ECONOMIC EVALUATION AND BREED COMPOSITION IN THE DEVELOPMENT OF A COMPOSITE LINE OF BEEF CATTLE

By

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DEDICATION

This thesis is dedicated to the Almighty God for His abundant mercies and love in the course of this project.

ABSTRACT

Breeds of cattle (Hereford, Angus, Gelbvieh, Simmental, Charolais and Limousin) were evaluated to establish economic values of production performance and determine the optimum breed proportion in the composite that will maximize net merit. Breed data were sourced from Beef Improvement Ontario and Meat Animal Research Center which conduct studies or collate data on beef cattle performance. Production performance included mature size, survival rates of calves with assisted and unassisted calving, residual feed intake in growing and mature animals, fertility rates of heifers and cows, survival rate of cows and peak milk production. Cost of production as well as average price of marketed animals in Manitoba were used to estimate economic values of production performance. A farm model was developed to describe animal feed intake, growth patterns and sales of the various classes of animals. The profitability of the classes of animals was estimated using a profit function. This model was then used to estimate the economic values of animal traits. The economic values derived from the profit function were used to obtain the optimum net merit and breed proportion in a composite line of beef cattle. Breed performance levels combined with economic values had an influence on the proportion of each breed in the optimum composite. The optimum composition of the composite included Angus, Gelbvieh, Simmental, Charolais and Limousin breeds. In addition to the influence of breed effects, heterosis contributed significantly to the profitability of the optimum composite. The proportion of each breed in the optimum composite varied according to breed data source and production system.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

A andMS	MATURE SIZE
ACalvc	ASSISTED CALVING IN COWS
ACalvh	ASSISTED CALVING IN HEIFERS
aCWW	ADJUSTED CALF WEANING WEIGHT
ADG	AVERAGE DAILY INTAKE
B	GROWTH PARAMETER IN BRODY'S GROWTH CURVE
BIO	BEEF IMPROVEMENT ONTARIO
BLUP	BEST LINEAR UNBIASED PREDICTION
CAA	CANADIAN ANGUS ASSOCIATION
CAGR	CANADIAN ANIMAL GENETIC RESOURCES
CH	CHAROLAIS
DMI	DRY MATTER INTAKE
EPD	EXPECTED PROGENY DIFFERENCE
FCR	FEED CONVERSION RATIO
FRc	FERTILITY RATE OF COWS
FRh	FERTILITY RATE OF HEIFERS
GV	GELBVIEH
HE	HEREFORD
k	INTERMEDIATE RATE CONSTANT IN BRODY'S GROWTH CURVE
LM	LIMOUSIN
LW	LIVEWEIGHT

MAFRI	MANITOBA AGRICULTURE, FOOD AND RURAL INITIATIVES
MARC	MEAT ANIMAL RESEARCH CENTRE
MCPA	MANITOBA CATTLE PRODUCERS ASSOCIATION
MEI	METABOLIZABLE ENERGY INTAKE
MER	METABOLIZABLE ENERGY REQUIRMENT
MS	MATURE SIZE
NCBA	NATIONAL CATTLEMEN'S BEEF ASSOCIATION
NEg	NET ENERGY FOR GROWTH
NElact	NET ENERGY FOR LACTATION
NEm	NET ENERGY FOR MAINTENANCE
NEma	NET ENERGY CONTENT OF DIET
NEpreg	NET ENERGY FOR GESTATION
NRC	NATIONAL RESEARCH COUNCIL
PKYD and PM	PEAK MILK YIELD
PSD	PHENOTYPIC STANDARD DEVIATION
Rcw	REVENUES FROM EACH CLASS OF ANIMAL
RFI	RESIDUAL FEED INTAKE
RR	REPLACEMENT RATE
S1BW	MEAN SURVIVAL RATE OF CALVES FROM BIRTH TO WEANING
S1AC	SURVIVAL RATE OF CALVES WITH ASSISTED CALVING
S1UAC	SURVIVAL RATE OF CALVES WITH UNASSISTED CALVING
SAFRR	SASKATCHEWAN AGRICULTURE, FOOD AND RURAL REVITALIZATION

SBW	SHRUNK BODY WEIGHT
SM	SIMMENTAL
SWG	SHRUNK WEIGHT GAIN
T	WEEK OF PEAK LACTATION
t	DAY
TMY	TOTAL MILK YIELD
USDA-ARS-LRRL	UNITED STATES DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, LIVESTOCK AND RANGE RESEARCH LABORATORY
W	BODY WEIGHT
WW	WEANING WEIGHT
Yn	DAILY MILK YIELD

1. General introduction

A composite breed is a breed formed from a combination of existing breeds and is meant to be more suitable for a given production system or environment than the existing breeds. The development of a composite breed of beef cattle requires crossing of existing cattle breeds which vary in morphological characteristics and production performance to give a new breed with optimum net merit. The net merit will be based on economic worth and depend upon important traits associated with beef production. Composite breeds of beef cattle are an alternative that the industry is beginning to use.

The beef cattle population in Canada has undergone a genetic change as a result of importation of breeds beginning in the early 1960's. Breeds from Continental Europe referred to as exotic breeds, have replaced a proportion of the British breeds, which were prevalent. This shift in breed popularity was driven by the demand from the consumers and need of producers for improvement in production efficiency, product quality and economics. The British breeds were characterized by smaller mature size, earlier rate of maturity and less lean carcass while the exotic breeds were known for heavier mature sizes, late maturing rate and leaner carcasses.

Breed differences among cattle have been evaluated in considerable detail (Amer et al., 1992; Gregory et al., 1993; Marshall, 1994; Schenkel et al., 2004). While some breeds have better performance in carcass traits, others do in dairy characters and growth traits. Information regarding these differences becomes pertinent to producers (especially purebred breeders) in the classification of breeds based on their productive potentials. The information on breed differences is based on studies at the Meat Animal Research

Center (Gregory et al., 1999; Cundiff et al., 2004) in the United States and crossbred performance records from Beef Improvement Ontario in Canada (Sullivan et al., 1999).

Economic worth of important traits is used to derive selection indices in many species of farm livestock. The adoption of multi-trait indexes has been slow in the beef cattle industry. The acceptance of such systems would result in increased genetic response to selection. Various studies have developed methodology for the identification and derivation of economic values of important traits in the beef industry (Brascamp et al., 1985; Koots and Gibson, 1998a; Lewis et al., 1990). Economic values for the traits as reported in these studies varied from study to study suggesting importance of traits depended upon specific environment or production systems. While the importance of survival traits is similar across most production environments, other traits may be unique to specific environment e.g. trypano-tolerant cattle

Important traits possessed by individual breeds can be exploited by crossbreeding. Some breeds excel in milking and mothering ability while others have superior growth rate and carcass quality. Breeds that excel in maternal ability may be used to generate replacements, while breeds with superior growth and carcass quality are better suited as terminal sires.

While crossbreeding has been accepted in the beef cattle industry, the use of composite breeds based on exploiting the desirable morphological characteristics and production performance among breeds has attracted interest in the industry (Hayes et al., 2000) especially when based on reasonable economic objectives and selection for the optimization of breeding objectives. More uniform progenies are produced from crossbreeding because of segregation in the newly developed composite breeds. The Beef

Booster, Hays Converter and Shaver Beef Blend are composites in Canada whereas Beef master, Brangus, Santa Gertrudis, Braford etc., were developed elsewhere.

The review of Shrestha (2005) suggests that the development of most composite populations in the world has not been based on quantitative genetic principles but rather an outcome of crossbreeding activities. To build upon the genetic base of such crosses, there is need to put together the components required in the formation of a composite line of beef cattle incorporating available information on the contributing breeds as well as knowledge of the performance of the expected composite. Lin (1996) has described a procedure of achieving an optimum proportion of each breed in the development of a composite breed.

This study was undertaken to follow the quantitative genetic principles guiding the formation of a beef cattle composite line, incorporating information on important traits of parental breeds, economic values of traits and derivation of the composite line that would maximize net merit. This would include

1. Determination of the profitability of the alternative genotypes best for production systems evaluated.
2. Derivation of the economic values of important traits in the production systems.
3. Derivation of the breed proportions in the composite that would generate the optimum profit.

2. LITERATURE REVIEW

2.1 Breeds

There are many definitions of what constitutes a breed, (Hammack, 2005). The most accepted definition is that given by Lush (1948) i.e. "a breed is a group of domestic animals, termed such by common consent of the breeders" and followed by registration. Many breeds are named according to geographical origin, for example Hereford and Aberdeen Angus. Breeds are often easily identified by physical characteristics such as color. Knowledge of requirements, pedigree, morphological characteristics and production performance of each breed is necessary for breed selection in crossbreeding programs (Fiss and Wilton, 1992). Evaluation of some beef breeds in the United States (Wheeler et al. 2005) concluded that differences exist among the continental breeds and the British breeds. The continental breeds have been reported to surpass the British breeds in leanness, muscling, carcass yields, but have less marbling and similar growth rate.

Phylogenetic studies have supported the grouping of the two classes of breeds on the basis of Microsatellite (MacHugh et al., 1997) and Amplified Fragment Length Polymorphism (AFLP) (Ajmone-Marsan et al., 2002). The studies showed closer clusters among the British breeds and the continental breeds i.e. Bos taurus according to geographic origin following domestication and migration.

2.1.1 The British breeds

The Hereford and the Angus (red and black) are the most popular British breeds in Canada and for many years, so was the Shorthorn and have had a long history of adaptation to the environment before the introduction of the exotic breeds from continental Europe. The traditional British breeds were known for their early maturity, small to medium frame and good foraging ability. The Hereford breed with origin in Herefordshire England was introduced into Canada in 1860 (CAGR, 1997). It is preponderantly red in colour with the head, brisket, throat, belly, feet and switch all white in colour. They can be polled or horned. Lack of pigmentation on the eyelids of some purebred Herefords predisposes them to cancer eye disease (New South Wales Department of Agriculture, 2005). The Aberdeen Angus breed was first imported into Canada in 1876. Most literature does not delineate the type of Angus breed since some of them may be the carriers of the red gene, nevertheless both red and black Angus cattle have same characteristics and are naturally polled (Canadian Angus Association, 2005).

2.1.2 The continental exotic breeds

The continental breeds from Europe introduced into Canada in the early 1960's were driven by the demand for lean meat. Apart from having lean carcasses, they are also characterized by larger frames, heavier weights and some with higher milk production than the traditional British breeds. These European breeds were late maturing with rapid growth. Four popular breeds are the Charolais, Gelbvieh, Limousin and Simmental.

The Gelbvieh is a dual purpose breed (milk and meat) of German origin derived from Celtic German Landrace, Simmental, Shorthorn and Heil-Brown Landrace although many other breeds have been incorporated into it (CAGR, 1997). The North American

Gelbvieh is often selected as a maternal breed due to milking ability. The breed has both horned and polled animals with the coat colour ranging from reddish-yellow to light brown although some black has been introduced into the breed. This Simmental is a Swiss breed introduced into Canada in 1966 from France. Originally developed as a triple purpose breed, they may be white or red in colour with the red ranging from dark red to fawn or tan with their faces, legs and tail white in colour. They can be horned or polled. The Charolais is usually white in color was imported from France. The breed was the first exotic breed to be introduced into Canada in 1966 comprising 30 bull calves and 79 heifer calves. The Canadian Charolais Association reports that the first Charolais crosses were imported into Alberta by a producer in 1953 and the association was formed in 1959 and formally recognized in 1960. The Charolais is known for rapid growth and large body size.

The Limousin originated from France and historically was mainly used for draft. It was introduced into Canada in 1967 and has been developed purely as a beef breed (CAGR, 1997). They are dark yellow-red or light red in areas around their eyes, muzzle and legs. They may be polled or horned.

2.2 Breed traits

Breed comparisons reported by Meat Animal Research Center (MARC) in U.S.A and Beef Improvement Ontario (BIO) in Canada provide information on the current trend and genetic progress. Breed comparisons reported by MARC are carried out among calves born in same period of time. They are progenies of parents of different breeds that have been kept under uniform environmental conditions and receive the same feeding and management. The standardization of the environment offers comparison of the breeds. The female progenies are usually compared for growth, fertility traits, maternal performance and age at puberty, while the steers are compared for growth and carcass traits (Cundiff et al., 1993).

The current genetic trends and status of some traits of breeds assessed in Canada expressed on annual basis represent the average changes that have taken place within the breed. The direction of improvement of the different traits varies from an increase in yearling weights or mature sizes, or decrease in birth weight. The results vary among breeders and are averaged over a variety of herd environments.

2.2.1 Body weights

Mature weight is reached when any further increase in live weight (other than gut fill) only results in increased fatness (Phillips, 2004) or maximum point of muscle deposition (Owens et al., 1993). While some body parts such as skeletal dimension rarely display negative growth, traits such as the body weights are much more affected by environmental factors (Fitzhugh and Taylor, 1971) such as the forage environment (Sandelin et al., 2002) which affect achievement of mature size at a particular age of the cattle.

The estimation of the mature weight of animals especially beef cattle is necessary because of its significance in the growth pattern. An accurate method may be to compute the average of all the weights on an individual animal when it has stopped growing. Another method may be use of the Brody's growth curve which gives the mature weight of an animal as the highest point of the curve that results in insignificant increases in growth (Bullock et al., 1993).

Mature weight is highly heritable (Kaps et al., 1999), with estimates of 0.5 for *Bos taurus* and 0.55 to 0.85 for *Bos indicus* (Phillips, 2004). Genetic correlations between mature weight with yearling weight(0.89), birth weight (0.64) and weaning weight (0.80) (Bullock et al., 1993). Taylor and Fitzhugh (1971) reported low to moderate genetic correlations between time taken to mature and mature weight. This however indicates that it takes a longer time for genetically heavier individual within a breed, to attain their mature body weight. Animals heavier than average at maturity tended to mature slowly. Heavy mature weights have been reported to be undesirable for ruminants intended to be kept for reproduction due to likelihood of increased birth weight and dystocia (Owens et al., 1993). These observations indicate that animals of higher mature sizes may not really have an advantage over the lighter ones given the time and feed considerations, therefore one must balance mature size and growth rate, especially in steers.

Mature weights are shown in Table 2.1 from Meat Animal Research Center (Gregory et al. 1999) where mature sizes are observed directly on 6 yr old cows and the Beef Improvement Ontario (Sullivan et al. 1999) inferred from the yearling weights based on the assumption that yearling weights constitute 58% of the mature weight.

