Revenues From Production				339		\$408.03	\$163,213

2. DIRECT CASH OPERATING EXPENSES

Animal Expense	196.53	78,613
Machine & Equipment Expense	16.22	6,486
Labor Expense	5.38	2,150
Land Expense	34.86	13,944
Finance Expense	59.33	23,731
Total Direct Cash Operating Expenses	\$312.31	\$124,924

3. NET CASH RECEIPTS FROM OPERATIONS

\$95.72 \$38,289

4. Non-Cash Operating Expense

\$42.19 16,875

5. Total Operating Expenses

\$354.50 141,799

6. NET RECEIPTS

\$53.53 \$21,414

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (all a decimal)

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1

1:

8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	529 lbs.
Heifers	532 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	64	70.00	11.27	4,509
Grass Hay	ton	761	65.00	123.66	49,463
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	28	243.00	17.00	6,799
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$161.93	\$64,772

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	14	22.50	0.79	315
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	0.00	0.00	0
Labor	each	400	0.00	0.00	0
A.I. Service	each	400	0.00	0.00	0
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$14.39	\$5,755

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	163,213	0.02	8.16	3,264
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.28	\$4,511

Total Animal Expense**\$196.53 \$78,613**

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,338	1.75	14.60	5,841
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld, Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.86	\$13,944

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	3,500	1.00	8.75	3,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$42.19	\$16,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred X Terminal AI/Natural 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	106.05	5.60	203	593.38	301.14	120,457
Heifer Calves	cwt.	98.10	5.14	74	504.15	93.27	37,307
Cull Cows	cwt.	53.25	10.50	60	558.88	83.83	33,533
Cull Bulls	cwt.	55.88	16.45	2	919.23	4.60	1,838
Total Gross Revenues From Production				339		\$482.84	\$193,135

2. DIRECT CASH OPERATING EXPENSES

Animal Expense		212.98	85,191
Machine & Equipment Expense		16.22	6,486
Labor Expense		5.38	2,150
Land Expense		34.94	13,976
Finance Expense		59.33	23,731
Total Direct Cash Operating Expenses		\$328.84	\$131,535

3. NET CASH RECEIPTS FROM OPERATIONS

\$154.00 \$61,600

4. Non-Cash Operating Expense

\$37.19 14,875

5. Total Operating Expenses

\$366.02 146,410

6. NET RECEIPTS

\$116.81 \$46,725

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	560 lbs.
Heifers	514 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	65	70.00	11.45	4,578
Grass Hay	ton	773	65.00	125.54	50,217
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	27	243.00	16.43	6,572
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$163.42	\$65,367

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	6	22.50	0.34	135
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	3.60	3.60	1,440
A.I. Service	each	400	5.00	5.00	2,000
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$27.85	\$11,139

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	193,135	0.02	9.66	3,863
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$12.77	\$5,109

Total Animal Expense**\$212.98 \$85,191**

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,356	1.75	14.68	5,873
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld, Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.94	\$13,976

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	1,500	1.00	3.75	1,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$37.19	\$14,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf: Straightbred X Terminal AI 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.70	242	529.79	320.52	128,208
Heifer Calves	cwt.	84.98	5.24	33	445.72	36.77	14,709
Cull Cows	cwt.	44.89	10.39	60	466.60	69.99	27,996
Cull Bulls	cwt.	48.34	16.45	0	795.19	0.00	0
Total Gross Revenues From Production				335		\$427.28	\$170,913

2. DIRECT CASH OPERATING EXPENSES

Animal Expense		217.87	87,148
Machine & Equipment Expense		16.22	6,486
Labor Expense		5.38	2,150
Land Expense		34.84	13,937
Finance Expense		59.33	23,731
Total Direct Cash Operating Expenses		\$333.63	\$133,452

3. NET CASH RECEIPTS FROM OPERATIONS

\$93.65 \$37,461

4. Non-Cash Operating Expense

\$33.44 13,375

5. Total Operating Expenses

\$367.07 146,827

6. NET RECEIPTS

\$60.21 \$24,086

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	570 lbs.
Heifers	524 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	66	70.00	11.57	4,628
Grass Hay	ton	781	65.00	126.90	50,762
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	30	243.00	18.18	7,272
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$166.66	\$66,662

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	0	22.50	0.00	0
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	4.91	4.91	1,964
A.I. Service	each	400	6.81	6.81	2,724
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$30.63	\$12,252