Table 2.1: Various weight measures for the different breeds of cattle

	Beef Improvement Ontario weights (Kg)				Meat Animal Research Center weights (Kg)		
Breeds	Birth weight	Weaning weight	Yearling weight	Mature size	Birth weight	Weaning weight	Mature size
Hereford	39.7	237.7	399.1	688.1	36.1	185.0	533.2
Angus	38.1	249.1	406.1	700.2	34.0	199.5	538.2
Gelbvieh	40.5	244.5	413.4	712.8	43.3	247.3	614.5
Simmental	43.3	280.3	435.1	750.2	42.8	247.3	613.2
Charolais	42.4	271.4	430.6	742.4	44.6	237.3	650.5
Limousin	38.8	244.8	408.3	704.0	39.3	209.5	588.2

The BIO mature sizes were derived from the BIO yearling weights (Sullivan et al. 1999) based on the assumption that the yearling weight is 58% of the mature size. The MARC (Gregory et al. 1999) mature sizes represent the average breed mature sizes from 6 yr old cows. Mature size values shown here are adjusted for genetic trend and used later in Table 3.4.

Weaning weight is another growth measure on calves which depends on the growing ability of the calves as well as the maternal ability of the dam. Weaning usually occurs at the end of the lactation of the cow when calves reach 7 to 8 months of age. Weaning weights are necessary in beef production because it is usually the market endpoint in many cow-calf production systems. In the system utilized in this thesis, calves are marketed at weaning and heavier calves attract greater value.

The birth weights of steers are estimated to be 0.064 of the mature cow weight (Fiss and Wilton, 1993) and of heifers is 0.97 the birth weight of steers. It is considered an important breed characteristic and reference point on subsequent development of individual cattle (Bakir et al., 2004). Various relationships exists between birth weight and other traits such as gestation length, calf sex, dystocia (Bellows et al., 1971b) and prenatal mortality (Johanson and Berger, 2003). Longer gestation length increases the weight of the foetus before calving. This is due to increased deposition of tissues on the calf before birth. Such Dystocia has been associated with calves of high birth weight unlike those with low birth weight. Higher birth weights have been reported for male calves than female calves (Melton et al., 1967). Breed effect is significant for birth weight (Ferrell, 1982; Jenkins and Ferrell, 1994). Some reasons suggested for the differences include differing gestation lengths and differences in the size of dams. High birth weights are discouraged due to the associated death of calves or the increase in cost spent in assisting cows experiencing dystocia.

2.2.2 Milk production characteristics

In general, beef breeds are not good milkers, although some are of dual purposes, for milk and beef. The milk producing abilities of any cattle breed affects their maternal characteristics as well as the rate of growth of the calves. Higher milking cows tend to produce rapid growing and heavier calves at weaning which may influence survival rates of calves to weaning.

Most cattle breeds follow the standard lactation curve (Jenkins and Ferrell, 1993). of the cow which progresses gradually until reaching the peak and starts declining. Milk production can be related to the breed, body size as well as the weight of the calf. Some North American studies have reported higher milk yield at peak lactation for the Gelbvieh and Simmental breeds (Jenkins and Ferrell, 1993; NRC, 1996) and lower values were reported for Charolais, Hereford and Limousin. Koots and Gibson (1998a) adapted an equation from the study of Fox et al. (1988) which describes an association of peak milk yield to the weaning weight and mature size.

The milk production pattern of most beef cattle progresses as the calf grows, peaks at a point before decreasing in the last lactation phase. The milk yield ability of a cow is influenced by the calf and the cow and is considered as an important trait (Miller and Wilton, 1999) in beef cattle production. Beef cattle milk production is considered a major maternal effect on growth of calves till weaning, having a genetic component and a permanent environmental component due to the cow (Meyer et al., 1994).

Estimations of various parameters for lactation incorporates factors such as cow or replacement heifer age, week of peak lactation (n) or days to peak lactation, peak milk yield (PKYD) and duration of lactation. Other requirements are composition of milk fat, solids non-fat and milk protein. Models for estimation of the milk yield have been presented both on daily basis (Koots, 1994) and on weekly basis (NRC, 1996) and which has been used to calculate the metabolizable energy requirement (Ferrell and Jenkins, 1985).

Beal et al. (1990) on Angus or Angus-Holstein crossbred cows used two procedures, these were suckle-weigh (SW) and milking machine (MM) procedures to estimate milk production. Hand milking can also be used in the estimation of milk production, although direct means in estimating milk production are not popular because of unavailability of records and difficulties encountered in measuring actual milk production (Diaz et al., 1992; MacNeil and Mott, 2006).

Other methods have been sought for in the estimation of milk yield of beef cattle. One of which is the use of maternal weaning weight expected progeny difference (EPD). The maternal weaning weight EPD is calculated from the preweaning gain of beef calves and can be used as an aid in selection on milk production (USDA-ARS-LRRL, 2005). Weaning weights of calves have been used as an indicator of the milk production ability (Diaz et al., 1992) or mothering ability of the dam as well as growth of the calves. The maternal weaning weight EPD or combined maternal EPD (Evans and Buchanan, 2004) is half the weaning weight EPD and the milk EPD and are measures of weaning weight. The milk production differences between sires can be predicted directly from the milk EPD of their daughters (Diaz et al., 1992; Marston et al., 1992). MacNeil (2002) reported that a 24kg increase in milk production in a lactation is associated with a 1kg increase in milk EPD. The relationships among milk EPD, total milk yields (TMY) and adjusted calf weaning weight (aCWW) are shown on table 2.2 for the Angus and the Simmental breeds.

Table 2.2: Regression coefficients among milk expected progeny difference (EPD), total milk yield (TMY) and adjusted calf weaning weight (aCWW).

Regression of	Angus	Simmental
Milk EPD on TMY	42.1	69.30
TMY on aCWW	0.14	0.03
Milk EPD on aCWW	4.85	3.74

[a] From Marston et al. (1992)

2.2.3 Fertility rate and embryonic survival rate

Fertility is a major indicator of a cow's reproductive performance. Darwas et al. (1997) defined fertility as the ability of an animal to conceive and maintain pregnancy. The conception rate can be used to evaluate the fertility of cows (Bousquet et al. 2004) due to the high correlation. Some factors such as age have been observed to influence the fertility of cows. The review by Bousquet et al. (2004) reports decreasing fertility in dairy cows with increasing age. Cows have been reported to have about 50% (Tribe, 1999) lower conception rates than heifers possibly due to restriction in performance, nutrition, health and production. Some producers may argue this given that first calf heifers are more difficult to breed than cows. Embryo loss after conception has been identified as a major problem facing the cattle industry (Morris et al., 2001) which may reach as high as 29-39% (Dunne et al., 2000)resulting in reduced reproductive efficiency.

2.2.4 Calving ease

Calving ease is a measure of the ease with which a calf is born, an important reproductive economic trait (Wang et al., 2002). Calving ease has been measured as unassisted (U), easy pull (E), hard pull (H), surgical (S) and malpresentation (M). The estimation of calving ease is difficult to analyze statistically and usually indirectly from birth weight (due to its moderate correlation with calving ease) which is a continuous quantitative observation while the calving ease categories are discrete (Wang et al., 2001). The Snell score is used to improve discrete approach of the traditional classification of calving ease by expressing it as a proportion of unassisted birth. Another was a scoring system with scores from 1 to 4 for "no assistance", "minor assistance", "major assistance" and "caesarian" (Ritchie and Anderson, 1994). Calving ease can be partitioned into two components i.e. the direct component and the maternal component. The maternal calving ease effect is due to characteristics of the dam giving birth e.g pelvic dimensions, while direct effects refer to characteristics of the calf such as the calf size (Dekkers, 1994).

The term, dystocia, refers to difficult birth. The difficulty in calving is more common in heifers. The major factor causing dystocia is birth weight (Paputungan et al., 1998) relative to size of mother. According to Meijering (1984) feto-pelvic incompatibility may be the most important single cause of dystocia. There is a higher occurrence of dystocia in male calves (Bellows et al., 1996; Laster et al., 1973) (in both first and second parturition) with birth weight of 45.5 kg or greater (Rutter et al., 1983) however, weight was not considered a significant factor influencing dystocia for female calves with no significant increase in dystocia occurred among female calves at first parturition until birth weight exceeded 50kg. The correlation between birth weight and calving ease is negative (-0.19) and non linear (Wang et al., 2001).

Other factors influencing dystocia are dam age at calving (Laster et al., 1973), hip width and rump length on pelvic area (Bellows et al., 1971a), season (in winter months, gestation length increased leading to increase in calf size) (McClintock et al., 2005) and crossbreeding. Crossbreeding cattle of different mature sizes may result in increased incidence of dystocia. It has been reported that crossbred calves tolerate higher levels of stress during dystocia than straightbreds (Laster and Gregory, 1973).

Calving difficulty seems to be an important risk factor contributing to the early culling of beef females, and management may seek to reduce its frequency or mitigate its effects (Rogers et al., 2004). Calving difficulty can be reduced or controlled by genetic selection using expected progeny differences (EPD) for birth weight or calving difficulty (Wang et al., 2001). Dystocia can also be reduced by up to 10% in the short term by selecting heifers that have larger pelvic area per kilogram of body weight, making use of the ratios of the heifer pelvic area to estimated average calf birth weight or heifer pelvic area to body weight (Basarab et al., 1993). The long term effect of this selection as reported may lead to increase in cow frame size which may counteract the short term gains.

The occurrence of difficulty in calving can vary in its effects from increased time of parturition to mortality of the calf or dam. Apart from the dangers posed to the animals, it increases the cost of production of the cow-calf sector. There is also the case of delayed returns in cases where rebreeding is deferred due to non conception of the cow or early culling of cows due to such reproductive problems. Furthermore, the requirements of medication and attention of a veterinarian also increase the input costs.

2.2.5 Preweaning survival rate

Jenkins and Ferrell (1994) while studying eleven breeds of cattle indicated some differences in the survival rates of the calves from birth to weaning from 80% for the Simmental to 100% for the Red Poll. Mortality in calves from birth to weaning adds significantly to beef production costs (Cundiff et al., 1986). Higher mortality rate has been reported in calves that experienced dystocia (Azzam et al., 1993; Laster and Gregory, 1973),while survival to weaning of calves increases with age of dam (Sacco et al., 1991). This may be as a result of improved maternal abilities of the dams in their subsequent parities. Survival to first week was also noticed to be affected by size of calf, weather condition (temperature and precipitation), age of dam and calving season (Azzam et al., 1993); showing that calves born in late spring to 2 yr old dams have lower mortality compared to those born early in the calving season

2.2.6 Survival rate of calves from weaning to market age

Steers or bulls and heifers survive in the herd from weaning to market weight. Cartwright (1974) reported 98% from weaning to yearling and 100% from yearling to market or slaughter. This affects the productivity costs of keeping the animals from birth through weaning. Losses of calves after weaning are not frequent, except for mortalities due to diseases or accidents. There has been no known study on breed effects on post weaning survival.

2.2.7 Cow survival rate

Koots (1994) defined cow survival as the probability of a cow to survive the yearly cycle, independent of involuntary culling (due to non pregnancy). Cow longevity (Rogers et al., 2004) and stayability (Snelling et al., 1995) are measures that are related to cow survival. Increased longevity or cow survival has been observed to include reduced annual production costs associated with raising replacement heifers and increase the number of high producing mature cows.

The rate of survival of the cow in the herd would also depend on the culling rate and reasons for culling of cows. These are influenced by reproduction (Bascom and Young, 1998; Rogers et al., 2004), production and mastitis (Bascom and Young, 1998). The proportion of heifers that form the replacements depend on the rate of culling of the older cows (Koots, 1994) which is about 20% in typical cow herds (Anderson et al., 2005). Older surviving cows of the herd will most likely produce more milk due to more developed udders and are likely to have better nursing ability which would indirectly influence the viability of calves.

2.2.8 Bull survival rate

The functionality of bulls in herds is important in the absence of artificial insemination. The retention of herd bulls is influenced by both phenotypic and genetic factors, some of which include good structural soundness, high libido and good scrotal circumference. High culling rate of bulls due to lack of sexual activity arising from physical defects or genetic shortcomings increases the production cost of the system.

2.2.9 Residual feed intake (growing /maturing animals)

Residual feed intake or net feed intake is considered an alternative to feed conversion ratio (FCR) in estimation of biological efficiency (Notter, 2002) and can be defined as the difference between the actual feed intake of animals and the predicted requirement for maintenance of body weight, growth and production. Residual feed intake has been described as the difference between metabolizable energy intake and metabolizable energy required for maintenance and gain (Okine, 2000).

Genetic variation in feed intake exists in both growing and adult cattle (Herd et al., 2003). The differences among animals in converting feed into body tissues are important in determining net income of beef cattle operations (Koch et al., 1963). Improvement of the efficiency of feed utilization should be given considerable attention in breeding programs since feed costs represent approximately one half the total cost of production for most classes of livestock (Kennedy et al., 1993). Despite the importance, little attention is given to reduction of inputs (Arthur et al., 2001) .

Feed intake is predicted from production requirements and body weight measurement. The study by Archer et al. (2002) calculated residual feed intake as actual feed (daily) intake minus predicted feed intake based on average daily gain and mid-weight (average of start and end weights) raised to the power of 0.73. This measurement is expensive compared to other traits used in genetic improvement programs (Herd et al., 2003) because animals are usually kept in individual pens and feed consumed is recorded. This is usually done electronically since rejected feed would also be accounted for. Residual feed intake partitions intake into portions required for stage and level of production and a residual portion that is related to true metabolic efficiency (Crews, 2005).

2.3 Cross breeding

Crossbreeding is a mating of two or more breeds. Differences exist in the objectives of producers which are usually improvements of their herds' production or reproduction. The choice of breeds to achieve the specific objectives is important. In a study on British and continental breeds in North America, Lamb et al. (1992) reported that purebreds of British origin are more biologically efficient while those of continental origin are more economically efficient.

Different reasons have been given for crossbreeding. New combinations may be formed when there is a perceived need for some production type better suited to the prevailing conditions (Hammack, 2005). These conditions are in some cases related to temperature and diseases prevalence in the environment and animals are improved to be more tolerant to the environment. Crossbreeding is a tool that can be used to optimize the level of performance that conform to the environment of the animal given their genetic potentials (Cundiff, 2004). Measures of efficiency such as energy requirements and input costs can be improved by 14% and 20% respectively in crossbreds (Lamb et al., 1992).