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	170,913	0.02	8.55	3,418
Brand Inspection	hd.	335	1.35	1.13	452
Health Inspection	hd.	335	0.25	0.21	84
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.65	\$4,658

Total Animal Expense**\$217.87 \$87,148**

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,334	1.75	14.59	5,834
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$34.84	\$13,937

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	0	1.00	0.00	0
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$33.44	\$13,375

APPENDIX O

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf:Rota-Terminal Natural Service
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.28	170	490.76	208.57	83,429
Heifer Calves	cwt.	84.98	5.28	105	448.89	117.83	47,133
Cull Cows	cwt.	44.89	11.28	60	506.22	75.93	30,373
Cull Bulls	cwt.	48.34	16.45	4	795.19	7.95	3,181
Total Gross Revenues From Production				339		\$410.29	\$164,115

2. DIRECT CASH OPERATING EXPENSES

Animal Expense	200.73	80,290
Machine & Equipment Expense	16.22	6,486
Labor Expense	5.38	2,150
Land Expense	35.44	14,178
Finance Expense	59.33	23,731
Total Direct Cash Operating Expenses	\$317.09	\$126,835

3. NET CASH RECEIPTS FROM OPERATIONS

\$93.20 \$37,280

4. Non-Cash Operating Expense

\$42.19 16,875

5. Total Operating Expenses

\$359.28 143,710

6. NET RECEIPTS

\$51.01 \$20,405

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal)

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1

1:

8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	528 lbs.
Heifers	528 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	67	70.00	11.77	4,710
Grass Hay	ton	795	65.00	129.15	51,661
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	25	243.00	15.15	6,060
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$166.08	\$66,431

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	14	22.50	0.79	315
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	0.00	0.00	0
Labor	each	400	0.00	0.00	0
A.I. Service	each	400	0.00	0.00	0
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$14.39	\$5,755

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	164,115	0.02	8.21	3,282
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.32	\$4,529

Total Animal Expense **\$200.73** **\$80,290**

Machinery and Equipment Expense:

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1,500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,471	1.75	15.19	6,075
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvst.)	dol.	4,923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$35.44	\$14,178

Finance Expense:

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Costs		
			Price Per Unit	Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	3,500	1.00	8.75	3,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$42.19	\$16,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf:Rota-Terminal AI/Natural 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.63	203	523.10	265.47	106,190
Heifer Calves	cwt.	84.98	5.15	74	438.03	81.04	32,414
Cull Cows	cwt.	44.89	11.29	60	506.83	76.02	30,410
Cull Bulls	cwt.	48.34	16.45	2	795.19	3.98	1,590
Total Gross Revenues From Production				339		\$426.51	\$170,605

2. DIRECT CASH OPERATING EXPENSES

Animal Expense		218.54	87,416
Machine & Equipment Expense		16.22	6,486
Labor Expense		5.38	2,150
Land Expense		35.55	14,221
Finance Expense		59.33	23,731
Total Direct Cash Operating Expenses		\$335.01	\$134,004

3. NET CASH RECEIPTS FROM OPERATIONS

\$91.50 \$36,601

4. Non-Cash Operating Expense

\$37.19 14,875

5. Total Operating Expenses

\$372.20 148,879

6. NET RECEIPTS

\$54.31 \$21,726

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1.

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	563 lbs.
Heifers	515 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	69	70.00	12.04	4,817
Grass Hay	ton	813	65.00	132.09	52,837
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	26	243.00	15.97	6,388
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$170.11	\$68,042

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	6	22.50	0.34	135
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	3.60	3.60	1,440
A.I. Service	each	400	5.00	5.00	2,000
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$27.85	\$11,139

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	170,605	0.02	8.53	3,412
Brand Inspection	hd.	339	1.35	1.14	458
Health Inspection	hd.	339	0.25	0.21	85
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.65	\$4,658

Total Animal Expense	\$218.54	\$87,416

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 2

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Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,496	1.75	15.30	6,118
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld, Mach., Lvst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$35.55	\$14,221

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	1,500	1.00	3.75	1,500
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$37.19	\$14,875

COLORADO LIVESTOCK ENTERPRISE BUDGET

ENTERPRISE:	Beef Cow-Calf:Rota-Terminal AI 90%
REGION:	Colorado
YEAR:	Average
HERD SIZE:	400 cows