Most traits in the beef cattle usually improved by crossbreeding are those that have lower heritability and non additive genetic effects. Beef production efficiency is improved by crossing diverse genetic resources of different breeds (Cundiff et al., 2004a). The use of continental breeds by the Canadian beef industry over the past 20 years has led to increased weaning weights, rates of gain, muscling and leanness (Mandell et al., 1997). Other observations in the crossbreds include higher dressing percentage, fewer digestive disorders and lesser variability of the crossbred steers. Nunez-Dominguez et al. (1991) and Cundiff et al. (1992) have observed heterotic effect in crossbred cow for longevity and in the lifetime production of crossbred calves respectively. Various estimates for heterosis are; 0.8 to 10.0 for reproductive traits (Bourdon, 1999; Hansen et al., 2005; McAllister, 2002), 3.2 to 5.7 for growth traits (McAllister, 2002), 1.7 to 4.6 for viability (ASA, 2005; Buchanan and Northcutt, 2005; McAllister, 2002), 3.0 to 5.0 for mature weight (Bourdon, 1999; Murray, 2002).0 to 0.6 for dressing percentage (ASA, 2005; Buchanan and Northcutt, 2005).

Crossbreeding has some downsides which limit its use in breed improvement. This may lead to difficulties in marketing crossbred stock and bull calves (Weigel and Barlass, 2003). Another limitation is that crossbreeding is associated with dystocia and subsequent mortalities.

2.4 Profit and economic evaluation of breeds

The ability to predict the productive ability of an animal is important in livestock production. Improvement of the animals, especially breeding stock is the wish of producers. They make their choice of selection based on the expected outcome of their herd considering their individual levels of production and/ or the performance of the relatives. These choices differ according to the system of production. Beef cattle production, as ruminants, is a forage-based industry where forage make up to 85% of diet (Greene, 2000). The feeding period is variable for the marketed animals which depend on the objective of the producer and the extent of finish at market. The feeding period for marketed calves to attain their finished weight may take between 15 and 24 months (NCBA, 2006). The knowledge of feeding length and feed quantity is imperative in any production process.

A breeding objective should consider the totality of the production system taking cognizance of traits that contribute to the efficiency of the system. It should form a part of the planning process in a farm system since it sets the direction for attaining the goals but in most cases, less regard is given to it (Koots and Gibson, 1998a). Beef cattle in general have low biological efficiency (Gregory et al., 1990) indicating that efforts should be geared towards optimizing the available resources and reproduction rate.

Breeding methodologies in beef cattle sector differ in emphasis placed on specific traits and approaches to maximize profit. While reproductive efficiency and calf vigor are emphasized in the cow-calf, the feedlot emphasizes growth and feed efficiency. Some of the traits found may be antagonistic limiting the success of the breeding objectives. High birth weight is usually discouraged in the cow-calf system because of its association with dystocia, increased veterinary and labor costs as well as risks to the dam. However in the feedlot, faster growing animals are desired because of their better feed efficiency. Unfortunately the faster growing animals are those that have higher body weight, at birth and at maturity.

2.4.1 Production systems

A system defined is the connection between interrelated set of physical objects which exist within their boundaries. Most studies have resorted to modeling to understand the behavior of the components. Cartwright (1979) evaluated beef cattle production systems based on inputs and outputs that contribute to an outcome. This helped identify the roles played by different sub-sectors towards the system especially in evaluation of breeding value of individuals. Wilton (1979) reported the use of production systems analysis in determining mating systems and selection goals. The components assessed were economic information, mating plan and evaluation techniques.

In terms of economics evaluation, system analysis should be able to identify the contributions made by the various sectors of the production system towards profit. The production factors (inputs) and products (outputs) determine the efficiency of the production system (Groen, 1989a). A good analysis of the beef production system is based on the inputs from different classes of animals which include cows, bulls, replacement heifers, heifers and steers (Koots and Gibson, 1998a; MacNeil et al., 1994).

Different production systems are influenced by different traits economically. These result in different economic values of such important traits under different production systems (Groen, 1990). The breakdown of the entire system into component parts simplifies the calculation involved and also assists in identification of the particular areas that have greatest effects on the costs and returns. For example, Groen (1989b) showed restrictions such as quota applied to products such as milk at the farm level had a negative effect on the economic value of milk (without fat and protein) at the same time increased the relative economic values of beef production traits.

2.4.2 Breeding objectives

Breeding objectives refer to a number of important traits which affect the efficiency of production of breeding animals. It defines and sets the direction for a selection program. It may be used to prioritize the animals under selection that meet the requirements. The primary objective of most livestock producers is to carry out a profitable (Saveli et al., 2003) operation so as to secure adequate income and realize their socio-economic desires (Harris, 1970). Correspondingly, goal of genetic improvement in livestock should be defined in terms of profit, return on investment or cost per unit production, and should be expressed in the primary unit of selection of the animal, which is the individual.

Breeding programs should be based on breeding goals (Groen, 1990). The goals give a definite direction in the various selection programs of the beef industry. Breeding goals or objectives are not only influenced by economic variables but can also embrace ethics of production and biodiversity (Groen et al., 1997). Although there may be common intents among producers along the production chain in beef cattle production, for example heavier animals are desired both in the cow calf (at weaning) and feedlot (at finishing) sectors. An objective of having individuals with higher body weights may be more favorable for the feedlot sector than the cow calf sector due to some difficulty that may arise in calving. These differences are marked by conflicting desires of the producers along the chain which direct the selection of their choice calves.

Another challenge in the case of the beef industry is the limitation created by the different forms of the marketing end product as well as the frequent changes in ownership of the animals. These factors limit the direct interaction between breeders and consumers for satisfaction of their demands. The breeders should be aware of the needs of consumers to satisfy their demands (MacNeil et al., 1994).

A breeding objective for the composite population and parental breeds is necessary for optimization of total productivity (Newman et al., 1998). According to Newman et al. (1993a), the proportions of the different breeds to be contained in the composite should depend on the purpose and adaptability to the environment. There is need for information on traits on economic importance for optimization of the composite. Some of these traits which have been identified as important in composites include calf growth and carcass composition (Newman et al., 1993b), fertility and parasite resistance (Hayes et al., 2000), longevity of breeding stock (Rogers et al., 2004). Some of these traits such disease or parasite resistance may be critical for survival in more difficult environments.

2.4.3 Economic values

The relative economic values help in identifying traits whose unit change has the most impact on the overall animal performance. Amer and Fox (1992) described them as weights which indicate the importance of various traits incorporated in a livestock improvement program. The relative economic value of a trait is the change in cost or returns as a result of unit change in the level of the trait. A profit function is used to determine the economic values of traits. This is based on the economics of the production system including costs and returns of inputs and outputs on the animals as well as the environmental influence.

Economic values serve different purposes in the beef production sector. These values are attached to different traits to indicate their relevance in a production setting and are used for estimations and derivations especially in the breeding industry. These may reflect incentive which producers will receive for improving the genetic traits of their stock (Amer et al., 1994). Economic values indicate the extent the economic efficiency of a production system by improving the traits contributing to it (Groen, 1989a). They are needed in the calculation of the profitability (van Arendonk, 1991) and development of selection index (Saveli et al., 2003) of individual animals.

Cost of production and prices of beef products determine the relative economic importance of cattle production traits due to their influence on the marginal inputs and outputs (Groen, 1989a). Many traits have a linear effect on profit, such that this increase or decrease results in the same change in profitability across a wide range in performance levels (Groen et al., 1997). Other traits such as those relating to quality have an intermediate economic range and would result to a zero economic value if the population mean deviates considerably from the optimum since there is a dependency between the economic value and the population mean (Hovenier et al., 1993). As an example, there is penalty for beef carcasses that exceed the optimum fat thickness.

The description of the production system is critical in deriving the economic values (Koots and Gibson, 1998a). These range from simple deterministic herd level profit models (MacNeil and Newman, 1994) to more complex bio-economic models (Koots and Gibson, 1998; Saveli et al., 2003).

Most common method used for determining economic weights of traits are the use of payment system for the product (for example in milk). This depends on the monetary value of the products or deduction of costs from the payment system (Gibson, 1989). The profit equation is also used to estimate relative economic values but this has been reported to be non linear (Moav and Hill, 1966) even in milk production traits, as a result of non-linear increase in the amount of energy required for marginal milk production. Economic values have also been used to define linear aggregate breeding objectives (Brascamp et al., 1985) by taking the partial derivative of the profit with respect to traits (Brascamp et al., 1985; Groen, 1989a; Koots and Gibson, 1998a; MacNeil et al., 1994; MacNeil and Newman, 1994). The basic profit concept used is the deduction of costs from revenues. The simple profit as described by Brascamp et al. (1985) is given below

$P = N(nwV - nC_1d - C_2)$

where P is profit,

N is the number breeding females,

w is weight of product per offspring,

V is value per unit of product,

n is the number of offspring per year,

C_1 and C_2 are the yearly costs per individual and per female respectively and

d is days to attain market size for each individual.

The costs are partitioned into the fixed costs and variable costs associated with the entire production system. The fixed costs refer to costs that are constant or discontinuously variable with respect to the size of the farm (Groen, 1989a).

The units for measuring the changes in profit has been reported in bases that refer to the different perspectives of production (Amer and Fox, 1992). These units are based on unit product, individual animal or per breeding female (Amer and Fox, 1992; Cartwright, 1979).

2.5 Composites

Harnessing the desired qualities of various breeds into one breed is one technique of genetic improvement especially in situation of changing consumer demands both in the areas of quality and quantity. The reasons for formation of composite lines in the beef cattle industry are similar to reasons for crossbreeding. Creation of a composite population requires diverse breeds (Cundiff et al., 2004b) and offers an alternative to continuous crossbreeding. For example the development of composite for small scale dairy farms has been identified to be easier route to improve the tropical dairy cow than rotational crossbreeding (Syrstad, 1996). Other reasons for creation of a composite population of beef cattle also include the maintenance or improvement of genetic productivity (Mohd-Yusuff et al., 1992; Newman et al., 1993b) and advancing the genetic potential of rare breeds (Shrestha, 2005). Formation of composites reduce the inconveniences associated with maintaining purebred lines for crossing purposes (Hayes et al., 2000) thereby enabling desirable breed combinations to be made producing some heterosis (Cundiff, 2004; Gregory et al., 1991a; Gregory and Cundiff, 1980; Hammack, 2005a). Cundiff (2004) reported that composites yield greater uniformity of progeny or the end product than the use of rotational crossing. There is a direct effect on the pricing and grading of the carcass. There are fewer discounts on carcasses of composites due to the equal proportions of the constituent breeds unlike the in rotational crossbreeding with unequal breed composition.

Composites are products of crossbreeding two or more founding breeds to establish a stable proportion of contribution from the parent breeds. Most composite populations that currently exist in the world were not put together in a systematic way (Shrestha, 2005). In Canada, composite breeds of cattle were developed by systematic crossbreeding (Hays Converter, Shaver Beef Blend and several Beef Boosters). Some of the composites developed in other parts of the world include Beefmaster, Brangus, Santa Gertrudis and Braford.

Composites are more heterozygous than their parental breeds and part of their performance improvement depends on level of retained heterosis. Heterosis has important effects on reproductive rate (Newman et al., 1993a), milk production in the female parent and in the male parent through paternal heterosis which may have effects on fertilization and embryonic survival (Shrestha, 2005).

Breed complementarity has been described as the total improvement in a crossbred offspring's performance as a result of "crossing breeds of different but complementary biological types" (Bourdon, 2000). It has also been described as the advantage a crossbred has due two or more complementing traits from parental breeds (Cartwright, 1970). An example of this is in combining a breed known for growth rate with a breed known for milking ability. This would produce a composite in which rapid early growth would be supported by milk production.

The other component of composites is the expression of heterosis. Composites are developed intentionally to maintain high levels of heterosis in future generations without additional crossbreeding (Hammack, 2005). Heterosis depends on the level of heterozygosity in the composite which in turn depends on the difference in gene frequency between contributing breeds. It is maximized when the founder breeds vary in gene frequency and the favorable gene must exhibit some dominance (Willham, 1970). There will be no heterosis if the difference in the gene frequency between the two parent breeds is zero for genes affecting the trait. The proportion of initial F1 heterozygosity after crossing and subsequent random mating within the crosses for equal contribution by n breeds is proportional to (n-1)/n. A composite formed from an equal contribution of 2 breeds has a heterozygosity level that is (2-1)/2 = 0.5 of the original F1. Table 2.3 showns values for heterozygosity and retained heterosis for a two breed composite up to eight-breed composite. With eight breeds contributing equally to a composite, the heterozygosity is 87.5%. The influence on calf weight per cow exposed is noted also with an increase of 20.4 kg of calf weight per cow exposed for an eight-breed composite relative to the pure bred average. If there is unequal contribution (P_i) of n breeds to the foundation composite, then the mean heterozygosity is proportional to $1-\sum_{i}^{n} p_i^2$ (Dickerson, 1973). In a two breed composite, for example, with ¾ of one breed and ¼ of another, the level of heterozygosity would be $1-\left(\frac{3}{4}\right)^2-\left(\frac{1}{4}\right)^2=0.375$ relative to the F1 (see Table 2.3)

Gregory et al. (1992) observed that retained heterosis was proportional to expected heterozygosity for growth traits, survival traits, puberty traits (in heifers), and scrotal traits (in bulls) for the population thus confirming the theoretical model. However they also observed that retained heterosis for fetal survival was less than the retained heterozygosity of the trait. Gregory et al. (1991b) reported that the retained heterosis observed for calf survival and growth rate in advanced generations of inter se mated composite populations was not less than that expected from retained heterozygosity. The report suggested that heterosis for these traits may be due to recovery from accumulated inbreeding depression in the breeds.

Table 2.3: Estimates of percentage heterozygosity and calf weight increase in crosses.

Mating type	Heterozygosity percent relative to F1	Estimated increase in calf weight weaned per cow exposed
Pure breeds	0	0
2 breed rotation	66.7	15.5
3 breed rotation	85.7	20
4 breed rotation	93.3	21.7
Two Breed Composite		
F 3 -1/2A 1/2B	50	11.6
F 3 -5/8A 3/8B	46.9	10.9
F3 - 3/4A 1/4B	37.5	8.7
Three Breed Composite		
F3 -1/2A 1/4B 1/4C	62.5	14.6
F3 – 3/8A 3/8B 1/4C	65.6	15.3
Four Breed Composite		
F3- 1/4A 1/4B 1/4C 1/4D	75	17.5
F3- 3/8A 3/8B 1/8C 1/8D	68.8	16
F3- 1/2A 1/4B 1/8C 1/8D	65.6	15.3
Five Breed Composite		
F3- 1/4A 1/4B 1/4C 1/8D 1/8E	78.1	18.2
F3- 1/2A 1/8B 1/8C 1/8D 1/8E	68.8	16
Six Breed Composite		
F3- 1/4A 1/4B 1/8C 1/8D 1/8E 1/8F	81.3	18.9
Seven Breed Composite		
F3 3/16A 3/16B 1/8C 1/8D 1/8E	85.2	19.8
Eight Breed Composite		
F3- 1/8A 1/8B 1/8C 1/8D 1/8E 1/8F 1/8G 1/8H	87.5	20.4

From Gregory et al. (1985)

3. MATERIALS AND METHODS

The purpose of this section is to develop a farm model to determine economic values of traits. Important traits in the beef industry are considered in areas of production, reproduction and milk traits. Two systems of production namely the cow-calf production system and the integrated production system were evaluated using some costs and returns of a typical farm in Manitoba. The resulting economic values will be applied in the derivation of the optimum breed proportion in the composite.

3.1 Beef production in Manitoba

A survey of beef producers in Manitoba shows that the number of beef cattle as well as the number of beef cattle producers in Manitoba has been increasing slowly for the last couple of decades (Small and McCaughey 1999).

The beef operations are mainly characterized as commercial with fewer purebreds. Most producers either had combination of both more continental breeds and continental and British, while a smaller proportion had British breeds. The exotic breeds of choice were mainly Charolais and Simmental while that of British were Angus and Hereford (Laborde, 2004; Small and McCaughey, 1999). Commercial production of cattle is composed of cow-calf, backgrounding (feeding strategy to increase the frame size of light calves) and feedlot operations (Miller, 2002). The majority of the producers in Manitoba are cow calf (95%) and the remaining 5% feedlot (MCPA, 2006b; Small and McCaughey, 1999). These animals are raised along with cereals or oilseed production. According to the survey, most regions had less than 50% farm income from beef production. More than half of the respondents had their primary product as weaned calves or feeder calves. Some cow-calf producers incorporated backgrounding of feeder calves into their farm operations. The purpose of this activity is to allow the feeder calves to develop a good frame before they enter the feedlot. A small proportion of producers in Manitoba are able to finish their calves. Feedlot operations, with slaughter and processing is largely done in Alberta (Schmitz et al., 2003).

The majority of the producers market animals through the public auction or use of a combination of various "marketing alternatives" and a lower percentage used exclusively private, contract or satellite sales. An average producer in Manitoba maintains a herd size of less than 50 animals. Across herds, a variety of feedstuffs is offered to the animals. This variety reflects what is available or/and in order to cut down on cost of feeding and also while supporting the maintenance and production needs of the cow. Low nutrient value feeds such as hay and straw are commonly offered to cows while minimum use is made of silage, stockpiled pasture or swath grazing. Winter housing consists of barns used for calving. Twelve percent of respondents supplemented feed during the winter with commercial mixes while 40% supplemented with barley and 36% with no supplementation. Most of the respondents indicated that winter feeding was supplemented with salt and minerals.

The abundance of pasture in the prairies gives the producers in Manitoba a large area of grazing which starts on the average in May (McMillan et al., 2002). Most pasture used by beef producers is composed of native or seeded grasses e.g. timothy grass and legumes. Compared to pasture areas used for beef production, less land was used for silage, swath grazing, green feed or grains. Seasonal supplementation was usually creep feed for calves and hay for cows. Hay was from seeded land which consists of typically grass or alfalfa-grass mixture. The calving season ranged from January to June with most calving taking place in January and February.

3.2 Model development

A bio-economic model was used to determine the economic values of important traits in a cow-calf production system and an integrated production system. Therefore, cow-calf production system typical in the Manitoba environment (Small and McCaughey, 1999) was used for the study. The integrated production system (Koots, 1994; Koots and Gibson, 1998a; Lamb et al., 1992) consists of the cow-calf and feedlot to market animals for slaughter. This type of production facility is not common in Canada but the purpose of using it here was to evaluate the impact of breeding choices on an industry wide basis.

Breed average performance values were taken from studies at two North American organizations on six breeds of cattle because of uniformity of comparison.. These include the Meat Animal Research Centre (MARC) U.S.A. (Gregory et al., 1999) and the Beef Improvement Ontario, Canada (Sullivan et al.. 1999).

3.2.1 Cow- calf production

The beef industry in Manitoba is made up of mainly of cow-calf production (Small and McCaughey, 1999). The production period is annual and feed requirements are calculated on daily basis. The requirements and outputs are calculated based on 50 cow herd size. In this model the endpoint for calves is at weaning (Figure 3.1) except those females that are retained for replacements. The major income is sale of weaned calves. Revenues as shown in Figure 3.2 include culled bulls, which are replaced every 2 years, the culled cows and replacement heifers and the cows that don't survive. It is assumed that about half of the non surviving cows are salvaged.

Figure 3.1: Model of the cow-calf production herd

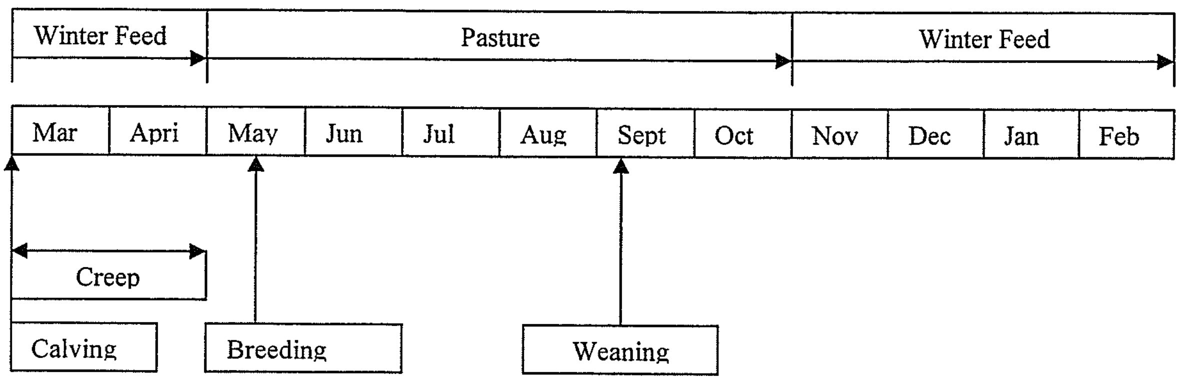
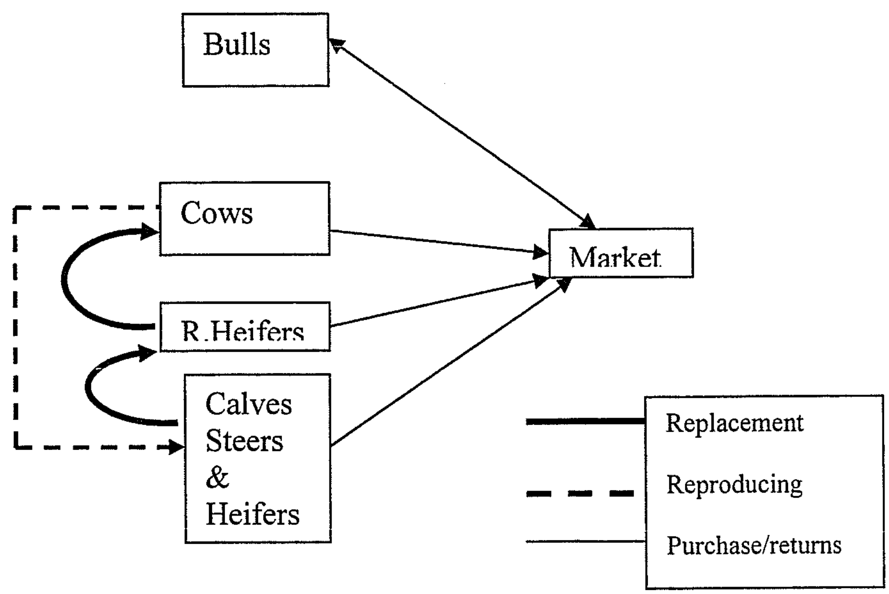


Figure 3.2: Cow-calf production input and output model



Cows in the herd are of different ages (2 to 10 years) averaging 4.6 years. Culling of cows based on reproductive failures depend on their fertility rates (Gregory et al., 1999). Cows 10 years or older were culled. Using the fertility rates of the cows and the heifers, the cow age distribution was determined as defined in Azzam et al. (1990). Table 3.1 contains proportions based on age distribution resulting from fertility rates of cows in the herd culling of infertile cows. The fertility rates used to calculate this table is shown later in Table 3.4. The replacement heifers calve at 2 years and their proportions indicate the replacement rate for each breed.

Angus and Charolais have the lowest replacement rate which is a function of the reproductive ability of the females known to be highly fecund. On the other hand the Hereford breed had the greatest replacement rate of approximately 21% with a fertility of 83%.

A weighted average of the daily weights and gains of the different age classes of the cow herd were used to estimate the nutritional requirements for maintenance, growth, lactation and gestation requirements. The growth pattern of the cows was on daily basis using the Brody growth equation. As expected, cows make little or no gains as they approached their mature weight.

Table 3.1: Cow age proportions for the different breeds.

	Age (years)								
Breed	2	3	4	5	6	7	8	9	10
Hereford	0.21	0.16	0.14	0.12	0.10	0.09	0.08	0.06	0.06
Angus	0.17	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07
Gelbvieh	0.19	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06
Simmental	0.19	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06
Charolais	0.17	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07
Limousin	0.19	0.15	0.13	0.12	0.10	0.09	0.08	0.07	0.06

Bulls are introduced into the herd as yearlings and replaced every two years meaning that half of the bulls in the herd are purchased and sold every year. They are sold at 30 months of age. The cow herd size determines the number of bulls to be used since a bull is usually allocated to 25 cows. Bulls are assumed to be 50% heavier at mature weight than cows (Taylor and Murray, 1987).

The cost of bull ($2166.67) is the average cost of replacing a bull in a herd. The input costs were average costs incurred by bulls from the Manitoba Agriculture Food and Rural Initiative (MAFRI) cow calf production costs from 2000 to 2005 (Blawat, 2006). The other costs of herd management for bulls are shown in Table 3.2.

The weights of bulls are assumed to be linear between months 12 and 24, then 24 and 30 months. The weights at these periods were estimated with the Brody's growth equation (Brody, 1945).

The calves under both systems are assumed to be born from February through April with March as the average calving date. Shorter calving periods are usually desired by producers to reduce the expenses and time associated with calving. In the cow-calf system, all the calves are sold at weaning except replacement heifers since it is a self replacing herd. All calves are sold at the prices indicated in table 3.2. They attract higher prices per unit weight than finished cattle.

Replacement heifers are assumed to be generated from within the herd. The replacement heifers form the proportion of the cow herd that is 2 years old and depends on the culling rate in the cow herd (Azzam et al., 1990). The replacement rates of heifers range from 18% in the Hereford to 25% in the Gelbvieh as shown in Table 3.1.

Table 3.2: Costs of production for various classes of cattle

Classes	Vet/supplies[d] ($/Head	Miscellaneous ($/Head)	Straw [d] ($/Head)	Total husbandry Costs[d] ($/head)	Marketing costs ($/kg)	Liveweight prices (finished calves) ($/kg)	Liveweight prices (weaned calves) [d] ($/kg)
Steers	17.32	10	19.5	46.82	0.025[a]	1.973[c]	2.74
Heifers	17.32	10	19.5	46.82	0.025[a]	1.965[c]	2.74
Cows	13.88	10	19.5	43.38	0.030[b]	0.89[d]	-
Replacement Heifers*	18.00	10	20	48.00	0.025[a]	1.965[c]	-
Bulls	66	10	-	76	0.030[b]	1.10[d]	-

6-year averages (2000-2005)

*Culled heifers for replacement stay extra time on herd and thereby incur more cost.

[a] Based on average cost of $15.67 for 625kg feedlot animal.

[b] Based on average cost of $18.25 for a 614kg cow

[c] From Agriculture and Agri-Food Canada (2006)

[d] From Blawat (2006)

3.2.2 Integrated beef production

An integrated beef production unit consists of production processes from calving to slaughter. This system is same as the cow-calf production system with the addition of the feedlot sector. The model for an integrated beef enterprise is shown in Figure 3.3. Calving is assumed to occur in March with weaning in September. Calves then enter a stocker/grower periods, followed by finishing or feedlot. The use of these two phases of post weaning management reflects what exists in the industry.

Revenues come mainly from the sale of finished steers and heifers (Figure 3.4). Cull animals, cows, bulls and heifers also contribute to the income. Half of the cows that do not survive are salvaged. Production and management costs come from all classes of animals although maintenance of cows accounts for most of the costs.

Steers and heifers in the integrated production system are separated from their dams after weaning at 205 days of age. The final weight at 296 days is derived by the Brody growth equation. The average daily gain at this period is taken from the difference between the weights at weaning and 296 days as a ratio 'n' of the difference in days (91 days). The animals are expected to attain 78% of their mature size at finishing. The finishing average daily gain derived from the growth curve reflected typical gains in the feedlot (MAFRI, 2006b).