1. GROSS REVENUES FROM PRODUCTION

Sale Item	Unit	Mkt. Price	Mkt. Weight	No. Head	Value Per Head	Value Per Cow	Total Value
Steer Calves	cwt.	92.92	5.72	242	531.05	321.28	128,514
Heifer Calves	cwt.	84.98	5.27	33	447.82	36.95	14,778
Cull Cows	cwt.	44.89	11.22	60	503.56	75.53	30,214
Cull Bulls	cwt.	48.34	16.45	0	795.19	0.00	0
Total Gross Revenues From Production				335		\$433.76	\$173,506

2. DIRECT CASH OPERATING EXPENSES

Animal Expense	223.26	89,303
Machine & Equipment Expense	16.22	6,486
Labor Expense	5.38	2,150
Land Expense	35.41	14,165
Finance Expense	59.33	23,731
Total Direct Cash Operating Expenses	\$339.59	\$135,835

3. NET CASH RECEIPTS FROM OPERATIONS

\$94.18 \$37,671

4. Non-Cash Operating Expense

\$33.44 13,375

5. Total Operating Expenses

\$373.02 149,210

6. NET RECEIPTS

\$60.74 \$24,296

7. BREAK-EVEN PRICES FOR CALVES

Weaning Percent	Weaning Weight	Annual Cow Costs					
		250	300	350	400	450	500
75%	400	\$0.83	\$1.00	\$1.17	\$1.33	\$1.50	\$1.67
	500	0.67	0.80	0.93	1.07	1.20	1.33
	600	0.56	0.67	0.78	0.89	1.00	1.11
80%	400	0.78	0.94	1.09	1.25	1.41	1.56
	500	0.63	0.75	0.88	1.00	1.13	1.25
	600	0.52	0.63	0.73	0.83	0.94	1.04
85%	400	0.74	0.88	1.03	1.18	1.32	1.47
	500	0.59	0.71	0.82	0.94	1.06	1.18
	600	0.49	0.59	0.69	0.78	0.88	0.98
90%	400	0.69	0.83	0.97	1.11	1.25	1.39
	500	0.56	0.67	0.78	0.89	1.00	1.11
	600	0.46	0.56	0.65	0.74	0.83	0.93
95%	400	0.66	0.79	0.92	1.05	1.18	1.32
	500	0.53	0.63	0.74	0.84	0.95	1.05
	600	0.44	0.53	0.61	0.70	0.79	0.88

Calculation: Annual Cow Costs divided by Weaning Weight divided by Weaning Percent (as a decimal).

Colorado Livestock Enterprise Budget-Beef Cow-Calf, Page 1

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8. BUDGET ASSUMPTIONS

Production Assumptions:

Exposed Females	400 cows
Cow Death Loss	3 percent
Replacement Rate	15 percent
Weaned Calf Crop	85 percent
Ave. Weaning Weights:	
Steers	572 lbs.
Heifers	527 lbs.

Management Practices:

Calves Born March through May
Calves Weaned (Sold) October/November
Feeding Period - 4 Months
Grazing Period - 8 Months

Animal Expense:**Livestock Feed**

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Alfalfa Hay	ton	69	70.00	12.14	4,854
Grass Hay	ton	819	65.00	133.11	53,243
Other Roughages	ton	0	0.00	0.00	0
Grain/Concentrates	ton	0	0.00	0.00	0
Protein Supplements	ton	27	243.00	16.67	6,667
Salt/Mineral	ton	80	50.00	10.00	4,000
Other Livestock Feed		0	0.00	0.00	0
Subtotal of Livestock Feed				\$171.91	\$68,765

Livestock Medical and Breeding

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Calf Vaccines	each	400	7.60	7.60	3,040
Breeding Vaccines	each	400	1.90	1.90	760
Other Vaccines				0.00	0
Pregnancy Test	cow	400	2.10	2.10	840
Bull Fertility Test	bull	0	22.50	0.00	0
Other Veterinary				0.00	0
Misc Medicine	each	400	1.25	1.25	500
Medical Supplies	each	400	0.75	0.75	300
Breeding Expense				0.00	0
Semen	each	400	0.00	0.00	0
Synch.	each	400	5.31	5.31	2,124
Labor	each	400	4.91	4.91	1,964
A.I. Service	each	400	6.81	6.81	2,724
Other Medical				0.00	0
Subtotal of Livestock Medical and Breeding				\$30.63	\$12,252

Livestock Supplies

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Feeding Supplies	each	400	3.24	3.24	1,296
Irrigation Supplies				0.00	0
Tack	each	400	1.00	1.00	400
Ear Tags	each	400	3.20	3.20	1,280
Other Supplies	each	400	1.50	1.50	600
Subtotal of Livestock Supplies				\$8.94	\$3,576

Marketing

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Freight and Trucking	mile	320	2.20	1.76	704
Selling Comm/Yardage	pct.	173,506	0.02	8.68	3,470
Brand Inspection	hd.	335	1.35	1.13	452
Health Inspection	hd.	335	0.25	0.21	84
Lodging/Meals Etc.				0.00	0
Hedging Expense				0.00	0
Other Marketing				0.00	0
Subtotal of Marketing				\$11.78	\$4,710

Total Animal Expense**\$223.26 \$89,303**

Machinery and Equipment Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fuel and Lubrication	dol.	3,200	0.98	7.84	3,136
Maint. and Repairs	dol.	2,100	1.00	5.25	2,100
Equipment Leases	dol.	700	1.00	1.75	700
Machine Hire	dol.	550	1.00	1.38	550
Other Mach. & Equip.				0.00	0
Total Machinery and Equipment Expense				\$16.22	\$6,486

Labor Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Wages	sal	0	0.00	0.00	0
FICA	pct.	0	0.08	0.00	0
Contract Labor	dol.	1500	1.00	3.75	1,500
Professional Fees	dol.	650	1.00	1.63	650
Workman's Comp	dol.	0	17.35	0.00	0
Other Labor				0.00	0
Total Labor Expense				\$5.38	\$2,150

Land Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Fert. & Chem.	acre	150	7.00	2.63	1,050
Rents and Leases	aum	3,464	1.75	15.16	6,062
M&R Land and Bldgs.	dol.	2,130	1.00	5.33	2,130
Insur. (Bld. Mach., Lvtst.)	dol.	4923	1	12.31	4,923
Other Land				0.00	0
Total Land Expense				\$35.41	\$14,165

Finance Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Interest-Oper. Note	dol.	4,375	1.00	10.94	4,375
Interest-Non Real Est.	dol.	2,900	1.00	7.25	2,900
Interest-Real Est.	dol.	16,456	1.00	41.14	16,456
Other Finance				0.00	0
Total Finance Expense				\$59.33	\$23,731

Non-Cash Operating Expense:

Description	Unit	Quantity	Price Per Unit	Costs	
				Per Cow	Total Value
Depr. Bldg. & Equip	dol.	13,375	1.00	33.44	13,375
Depr. on Bulls	dol.	0	1.00	0.00	0
Other Depr.	dol.	0	0.00	0.00	0
Other Non-Cash Expenses				0.00	0
Total Non-Cash Operating Expense				\$33.44	\$13,375

APPENDIX P

Scenario: Straightbred; AI/natural service;85% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	170	166	167	171	177	188
Avg. weaning weight (lbs./cow)	202.98	203.83	201.57	212.72	222.39	239.05
No. of heifers	84	84	85	81	75	68
Avg. weaning weight (lbs./cow)	95.89	100.69	103.88	96.98	87.91	79.25
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	217.08	208.78	209.76	209.22	209.30	210.86
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenues	375.50	372.66	373.71	377.97	379.28	388.11
Cash Operating Expenses:	310.88	322.42	323.58	321.74	321.07	322.49
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	22.42	13.06	12.94	19.05	21.02	28.43
Value of Semen (\$/cow)	0.00	(9.36)	(9.48)	(3.37)	(1.40)	6.01

Scenario: Straightbred; AI/natural service; 90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers (N)	180	177	184	193	204	218
Avg. weaning weight (lbs./cow)	216.11	220.22	223.84	242.98	257.60	279.31
No. of heifers (N)	115	116	110	102	91	79
Avg. weaning weight (lbs./cow)	131.46	138.41	135.10	119.80	106.93	92.23
No. of cull cows (N)	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	156.58	157.32	156.91	156.97	158.14
No. of cull bulls (N)	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total gross revenue	393.56	396.51	397.40	402.00	404.67	412.88
Cash operating expense	311.33	322.98	324.14	322.31	321.67	323.07
Non-cash operating expense	42.19	37.19	37.19	37.19	37.19	37.19
Net receipts	40.04	36.34	36.07	42.50	45.81	52.62
Value of inseminate (\$/cow):	0.00	(3.70)	(3.97)	2.46	5.77	12.58