Figure 3.3: Model of the integrated beef production herd:

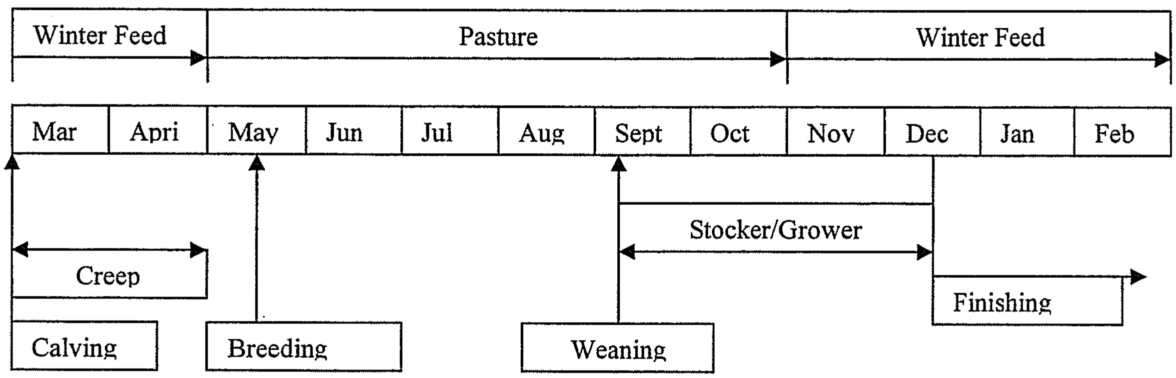
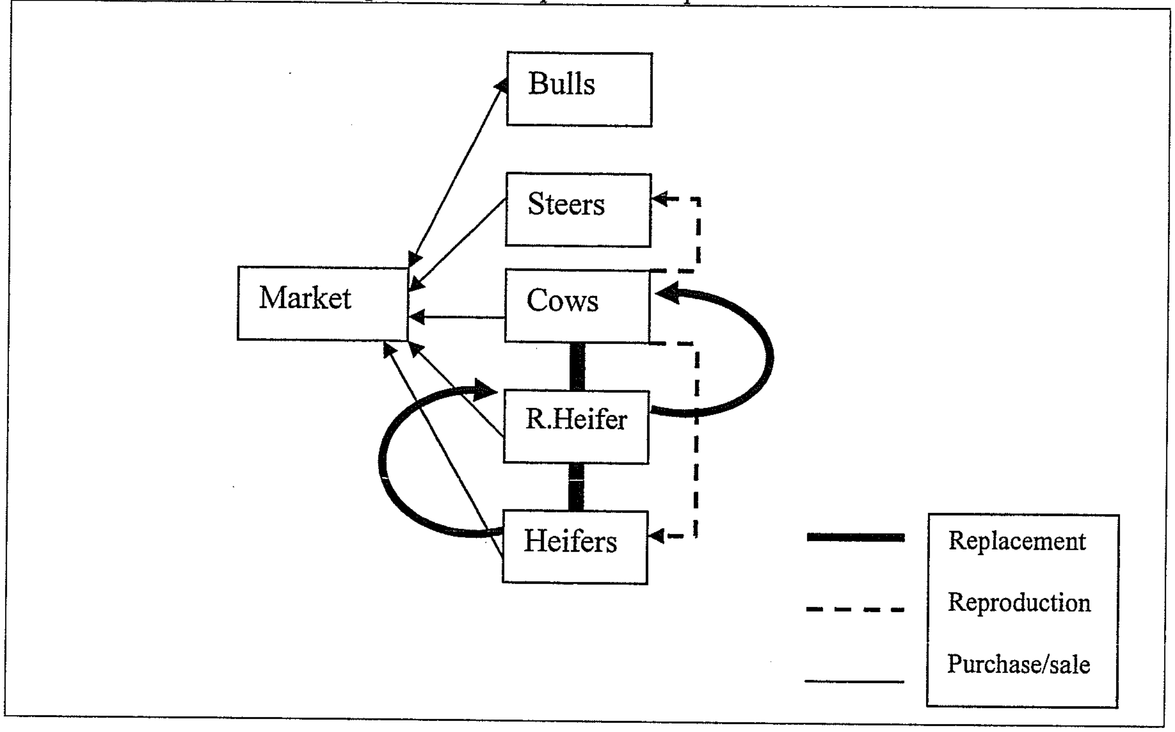


Figure 3.4: Integrated beef production input and output model



3.3 Feeding regimes

Animals are fed to meet energy requirements for maintenance, growth, gestation and lactation (Ferrell and Jenkins, 1985). Although some physiological functions refer to all classes of animals such as the maintenance and growth, others are class specific. For example, gestation and lactation requirements are specific to cows and replacement heifers, while certain phases of growth are for marketed offsprings.

3.3.1 Feeding young animals to market weight

In the preweaning phase immediately after calving, calves have total dependence on the milk of cows for energy source and survival. The milk consumption increases with the milk production of the cows as well until a certain point when it is insufficient to meet the needs of the calves due to growth. The milk production of the cow to an extent is driven by the requirements of the calf until peak lactation is attained. Creep feeding is then incorporated as a supplement to the milk produced by the cow and to encourage the consumption of solid food. It gradually replaces the milk of the cattle just before the calf is weaned and serves as a means of increasing weaning weights (Drouillard and Kuhl, 1999; Vicini et al., 1982b). Beef cows produce less milk than dairy cows and may not provide the sufficient requirements of the calves for maintenance and growth. Various feedstuffs have been used as creep ranging from milk replacers (Johnsson and Obst, 1984) to pasture. Fescue creep fed calves have been reported to have DM intake (kg/d) and ME intake (Mcal/d) of 2.4 and 5.3 respectively; DM intake and ME intake of 1.6 to 3.4 and 3.6 to 7.3 respectively have been reported (Vicini et al., 1982a). The authors concluded that inclusion of higher quality forages as creep pasture for calves such as blue-grass white clover resulted in greater DM consumption. The review of Drouillard and Kuhl (1999) indicates that creep feeding had no effect on milk consumption but reduced the intake of forage. Importance of creep feeding in the supplementation of milk is to achieve the calf's genetic potential unless restricted.

In the model the calves are creep fed for the first 61 days with rolled oats (Table 3.3). Intakes for growth and maintenance are first satisfied by the dam's milk, additional requirements by the calves are then met with the creep feed (oats). The following 144 days before weaning are spent on pasture from May to early September. During this preweaning period, producers maximize the use of pastures in feeding the calves. The pre-weaning average daily gain was assumed to be linear from birth to weaning and was derived as the average of the difference between the birth weight and the weaning weight during this period.

Grower phase of the calves refers to the various activities that occur between weaning and the finishing phase. The backgrounding phase entails the feeding, growing and managing of newly weaned calves to feeder yearling weights (MAFRI, 2006a). The calves are placed on low energy feeds usually roughages for varying periods. Backgrounding enables more muscle to be deposited and frame developed before the deposition of fat (Block et al., 2001a; Block et al., 2001b; SAFRR, 2003).

In the model, after weaning, the steers and the heifers are backgrounded for a period of 91 days. They are initially continued on pasture which consists mainly of mixed grasses/pasture. They are later transferred to a grower diet of 80% Timothy hay and 20% barley grain for a period of 53 days when pasture quality reduces.

Table 3.3: Feeding components, energy values and costs.

Period	Components	Net energy of diet for maintenance NEm[b] (Mcal/kg)	Net energy of diet for growth NEg[b] (Mcal/kg)	Metabolizable energy of diet ME[b] (Mcal/kg)	Cost of feed per ME[a] $/ME
Creep	Oats	1.850	1.220	2.780	0.0495
Grower	80%Timothy hay 20% barley grain	1.436	0.848	2.314	0.0239
Feedlot	80%barley grain, 20%Timothy hay	1.904	1.262	2.858	0.0384
Pasture	Grass pasture	1.540	0.940	2.420	0.0048*
Winter	20% Alfalfa-60% grass(Timothy) hay 20% Barley grain	1.456	0.866	2.334	0.0275

[a]From Blawat (2006)
[b] from NRC (1996)
*Derived from 6-yr averages.

Finishing phase of the beef calves involves feeding of high energy feed materials to achieve rapid gains and fatten to the desired market weight. The ration of feedlot animals usually contains 85 to 95% grain (Andrae et al., 2000; MAFRI, 2006b). The steers and the heifers on feedlot are on a finishing diet of 80% barley grain and 20% Timothy hay (Table 3.3) at 296 days until they reach the target slaughter weight. A study on grain type and processing for feedlot animals indicates that it varies among cattle, farm type and costs associated with processing (Owens et al., 1997).

3.3.2 Breeding heifers

A proportion of the heifers raised that are not finished for market are retained as replacements and selected on their pedigree or individual performance. They are fed to be in good body condition for reproductive purposes but do not make high gains.

Heifers are bred to conceive between 14 and 16 months (Ferrell, 1982; Schillo et al., 1992) to calve at 2 years (Ferrell, 1982; Morrison et al., 1992). Emphasis is usually placed on the time of breeding of the replacement heifer which is dependent on puberty (Dow(Jr) et al., 1982; Schillo et al., 1992). The lifetime productivity of the replacement heifers is maximized when bred to calve at two years (Patterson et al., 1992)

3.3.3 Cow herd and breeding bulls

There is a period of pasture feeding and a period of winter feeding. Bulls are bred to cows in May after spending two months in the herd. Both classes are kept for 183 days on mixed pasture from May to October. The winter feeding lasts about 182 days from

November to April as shown in Figures 3.1 and 3.2. The daily energy and growth requirements were calculated using the NRC (1984) requirements of beef cattle nutrition.

Winter feeding refers to use of stored forages for feeding the animals. This activity is necessary in Canada due to long period of winter from November to April. It is usually expensive (Drouillard and Kuhl, 1999) when compared to pasture feeding. This is due to costs associated with labour, harvesting and storage. Winter feed materials have reduced quality depending on time of harvest or length of storage. These are usually hay made from grasses or legumes which contain less energy and high fiber. The winter feed is assumed to comprise alfalfa grass, timothy hay and barley grain. Energy requirements during winter are influenced by breed, size, environment, and body condition. The body condition of cows is the most unstable (Thompson et al., 1983) indicating that a cow in an optimum body condition would have less requirements than one in a bad body condition especially during the winter.

Pasture (grasses and legumes) used for grazing animals forms an inexpensive source of feedstuff for beef cattle. The land for seeded pastures may not be suitable for growing food crops, although sometimes residues from harvested crops are used for grazing cattle. The pasture on which cattle is grazed may vary in quality depending on the stage of growth and availability. The quality of pasture is greatest when young and lush and diminishes while approaching maturity. The age of the pasture also affects its dry matter content.

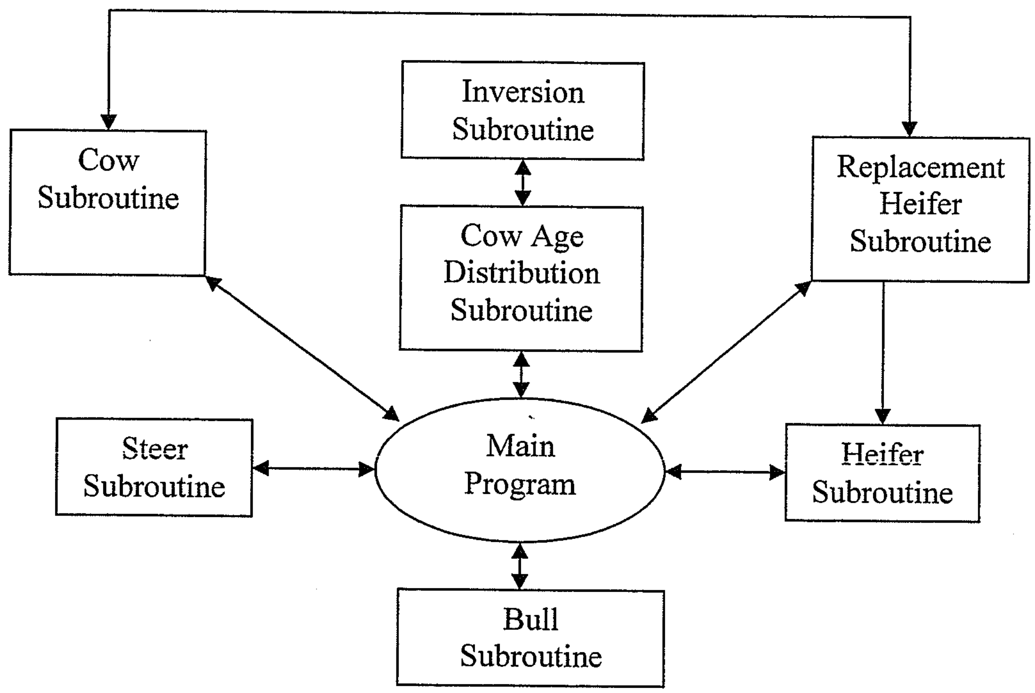
Animals are pastured in Canada from May to October when the weather is appropriate for growing plants. This coincides with the calving period up to weaning with lactating cows and the growing calves. At this period, the cows and bulls are maintained on pasture with some supplements. The calves may also be supplemented while on pasture as they approach weaning. The use of pasture feeding cannot be overemphasized in terms of economics. Cost of production is lower with inclusion of pasturing in beef production (Lewis et al., 1990).

Finishing steers or heifers on pasture has been known to be associated with deposition of yellow fat which is usually downgraded. There is also less marbling on pasture finished beef. Jannasch et al. (1998) reported that beef cattle on pasture and feedlot had similar grades of carcass. Although on energy basis, forage is the most expensive energy source (Bartle and Preston, 1991) it is almost impossible to exclude it in rations. Efficiency of pasture utilization in a cow-calf production depends on many interacting factors such as forage quality, forage availability, physiological needs and other nutrient sources (Vicini et al., 1982a).

3.4 Describing animal feed requirements

Feed requirements for each class of stock in the model were based on the equations in NRC (1984) requirements considering the level of performance of each breed. Feed requirements for the different classes of stock are estimated within each of the subroutines shown in Figure 3.5.

Figure 3.5: Schema of the FORTRAN program



Maintenance requirement is energy required to maintain its physiological functions without gaining or losing weight (Evans et al., 2002; Ferrell and Jenkins, 1985). About 70-75% of total annual energy requirements of cows are for maintenance (Ferrell and Jenkins, 1985) and 50% of total beef production energy (Montano-Bermudez et al., 1990). Variation in energy expenditure that exists between animals is attributed to maintenance compared to growth and reproduction (Ferrell and Jenkins, 1985).

The net energy system is used to describe the total energy an animal uses for maintenance and production. The net energy for maintenance (NEm) requirement is primarily due to heat production (Lofgreen and Garrett, 1968). Adjustments for breed, physiological state and activity (if on pasture) can be incorporated in the estimation of maintenance requirements (NRC, 1996).

The estimation of net energy requirements for maintenance (NEm) depends on the body weight (W) of animals and calculated as

$NEm= (0.077xW^{0.75})$

Increments of 10% and 15% of maintenance requirements have been made when all animals were on pasture and during lactation (for cows and replacement heifers) respectively (Koots and Gibson, 1998a).

Growth requirement estimation of the net energy for gain (NEg) incorporates the body weight (W) of the animal and average daily gain values (ADG). The constants refer to differences in the growth requirements for growing animals and mature animals (NRC, 1984) are shown below

$NEg= 0.0493xW^{0.75}xADG^{1.097}$ for bulls

$NEg= 0.0686xW^{0.75}xADG^{1.119}$ for heifers

$NEg = 0.0557xW^{0.75}xADG^{1.097}$ for steers

$NEg = 0.0635xW^{0.75}xADG^{1.097}$ for cows

Gestation is the period from conception to calving. There is progressive foetal growth for an average of 282 days. There is a lower energy requirement for foetal nourishment from the cow in the initial stages of pregnancy but this increases during the last trimester of pregnancy.

The nutrient requirements for pregnancy (NEpreg) (Mcal NEm/day) in replacement heifers and cows were calculated using the estimated birth weight (BW) of calf and current day of gestation (P) (Koots and Gibson, 1998a; NRC, 1996)

$NEpreg = (0.576xBWx(0.4504-0.000766xP)xe^{(0.03233-0.0000275xP)P})/1000$

The energy requirement to maintain lactation (NElact) in cows was estimated from the equation of Ferrell and Jenkins (1985) using milk energy value (E), day of lactation (t) and rate constants (a , p)

$NElact = p(t/(ae^{(pt)}))E$

Where

a is (days to peak lactation)/(e PM) PM is peak milk yield.

p is 1/(days to peak lactation).

e is the base of natural logarithm

Feed consumption of all classes of cattle in the herd is a primary factor affecting biological production efficiency of the herd. This influences reproduction and production of diverse germplasm resources (Jenkins and Ferrell, 1994). The dry matter intake (DMI) of an animal describes the consumption capacity of the animal in order to satiate its energy requirements given the nutrient content of the feed.

Factors that regulate dry matter intake by ruminants are complex and not fully understood but the factors that affect DMI are classified into physiological, environmental, management and dietary factors (NRC, 1996). The level of intake is usually based on weight of the animal, level of production and energy content of the feedstuffs. Animals of larger sizes have greater intake than smaller ones to meet their body size demands at any feed nutrient content. There is also higher dry matter intake in animals with greater production levels. For example pregnant or lactating cows demand extra for body maintenance to support the growing foetus or milk production. Lower quantities of high energy feeds such as concentrates are provided instead of feedstuff of less nutrient value. High energy feeds (grains) would require less intake than low energy feeds such as hay. The dry matter intakes of the various classes of animals in this model were estimated from the net energy requirement of the animals and the net energy value of the feedstuff offered.

3.5 Animal performance and input traits

All mammals share a similar sigmoid pattern of growth (Taylor, 1985). The body weight of most animals increases at an increasing rate in early life. This rate slows down so that at maturity, the rate approaches zero. Knowing this pattern of growth, the size of the animal at any time can be estimated.

An animal's body weight (W) at any particular day (t) is estimated from the Brody's growth function (Brody, 1945) which makes use of the mature size (A), maturing rate parameter (k) and growth scale parameter (B). Animals grow differently as a result of the differing mature sizes, so the B values were calculated differently for each breed at a constant k value.

The equation is given below as

$W(t) = A(1\text{-}Be^{-kt})$

The growth scale parameter (Koots 1994) indicates a ratio of the remaining size (the mature size minus the birth weight) as a fraction of the mature size.

B= (Mature size- Birth weight)/ Mature size.

The birth weights of calves are derived from mature size of the breed. The birth weight of males is set at 0.0667 of the mature size while that of heifers is 0.064699 of the mature size being 3% lower than that of the males as incorporated by Koots and Gibson (1998a). The mean birth weights for the different breeds were taken from the average of the birth weights of steers and heifers.

The growth patterns for the different classes of animals were assumed to be linear within certain ages/ periods. Average daily gains were calculated from the differences between the initial weight and the final weights of the particular periods. These initial and final weights were based on the growth curve assumed for the breed. For example the pre-weaning and backgrounding average daily gains were calculated as

Pre-weaning ADG= (Weaning weight- Birth weight)/pre-weaning period

Backgrounding ADG= (Backgrounding endweight–Weaning weight)/ backgrounding period.

The weights from the end of backgrounding to attainment of the finishing weight were calculated from the Brody's growth curve. The average daily gain during this period was calculated from the cumulated gain during this period. The average daily gain for the bulls is assumed to be linear between 12 and 24 months; then 24 to 30 months. The daily gains were computed as average of the differences between the weights at these periods. The average daily gains for the cows and the replacement heifers were assumed to be linear within different age classes whereby the annual average of the differences in weights for the different age classes constituted their average daily gains.

Prediction of weaning weight for a breed may come from the mature size as well as the milk production. Koots and Gibson (1998a) reported a model for predicting the weaning weight of steers from the mature size and peak milk yield of dam. Higher milking dams would produce heavier calves due to more available milk.

Weaning weight for steers is equal to

87.7 + 0.202 x Mature size + 6.04 x Peakmilk yield (Fox et al., 1988)

The weaning weight of heifers is assumed to be 94% that of the steers. The weights of calves at the end of the backgrounding/growing period (296 days of age) are derived from the Brody's growth curve. The weights of the heifers are also assumed to be 6 % less than that of the steers. The weights of the calves at finishing were proportions of the mature size, according to Koots (1994) 78% for steers and 66.3% for the heifers.

The mature cow sizes of the different breeds of cattle evaluated are shown in Table 3.4. They have been adjusted to reflect current values by considering the genetic changes in each breed. The mature size of bulls is assumed to be 50% greater than the mature sizes of cows (Koots and Gibson, 1998a).

The justification for using data from MARC for the present study is that for each breed, for animal genetic evaluation purposes, the North American population is considered as one population. The MARC experiment was a result of sampling from the respective breeds of these populations.

Table 3.4: Peak milk and mature sizes for the different breeds

The peak milk yields for both MARC and BIO were derived from the milk EPD tables from Van Vleck (2006) and Sullivan et al. (1999) respectively.

	Beef Improvement Ontario (BIO)		Meat Animal Research Center (MARC)	
Breed	Peak milk (Kg)	Mature size (Kg)	Peak milk (Kg)	Mature size (Kg)
Hereford	9.15	756.9	7.16	693.2
Angus	11.03	770.2	8.89	699.7
Gelbvieh	11.03	784.1	11.07	798.9
Simmental	11.41	825.2	12.31	797.2
Charolais	9.9	816.6	10.5	845.7
Limousin	10.85	774.4	7.46	764.7

The present mature sizes for MARC data are assumed to have increased by 30% since 1985 while BIO data is assumed to have increased by 10% since 1999 and were derived from the values shown in Table 2.1.

With an assumed average of 70 days to attain peak lactation in beef cows, the yields at peak lactation were derived for each of the breeds. The lactation model of Koots and Gibson (1998a) was used as a base for the deviation for the individual breed milk yields. The yield at peak lactation was derived from the total milk yield using the maternal EPD reports from BIO and MARC. Maternal EPD values are reported for these breeds and represent the kg of weaning weight due to milk production of their dam. These are breed deviations. These values can be converted into differences in milk production in a lactation using results from Marston et al. (1992). They give an average of 55.7 kg milk per kg maternal EPD across a range of breeds. This was used to determine total milk yield deviation and yield at peak lactation for the different breeds.

The milk lactation curves shown in Figures 3.6 and 3.7 were derived using the standard lactation curve. The peak time of lactation (70 days) incorporated in this study was greater than that assumed by Koots and Gibson (1998a). Peak lactations for various breeds vary from 62 to 78 days (Jenkins and Ferrell, 1992) or more (Marston et al., 1992).

Figure 3.6: Lactation curves for different breeds based on Sullivan et al. (1999) values.

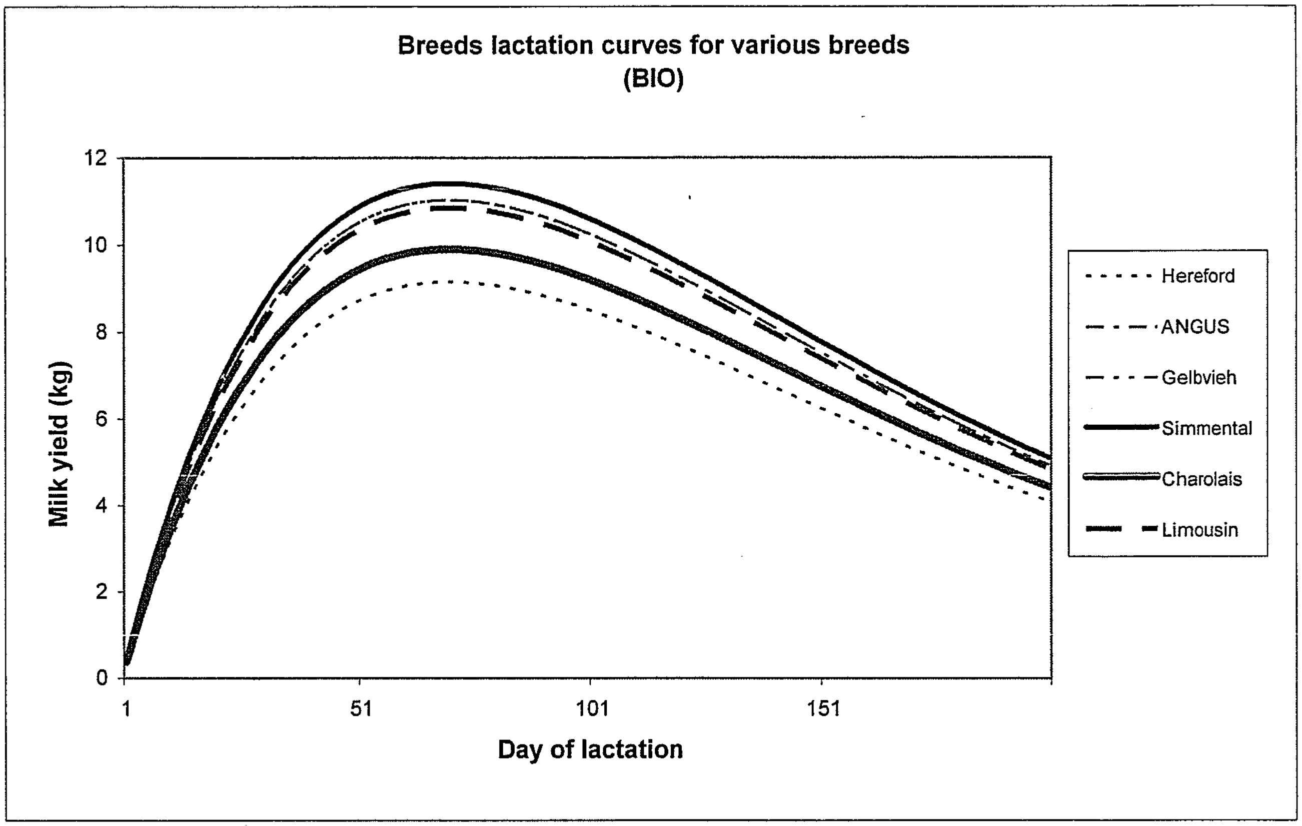


Figure 3.7: Lactation curves for different breeds based on Cundiff et al. (2004)

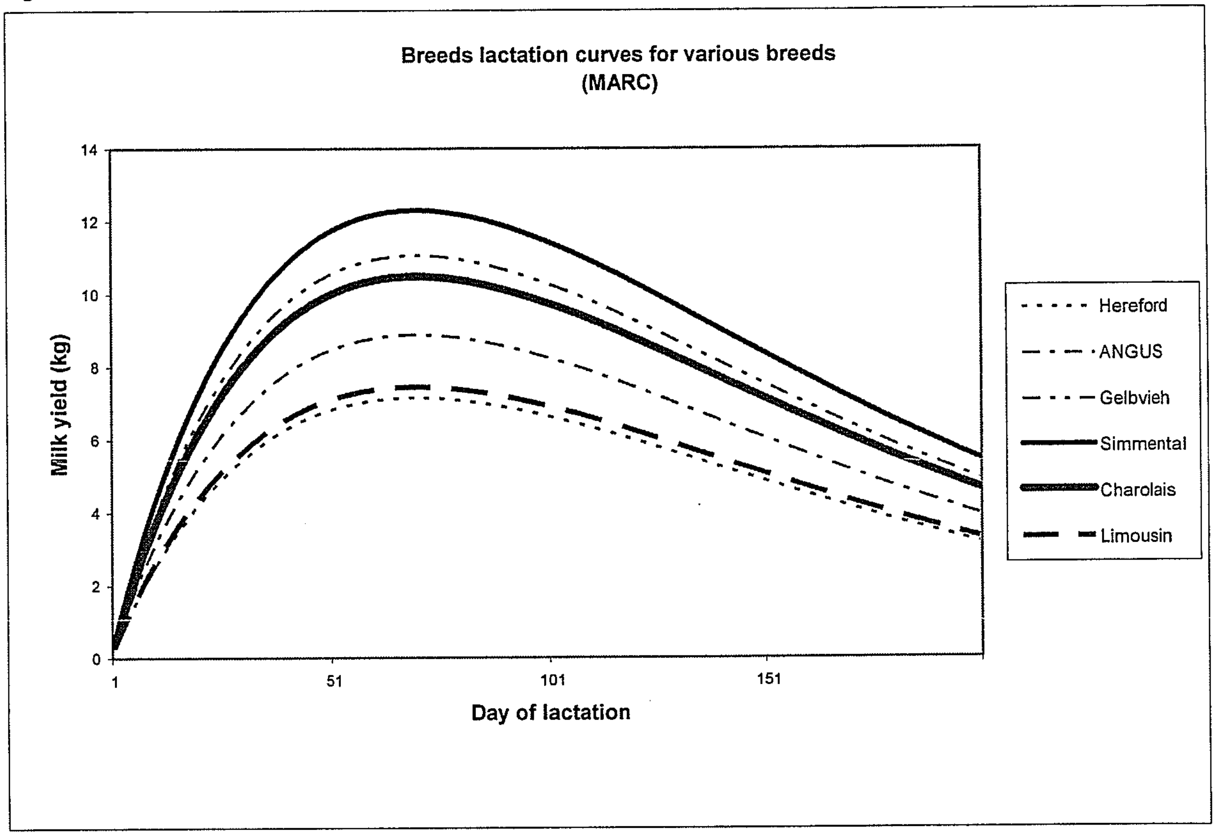


Table 3.5: Survival and fertility parameters

Breed	Survival rate from unassisted calving[n] (S1UAC) (%)	Survival rate of calves from birth to weaning (S1BW) (%)	Fertility rate of cows FRc[m] (%)	Fertility rate of heifers (FRh) (%)	Cow retention rate (%) (S3CS)
Hereford	92	91	86.0	77.4	93
Angus	96	95	91.3	82.2	91
Gelbvieh	95	94	88.5	79.7	92
Simmental	94	93	87.8	79.0	92
Charolais	90	89	90.8	81.7	91
Limousin	95	93	87.8	79.0	92

[m] from Gregory et al. (1999)

Fertility rate of heifers is assumed to be 10% less than that of cows. Cow survival rate is derived from the proportion of cows above 2 years in the herd.

[n]S1UAC is derived from Cundiff et al. (2004), from the same population as Gregory et al. (1999).

S1BW is derived from S1UAC, see text.

Reproductive and survival parameters shown in Table 3.5 are from cattle studies at MARC reported by Cundiff et al. (2004). These values were used for both sets of weight data (MARC and BIO). The survival rate of calves from birth to weaning (S1BW) was dependent on the replacement rate (RR), assisted calving in cows (ACalvc) and heifers (ACalvh), survival rate of calves with assisted calving (S1AC) and unassisted calving (S1UAC).