Scenario: Straightbred; AI/natural service;90% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	176	178	183	191	203
Avg. weaning weight (lbs./cow)	215.15	216.66	215.18	229.48	240.49	258.54
No. of heifers	94	94	94	89	82	73
Avg. weaning weight (lbs./cow)	107.34	112.78	114.99	106.51	96.17	86.28
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	217.08	208.78	209.76	209.22	209.30	210.86
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	396.53	394.85	395.80	401.64	403.11	412.18
Cash Operating Expenses:	311.39	322.94	324.10	322.29	321.63	323.05
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	42.96	34.73	34.51	42.16	44.29	51.94
Value of Semen (\$/cow)	0.00	(8.23)	(8.45)	(0.80)	1.33	8.98

Scenario: Straightbred; AI:90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	180	192	211	234	260
Avg. weaning weight (lbs./cow)	216.11	227.84	244.93	272.11	302.98	337.77
No. of heifers	115	115	103	84	61	35
Avg. weaning weight (lbs./cow)	131.46	140.46	126.27	102.99	74.16	42.38
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	162.81	157.99	156.85	156.38	156.43	155.97
No. of cull bulls	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total Gross Revenue	393.56	401.98	405.31	410.56	414.77	419.89
Cash Operating Expenses:	311.33	326.01	327.95	327.62	325.24	327.90
Non-Cash Operating Expenses:	42.19	33.44	33.44	33.44	33.44	33.44
Net Receipts	40.04	42.54	43.92	49.50	56.09	58.55
Value of AI (\$/cow)	0.00	2.50	3.88	9.46	16.05	18.51
Value of AI Inseminate (\$/cow)	0.00	1.56	2.28	5.56	9.44	10.89

APPENDIX Q

Scenario: Straightbred by terminal; AI/natural service;85% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	170	166	167	171	177	188
Avg. weaning weight (lbs./cow)	219.02	213.11	218.65	228.66	241.05	260.00
No. of heifers	84	84	85	81	75	68
Avg. weaning weight (lbs./cow)	110.71	110.26	110.87	107.05	96.79	86.77
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	215.91	210.17	209.57	210.01	210.62	209.91
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	402.47	390.05	395.44	401.69	404.76	413.54
Cash Operating Expenses:	312.20	322.65	325.37	324.68	323.33	327.45
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	48.09	30.21	32.88	39.83	44.25	48.90
Value of Semen (\$/cow)	0.00	(17.88)	(15.21)	(8.26)	(3.84)	0.81

Scenario: Straightbred by terminal; AI/natural service;90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	177	184	193	204	218
Avg. weaning weight (lbs./cow)	238.85	233.96	247.11	263.55	281.22	305.48
No. of heifers	115	116	110	102	91	79
Avg. weaning weight (lbs./cow)	153.06	152.40	144.68	132.91	118.35	101.58
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.63	157.18	157.51	157.97	157.43
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	432.66	421.64	427.10	432.52	436.77	444.82
Cash Operating Expenses:	312.88	323.37	326.10	325.39	324.06	328.16
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	77.59	61.08	63.81	69.94	75.52	79.48
Value of Semen (\$/cow)	0.00	(16.51)	(13.78)	(7.65)	(2.07)	1.89

Scenario: Straightbred by terminal; AI/natural service;90% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	176	178	183	191	203
Avg. weaning weight (lbs./cow)	233.23	227.23	234.21	247.15	261.07	281.52
No. of heifers	94	94	94	89	82	73
Avg. weaning weight (lbs./cow)	124.15	123.64	122.83	117.69	105.99	94.58
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	215.91	210.17	209.57	210.01	210.62	209.91
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	427.10	414.54	420.06	427.92	431.18	440.17
Cash Operating Expenses:	312.77	323.22	325.95	325.28	323.94	328.06
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	72.14	54.13	56.93	65.45	70.05	74.92
Value of Semen (\$/cow)	0.00	(18.01)	(15.21)	(6.69)	(2.09)	2.78

Scenario: Straightbred by terminal; AI;90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	180	192	211	234	260
Avg. weaning weight (lbs./cow)	238.85	241.26	263.75	295.13	330.89	370.75
No. of heifers	115	115	103	84	61	35
Avg. weaning weight (lbs./cow)	153.06	154.58	138.36	112.85	81.36	45.99
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	161.94	157.27	156.58	156.14	155.89	155.92
No. of cull bulls	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total Gross Revenue	432.66	426.13	432.94	440.23	446.59	453.58
Cash Operating Expenses:	312.88	328.27	331.50	332.25	332.01	334.24
Non-Cash Operating Expenses:	42.19	33.44	33.44	33.44	33.44	33.44
Net Receipts	77.59	64.42	68.00	74.54	81.13	85.90
Value of Semen (\$/cow)	0.00	(13.17)	(9.59)	(3.05)	3.54	8.31
Value of AI inseminate (\$/cow)	0.00	(8.78)	(5.64)	(1.79)	2.08	4.89