S1BW=RR(ACalvh S1AC+(1-ACalvh)S1UAC)+(1-RR) (ACalvc S1AC+(1-ACalvc)S1UAC

Differences in breeds accounted for the different values of traits used as inputs for the estimation of some requirements include the mature size, peak milk yield and fertility rate of heifers (Cundiff et al., 2004; Gregory et al., 1999; Sullivan et al., 1999) as shown on Table 3.7. The fertility rate of heifers was assumed to be 10% less than that of cows and so was a function of the fertility rate of cows. The replacement rate was the proportion of the cows of 2 years of age. The replacement rates for the different breeds were dependent upon the fertility rates and the survival rates of the cow of ages 3-10 years.

Some traits were assumed to be constant for all the breeds. These were the assisted calving (25%) for heifers (ACalvh), 6% assisted calving for cows (ACalvc), 83% for pre-weaning survival rate with assisted calving (S1AC), 98% survival rate of cows and dry matter content of milk which is assumed to be 12%. Due to limited information on the studies done on the embryo survival rate, the assumption is made that embryonic survival rate is 98%. The day of peak lactation was assumed to be 70 days.

3.6 Input costs

The various prices attached to the feeds and husbandry activities that were used in the estimation of the total cost for maintenance of the cow herd (Agriculture and Agri-Food Canada (2006) and MAFRI (2006c)) are shown in Table 3.2. Average prices of the inputs for 6 years were computed from 2000 to 2005.

3.7 Animal prices and marketing prices

The prices attributed to the different classes of cattle and the costs of marketing them (Table 3.2) were acquired from the archives of the beef cattle prices on the average annual prices from the Agriculture and Agri-food Canada website for Manitoba and also the Manitoba Agriculture Food and Rural Initiatives (Blawat, 2006). These selling prices of animals (on hoof) were from 6 year production cost estimates. The effect of change in the selling price of heifers and steers was applied and observed within the model. The selling prices of the steers and the heifers were increased by 10%. This was referred to as the Adjusted scenario, while the Base scenario consisted of the original prices. These averages would yield another estimate given the fluctuations that occur due to seasonality of these agricultural products and unexpected outcomes like the BSE in 2003.

3.8 Profit equations

The equations for calculating profits (Appendix 4) for the different classes of animals were based on Koots and Gibson (1998a). They made use of the cost of the inputs and revenues generated from the sale of the animals, which are on a liveweight basis for finished animals in the integrated beef production system and weaned calves in the cow-calf production system. The total costs associated with the production systems include cost of feed energy requirements of the different classes of animals, husbandry and marketing costs.

The profit from cows depends on the number of cows and on factors such as the survival rate of cows, survival rate of calves from birth to weaning, fertility rate of cows, embryonic survival, cost of calving ease of cows, cost of feed for growth, maintenance, gestation and lactation. Other factors include the returns from each cow as well as herd management cost. It is assumed that the ratio of bulls to cows is 1:25.

Profit from replacement heifers depend on the number of replacement heifers and on survival and fertility rate of cows, cost of associated calving difficulty, and survival rate of calves from birth to weaning as well as cost of feed requirements for maintenance, growth, gestation and lactation. The revenues from the replacement heifers as well as management costs contribute to determination of the profit.

The profit from market calves (steers and heifers) depend on the number of calves to be sold. The number of calves sold depends on the embryonic survival rate, survival rate of calves from birth to weaning and from weaning to market size or slaughter. Their feeding costs for growth and maintenance as well as herd management costs are considered in determining the profits. Other determinants of profits from bulls are their purchase prices, feeding costs for growth and maintenance, management costs as well as the salvage values from each bull.

The revenue for each class of animal is calculated from the sales of the slaughter and weaned animals on a liveweight (LW) basis given the prices (V) for the different classes of animals shown in Table 3.2. Revenues (Rcc) from cow-calf production system come from sale of live animals. The marketing costs (Cm) are deducted from the sales as described in the following equations

Rcc=LW (V-Cm)

3.9 Economic values

Economic values as mentioned earlier indicate the relative importance of a trait to the production process. They indicate the extent to which profit is altered as a result of changing the level of any of the traits in the model. The model is assumed to be a pure-breeding mating system whereby the eventual breeds selected would form the composite line. Heritability and phenotypic standard deviation (PSD) values reported in literatures were assumed for the input traits as shown in Table 3.6. The PSD for S1AC, S1UAC, FRh, FRc and S3 were assumed to be 1% under the threshold model (Koots and Gibson, 1998a). For each of the traits shown in Table 3.6, the level of each of the traits was increased by 5% of the phenotypic standard deviation while holding others constant. The increase in farm profit as a result of increasing the trait was taken as the economic value of the trait. The results were expressed in dollars per genetic standard deviation per cow.

Table 3.6: Heritability and phenotypic standard deviations for the traits.

Traits	Heritability	Phenotypic Standard Deviation
Mature Size	0.50	54.0
Survival rate of calves with assisted calving	0.14	0.01
Survival of calves from birth to weaning with unassisted calving	0.14	0.01
Residual feed intake in growing animals	0.35	1.3
Residual feed intake in mature animals	0.35	1.3
Fertility rate in heifers	0.27	0.01
Fertility rate of cows	0.27	0.01
Survival rate of cows	0.04	0.01

From Koots (1994)

3.10 Sensitivity analysis

Sensitivity analysis is conducted in this study to find out how changes in some independent variables affect an outcome. This was important for those parameters for which there is limited information.

The effects of change in some phenotypic measures were evaluated for each breed. These are indicators that may likely influence the selection process of producers. The effects of changes in the mature sizes and milk production abilities of the breeds were evaluated by changing the breeds constituted in the BIO data set. The objective here then is to weigh the effects of increase or decrease in mature size and milk production on the economic value. Selections for increase in mature sizes are accompanied by heavier weights at weaning and slaughter resulting in higher income from sales. However, higher mature sizes increase maintenance and husbandry costs. In addition crossbreeding increases incidence dystocia and costs associated with it.

Increases and decreases of 10% were applied to mature size and milk production to breeds with the largest and the smallest mature size and milk production respectively. The new set of breeds will then constitute a mix of highly variable phenotypes. From the average performance table, the Simmental ranked highest in mature size and milk production while Hereford was the least for mature size and peak milk yield. The changes on each of the breed's performance for mature weight were 907.7kg and 681.2kg for Simmental and Hereford respectively and 12.55kg and 8.24kg respectively for peak milk yield.

3.11 Optimality in forming a composite

Composites are developed to maintain a definite proportion of the founding breeds and aim for uniformity of performance after several generations (Newman et al., 1998). In the development of a synthetic population, the goal is usually the genetic improvement in the traits of the new line whereby the merits of the founding breeds are combined. While crossbreeding programs are undertaken to improve genetic merit of progeny (Shepherd and Kinghorn, 2005) composites are usually developed to maximize the net merit. Previous procedures of determining the optimal composition of a synthetic breed for single trait were based on empirical measures, the challenge arises when the more breeds are incorporated or more traits are included. Lin (1996) described a technique which yields a breed composition that would give maximum net merit in a synthetic line.

The mean net merit of a composite breed according to (Lin, 1996) is given by

$$\mu = \sum_{i=1}^{b} \sum_{j=1}^{b} p_i p_j t_{ij}$$

where μ is net merit of the synthetic line,

P_i or P_j are the various breed proportions of the constituent breeds,

t_{ij} is the economic merit of the F1 cows in a cross between breeds i and j.

This net merit can also be expressed in matrix notation as

$\mu = P' T P$

Lin shows that the optimal proportions can be calculated with the expressions

$$P = \left(u'T^{-1}u\right)^{-1} T^{-1}u$$

where $T = 0.5(Avu' + uv'A') + H$

P is the vector of breed proportions,

u is a unit vector of (bx1) dimension (b is the number of breeds) v is a vector matrix of economic values of traits with dimension tx1 (t is the number of traits),

A is a vector of additive genetic effects for all traits for all breeds,

T is a matrix of net merit derived from the combination of the breed. Its constituents are the genetic values (additive and non additive genetic effects) and the economic values of the traits included and

H is the vector of heterosis values from the possible breed combinations, it is of size bxb (b is the number of breeds).

An example is shown below that will demonstrate the process

If we have 3 breeds E, F and G each having additive genetic effects for each of the 3 traits mature size, dressing percentage and fertility rate (x, y, z) we want to improve. Assuming only additive genetic effects, the A matrix is shown below

$$A=\begin{bmatrix} Ex & Ey & Ez \\ Fx & Fy & Gz \\ Gx & Gy & Gz \end{bmatrix}=\begin{bmatrix} 800 & 61.60 & 91.00 \\ 820 & 61.00 & 83.00 \\ 810 & 61.40 & 84.50 \end{bmatrix}$$

With the rows being the breeds while the columns are traits. The traits (x, y and z) have economic values \$0.98, \$5.18 and \$0.49 respectively. The vector of the economic values become

$$v=\begin{bmatrix} v1 \\ v2 \\ v3 \end{bmatrix}=\begin{bmatrix} 0.983 \\ 5.177 \\ 0.492 \end{bmatrix}$$

If we assume heterotic values of 5kg, 1% and 6% result from the possible combinations the H-matrices for the different traits will be

$$H_x = \begin{bmatrix} 0 & 5 & 5 \\ 5 & 0 & 5 \\ 5 & 5 & 0 \end{bmatrix} \quad H_y = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} \quad H_z = \begin{bmatrix} 0 & 6 & 6 \\ 6 & 0 & 6 \\ 6 & 6 & 0 \end{bmatrix}$$

The diagonals of the H matrix are zeros because there will be no heterosis in purebred situations rather between crosses (off-diagonals)

Using the A matrix and the v vector (bx1) of economic values, we derive the T matrix by also incorporating a (bx1) unit vector **u** and a H matrix for the traits. The H matrix has zeros in the diagonals representing the purebreds which do not have any associated heterosis effect.

T=

$$\frac{1}{2}\left(\begin{bmatrix} 800 & 61.60 & 91.00 \\ 820 & 61.0 & 83.00 \\ 810 & 61.4 & 84.50 \end{bmatrix}\begin{bmatrix} 0.983 \\ 5.177 \\ 0.492 \end{bmatrix}\begin{bmatrix} 1 & 1 & 1 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}\begin{bmatrix} 0.983 & 5.177 & 0.492 \end{bmatrix}\begin{bmatrix} 800 & 820 & 810 \\ 61.6 & 61 & 61.4 \\ 91 & 83 & 84.5 \end{bmatrix}\right.$$

$$+\begin{bmatrix} 0.983 \end{bmatrix}\begin{bmatrix} 0 & 5 & 5 \\ 5 & 0 & 5 \\ 5 & 5 & 0 \end{bmatrix} + \begin{bmatrix} 5.177 \end{bmatrix}\begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} + \begin{bmatrix} 0.492 \end{bmatrix}\begin{bmatrix} 0 & 6 & 6 \\ 6 & 0 & 6 \\ 6 & 6 & 0 \end{bmatrix}$$

the T matrix becomes

$$T= \begin{bmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{bmatrix} = \begin{bmatrix} 1150.075 & 1169.428 & 1165.918 \\ 1169.428 & 1162.693 & 1172.226 \\ 1165.918 & 1172.226 & 1155.672 \end{bmatrix}$$

The values on the diagonals t_{11}, t_{22} and t_{33} represent the economic merit in dollar units of the i^{th} purebred individuals represented by $\mu + a_i$. With μ representing the population mean profit and a_i representing profit deviation due to the i^{th} breed. The off diagonals indicate the economic merit of the F1 breed combinations (breed i and j) with μ +

$(a_i+a_j)/2+H$. The value of heterosis arising from F1 breed combinations is added to the average of the values of additive genetic effects of two combined breeds and this gives the off-diagonals a higher value due to the advantage of heterosis.

With Lin's formula, the optimal breed composition P is calculated as follows:

$$P = \left(\begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 1150.075 & 1169.428 & 1165.918 \\ 1169.428 & 1162.693 & 1172.226 \\ 1165.918 & 1172.226 & 1155.672 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \right)^{-1} X$$

$$\begin{bmatrix} 1150.075 & 1169.428 & 1165.918 \\ 1169.428 & 1162.693 & 1172.226 \\ 1165.918 & 1172.226 & 1155.672 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} p1 \\ p2 \\ p3 \end{bmatrix} = \begin{bmatrix} 0.10 \\ 0.58 \\ 0.32 \end{bmatrix}$$

The net merit of the composite is obtained by combining the optimum breed proportion (P vector) and the dollar value of the genetic effects of the composite.

$$\text{Net Merit} = \begin{bmatrix} 0.10 & 0.58 & 0.32 \end{bmatrix} \begin{bmatrix} 1150.075 & 1169.428 & 1165.918 \\ 1169.428 & 1162.693 & 1172.226 \\ 1165.918 & 1172.226 & 1155.672 \end{bmatrix} \begin{bmatrix} 0.10 \\ 0.58 \\ 0.32 \end{bmatrix}$$

$$= \$1166.37$$

Thus a composite formed with 0.10 E, 0.58 F and 0.32 G produces the highest return of $1166.37. In case one of the breed proportions is found to be negative, then that breed is deleted and the optimization repeated

The procedure described by Lin (1996) was used in the present study to derive the optimum breed composition for a composite. Six breeds of cattle were evaluated in the two systems cow calf and integrated. The traits which were used here were mature size (MS), fertility rate of females (FRf) averaged over heifers and cows, calf survival (S1) averaged for the calves born with and without assistance and peak milk yield (PM). The traits included were observed to have some economic impacts on both the integrated and cow-calf production systems. The RFIM and RFIG were not included because there is limited information on these traits. It is also difficult to have practical measures of these traits.

An alternative method using SAS 9.1 (2003) was developed to validate the solutions of the Lin (1996) procedure. This method evaluated all possible breed combinations. This was computationally demanding and was used for verification only. In all cases the Lin method was validated.

3.11.1 The optimal composite considering six breeds

Breed parameters were expressed as deviations from the Simmental trait values for the analysis done here since it is one of the heaviest breeds as well as the highest milk producer. The fertility rate of females is a weighted average of heifers and cows given the proportion of heifers and cows in the herd. The calf survival is also an average of calves born with and without assistance given the average proportion of assistance in the herd.