APPENDIX R

Scenario: Rota-terminal; AI/natural service;85% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	170	166	167	171	177	188
Avg. weaning weight (lbs./cow)	219.34	215.27	220.53	230.97	243.03	261.91
No. of heifers	84	84	85	81	75	68
Avg. weaning weight (lbs./cow)	110.03	110.25	111.22	106.58	96.84	87.09
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	225.54	225.00	225.47	225.03	224.55	213.25
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	406.51	398.70	404.62	410.18	412.89	417.07
Cash Operating Expenses:	317.01	331.42	331.55	331.66	333.08	334.82
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	47.31	30.09	35.89	41.33	42.62	45.07
Value of Semen (\$/cow)	0.00	(17.22)	(11.42)	(5.98)	(4.69)	(2.24)

Scenario: Rota terminal; AI/natural service;90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	177	184	193	204	218
Avg. weaning weight (lbs./cow)	238.57	235.58	248.72	266.10	283.44	307.30
No. of heifers	115	116	110	102	91	79
Avg. weaning weight (lbs./cow)	151.99	152.24	145.06	132.23	118.33	101.87
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	168.75	169.10	168.78	168.41	159.93
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	434.74	428.01	434.28	439.37	443.51	447.89
Cash Operating Expenses:	317.66	332.10	332.23	332.34	333.79	335.52
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	74.89	58.72	64.86	69.85	72.54	75.18
Value of Semen (\$/cow)	0.00	(16.17)	(10.03)	(5.04)	(2.35)	0.29

Scenario: Rota-terminal; AI/natural service;90% weaning rate; 20% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	176	178	183	191	203
Avg. weaning weight (lbs./cow)	233.44	229.39	236.13	249.63	263.19	283.51
No. of heifers	94	94	94	89	82	73
Avg. weaning weight (lbs./cow)	123.37	123.61	123.20	117.16	106.03	94.91
No. of cull cows	80	80	80	80	80	80
Avg. cull weight (lbs./cow)	225.54	225.00	225.47	225.03	224.55	213.25
No. of cull bulls	4	2	2	2	2	2
Avg. cull weight (lbs./cow)	16.45	8.23	8.23	8.23	8.23	8.23
Revenues/Expenses (\$/cow):						
Total Gross Revenue	430.96	423.17	429.30	436.51	439.43	443.79
Cash Operating Expenses:	317.58	331.99	332.12	332.27	333.70	335.43
Non-Cash Operating Expenses:	42.19	37.19	37.19	37.19	37.19	37.19
Net Receipts	71.19	53.99	59.33	67.05	68.55	71.17
Value of Semen (\$/cow)	0.00	(17.20)	(11.86)	(4.14)	(2.64)	(0.02)

Scenario: Rota-terminal; AI;90% weaning rate; 15% replacement rate.

	Sex Ratio					
	Natural 50	AI 50	AI 60	AI 70	AI 80	AI 90
Production:						
No. of steers	180	180	192	211	234	260
Avg. weaning weight (lbs./cow)	238.57	244.33	266.23	296.48	333.02	371.62
No. of heifers	115	115	103	84	61	35
Avg. weaning weight (lbs./cow)	151.99	155.26	138.91	113.04	81.69	46.2
No. of cull cows	60	60	60	60	60	60
Avg. cull weight (lbs./cow)	169.15	169.35	169.1	167.99	168.7	168.27
No. of cull bulls	4	0	0	0	0	0
Avg. cull weight (lbs./cow)	16.45	0	0	0	0	0
Revenues/Expenses (\$/cow):						
Total Gross Revenue	434.74	434.99	441.34	446.96	454.60	460.10
Cash Operating Expenses:	317.66	336.39	336.87	336.80	339.03	340.19
Non-Cash Operating Expenses:	42.19	33.44	33.44	33.44	33.44	33.44
Net Receipts	74.89	65.17	71.03	76.72	82.13	86.47
Value of Semen (\$/cow)	0.00	(9.72)	(3.86)	1.83	7.24	11.58
Value of AI Inseminate (\$/cow)	0.00	(6.08)	(2.27)	1.08	4.26	6.81