Table 3.7: Breed means for composite optimization

Breed	Mature size (Kg) [z]	Mature size (Kg)[y]	Peak milk (Kg)[z]	Peak milk (Kg)[y]	Mean survival rate of calves (%)	Mean fertility rate of females (%)
Hereford	693.2	756.9	7.16	9.15	91	86.31
Angus	699.7	770.2	8.89	11.03	95	83.72
Gelbvieh	798.9	784.1	11.07	11.03	94	76.79
Simmental	797.2	825.2	12.31	11.41	93	82.85
Charolais	845.7	816.6	10.50	9.90	89	83.72
Limousin	764.7	774.4	7.46	10.85	93	80.26

Weights were derived from Table 3.4, the genetic change in each breed was assumed similar to give the 2004 breed means. Milk EPDs were derived from 2004 MARC averages (Van Vleck and Cundiff, 2006). Survival and fertility rates are based on MARC data used for both BIO and MARC analysis.

[z] Breed average performance values from Meat Animal Research Center

[y] Breed average performance values from Beef Improvement Ontario

The breed additive effects were expressed as deviation from the Simmental. The columns of the A matrix indicates the traits (mature size, survival rate of calves to weaning, fertility rate of females and peak milk) while the rows are the various breeds (Hereford, Angus, Gelbvieh, Simmental, Charolais and Limousin). The matrices in the two sources of information are shown below

$$A\ (BIO) = \begin{bmatrix} -68.3 & -2 & 3.46 & -2.26 \\ -55 & 2 & 0.87 & -0.38 \\ -41.1 & 1 & -6.06 & -0.38 \\ 0 & 0 & 0 & 0 \\ -8.6 & -4 & 0.87 & -1.51 \\ -50.8 & 0 & -2.59 & -0.56 \end{bmatrix}$$

$$A\ (MARC) = \begin{bmatrix} -104 & -2 & 3.46 & -5.15 \\ -97.5 & 2 & 0.87 & -3.42 \\ 1.7 & 1 & -6.06 & -1.24 \\ 0 & 0 & 0 & 0 \\ 48.5 & -4 & 0.87 & 1.81 \\ -32.5 & 0 & -2.59 & -4.85 \end{bmatrix}$$

The heterosis matrices for the four traits are H1 (mature size), H2 (average calf survival), H3 (fertility rate of females) and H4 (Peak milk yield). Since the breeds are all *Bos taurus* breeds, it was assumed that the F1 heterosis effects for each pair of breeds on a percentage basis would be similar. The contents of the H matrices were derived as the heterosis percentage of the average of any 2 combining breeds.

ie $H_{ij} = h\% ((\text{Breed } i + \text{Breed } j)/2)$

The heterosis values were also shown in Table 4.3 for mature size (Murray, 2002), fertility rate of females(Bourdon, 2000a) calf survival to weaning (American Shorthorn Association, 2005) and milk production (Buchanan and Northcutt, 2005). The heterosis matrices for the BIO breeds are shown below

$$H1=\begin{bmatrix} 0 & 22.91 & 23.12 & 23.73 & 23.60 & 22.96 \\ 22.91 & 0 & 23.31 & 23.93 & 23.80 & 23.17 \\ 23.12 & 23.31 & 0 & 24.14 & 24.01 & 23.38 \\ 23.73 & 23.93 & 24.14 & 0 & 24.63 & 23.99 \\ 23.60 & 23.80 & 24.01 & 24.63 & 0 & 23.87 \\ 22.96 & 23.17 & 23.38 & 23.99 & 23.87 & 0 \end{bmatrix}$$

$$H2=\begin{bmatrix} 0 & 3.72 & 3.70 & 3.68 & 3.60 & 3.68 \\ 3.72 & 0 & 3.78 & 3.76 & 3.68 & 3.76 \\ 3.70 & 3.78 & 0 & 3.74 & 3.66 & 3.74 \\ 3.68 & 3.76 & 3.74 & 0 & 3.64 & 3.72 \\ 3.60 & 3.68 & 3.66 & 3.64 & 0 & 3.64 \\ 3.68 & 3.76 & 3.74 & 3.72 & 3.64 & 0 \end{bmatrix}$$

$$
H3 = \begin{bmatrix} 0 & 5.10 & 4.89 & 5.07 & 5.10 & 5.00 \\ 5.10 & 0 & 4.82 & 5.00 & 5.02 & 4.92 \\ 4.89 & 4.82 & 0 & 4.79 & 4.82 & 4.71 \\ 5.07 & 5.00 & 4.79 & 0 & 5.00 & 4.89 \\ 5.10 & 5.02 & 4.82 & 5.00 & 0 & 4.92 \\ 5.00 & 4.92 & 4.71 & 4.89 & 4.92 & 0 \end{bmatrix}
$$

$$
H4 = \begin{bmatrix} 0 & 0.91 & 0.91 & 0.93 & 0.86 & 0.90 \\ 0.91 & 0 & 0.99 & 1.01 & 0.94 & 0.98 \\ 0.91 & 0.99 & 0 & 1.01 & 0.94 & 0.98 \\ 0.93 & 1.01 & 1.01 & 0 & 0.96 & 1.00 \\ 0.86 & 0.94 & 0.94 & 0.96 & 0 & 0.93 \\ 0.90 & 0.98 & 0.98 & 1.00 & 0.93 & 0 \end{bmatrix}
$$

4. RESULTS AND DISCUSSION

Weights and average daily gains for calves in the different phases of growth are shown in Tables 4.1a (MARC) and 4.1b (BIO). Higher weaning weights were observed for the higher milking breeds especially the Simmental and the Gelbvieh breeds. This was due to the effects of the favorable growing environment created by the dam's high milk producing ability on such calves. The high weaning weights of calves from Charolais were due to effect of genetic ability for growth of individual calves.

Economic weights for the traits were derived for each of the six breeds of cattle under consideration. Results for the cow- calf and integrated production systems are presented each for BIO and MARC data sets.

Table 4.1a: Weight measures, average daily gains and days in feedlot for the different breeds

Breed/Class	Birth weight	Preweaning ADG	205 day Weaning weight	Growth phase ADG	296 day Growth Endweight	Finishing ADG	Finish Endweight	Weaning efficiency[z] (%)	Days on feedlot
Hereford									
Heifer	44.85	1.02	254.71	0.87	334.17	1.32	459.59	37	95
Steer	46.24	1.10	270.97	0.93	355.5	1.42	540.70	39	130
Angus									
Heifer	45.27	1.08	265.77	0.79	337.30	1.42	463.90	38	89
Steer	46.67	1.15	282.73	0.84	358.83	1.51	545.77	40	124
Gelbvieh									
Heifer	51.69	1.20	296.98	0.97	385.12	1.55	529.67	37	93
Steer	53.29	1.28	315.94	1.03	409.71	1.67	623.14	40	128
Simmental									
Heifer	51.58	1.23	303.70	0.89	384.30	1.62	528.54	38	89
Steer	53.17	1.32	323.09	0.94	408.83	1.73	621.82	41	123
Charolais									
Heifer	54.72	1.21	302.63	1.15	407.68	1.53	560.70	36	100
Steer	56.41	1.30	321.95	1.23	433.71	1.69	659.65	38	134
Limousin									
Heifer	49.48	1.08	269.99	1.08	368.64	1.36	507.00	35	102
Steer	51.01	1.15	287.23	1.15	392.17	1.49	596.47	38	137

Average Daily Gain (ADG)
[z] weaning weight as a proportion of the mature size
Breed average performance values from Gregory et al. (1999)

Table 4.1b: Weight measures, average daily gains and days in feedlot for the different breeds

Breed/Class	Birth weight	Preweaning ADG	205 day Weaning weight	Growth phase ADG	296 day Growth Endweight	Finishing ADG	Finish Endweight	Weaning efficiency[z] (%)	Days on feedlot
Hereford									
Heifer	48.97	1.12	278.11	0.95	364.88	1.44	501.82	37	95
Steer	50.49	1.20	295.86	1.01	388.17	1.56	590.38	39	130
Angus									
Heifer	49.83	1.18	291.31	0.88	371.29	1.55	510.64	38	90
Steer	51.37	1.26	309.90	0.94	394.99	1.66	600.76	40	124
Gelbvieh									
Heifer	50.73	1.19	293.95	0.92	377.99	1.54	519.86	37	92
Steer	52.30	1.27	312.71	0.98	402.12	1.66	611.60	40	126
Simmental									
Heifer	53.39	1.22	303.91	1.03	397.80	1.57	547.11	37	95
Steer	55.04	1.31	323.31	1.10	423.19	1.71	643.66	39	129
Charolais									
Heifer	52.83	1.18	293.70	1.10	393.66	1.49	541.41	36	99
Steer	54.47	1.26	312.45	1.17	418.78	1.64	636.95	38	133
Limousin									
Heifer	50.10	1.18	291.08	0.90	373.31	1.54	513.43	38	91
Steer	51.65	1.26	309.66	0.96	397.14	1.64	604.03	40	126

Average Daily Gain (ADG)

[z] weaning weight as a proportion of the mature size

Breed average performance values from Sullivan et al. (1999)

Table 4.2: Profit levels for each of the breeds.

	Profit level ($) Cow-calf[z]		Profit level ($) Integrated[y]		Cow Mature size (Kg)		Peak milk yield (Kg)	
	MARC	BIO	MARC	BIO	MARC	BIO	MARC	BIO
Hereford	15284.71	17410.09	15271.09	17192.47	693.2	756.9	7.16	9.15
Angus	17677.13	20104.64	17167.64	19345.15	699.7	770.2	8.89	11.03
Gelbvieh	20220.96	19961.41	19610.48	19323.56	798.9	784.1	11.07	11.03
Simmental	20726.69	20653.57	19879.92	20067.16	797.2	825.2	12.31	11.41
Charolais	19000.08	18241.61	18557.08	17864.19	845.7	816.6	10.50	9.90
Limousin	17398.14	19548.80	17543.74	18951.64	764.7	774.4	7.46	10.85

[z] Profits from cow-calf are calculated up to weaning of calves
[y] Profits from integrated system include the feedlot operations

4.1 Influence of breeds on farm profitability

Profits for the different breeds (shown in Table 4.2) were evaluated based on production and marketing conditions in Tables 3.2, 3.3, 3.4 and 3.5. Profits for the integrated production systems were generally lower than those of the cow-calf system for all the breeds except the Limousin breed using the MARC data. Although the weaned calves are marketed at lower weights and younger ages, they are compensated by the payment of higher prices per kilogram of weight as in agreement with MAFRI (2006c).

The ranges for profits under the cow-calf production systems for the MARC and BIO values were $15284.71 to $20726.69 and $17410.09 to $20653.57. The ranges of profits for the integrated systems for MARC and BIO were $15271.09 to $19879.92 and $17192.47 to $20067.16 respectively. These profits indicate a loss in the integrated production system ranging from $13.62 to $846.77 and $217.62 to $759.49 respectively for the MARC and BIO values.

The profits derived for both systems of production were higher than the values reported by Koots and Gibson (1998a). These may be as a result of the input prices and costs used in this model. Higher profits are expected in the integrated production system due to addition of values to the individual animals through finishing and other production activities however the results from this study suggests otherwise given the Manitoba costs. This may be due to higher cost of production especially in meeting the nutritional requirements of the animals in the feedlot.

Highest profit for the cow-calf production system came from the Simmental breed with $20726.69 and $20653.57 for the MARC and BIO breed values respectively. The least profit came from the Hereford with $15284.71 and $17410.09 for the MARC and

BIO values respectively. The profit for the integrated production system was also highest for the Simmental breed using while the least also came from the Hereford breed.

Higher profits were more consistent for higher milking breeds (such as Gelbvieh and Simmental) than for the heavier breeds. Simple correlations were calculated between size and profits and between milk production and profit. The correlation results of profits with mature size and milk production abilities gave averages of 0.55 for mature weight (cow-calf), 0.97 peak milk (cow-calf), 0.59 mature weight (integrated) and 0.95 peak milk production (integrated). There is thus a greater contribution of cow milk producing ability to profit. The cow mature size also contributes to profitability to an extent given the correlations with profits; however the result is as not strong as that for milk production. Other contributions to profitability may also come from the reproductive characteristics of the breeds especially fertility rates which was an indicator of calf number. The survival rates of calves also affected the number of animals that reached market age.

Differences in profit between the cow-calf and integrated systems (Table 4.2) were variable. For example a profit of $17398.14 for cow calf (Limousin, MARC) while $17543.74 for the integrated. This gives a return due to feedlot operation of $146. This profit change between the cow- calf and the integrated operations ranged from -$847 in the Simmental to -$146 in the Limousin (under the MARC data). The heavier milking breeds as well as some of those with high mature sizes tended to attract more losses in the integrated production system. Bourdon and Brinks (1987) in their simulated study observed that biological efficiency of animals with high mature sizes were reduced due to higher feed consumption. There is also increased requirements for lactation by heavier milking breeds. Given the profits in both systems, highest losses in the integrated system with respect to the cow-calf system were observed for the Simmental breed ($847) using the MARC values while the Angus indicated the greatest loss using the BIO values with $759. The least losses came from the Hereford breed for the MARC and BIO values respectively, whereas the Limousin gained using the MARC data.

Most producers in Manitoba do not finish their calves in the feedlot but rather sell them at weaning. The profitability profile for feedlots issued by MAFRI (2002) indicates that most feedlots operators do not break even. Sales of finished steers to other provinces attract negative returns (-$12.62 to -$65.20) per head except those sold in Nebraska. This is because the U.S. was a major market for most of Manitoba slaughter cattle and thus making the market forces of demand and supply in the U.S. to determine the price of cattle produced in Manitoba (Honey, 2006). The beef industry in Canada (Manitoba inclusive) is still recovering from the poor market of finished beef as a result of the incidence of BSE. The disease outbreak which led to closure of the U.S. border to Canadian meat had greater effect on the Manitoba producers who relied mainly on the U.S. market without sourcing for alternative markets in Canada. CanFax reports have also indicated that the feedlot sector is prone to market fluctuations which may lead to negative profits in some periods (MCPA, 2006a).

Tables 4.3a, 4.3b and 4.4a, 4.4b show the different economic weights under the two systems respectively for mature size (MS), calf survival with assisted calving (S1AC), calf survival with unassisted calving and (S1UAC), residual feed intake in growing (RFIG) and mature cattle (RFIM). Others include fertility rate in heifers (FRh) and cows (FRc), cow survival rate (S3) and peak milk yield (PM). MS, S1AC, S1UAC, FRc and PM indicated positive economic values in both systems while the RFIG, RFIM and S3 showed negative economic values. Economic values for FRh were all positive in the cow calf sector but were negative in the integrated production system.

The cow-calf system has economic values for mature size ranging from \$11.19 to \$12.63 σ g^{-1}cow^{-1} and \$11.24 to \$12.50 σ g^{-1}cow^{-1} respectively for the MARC and BIO data. The economic values for mature size were higher in the integrated production system than in the cow-calf system. The values ranged from \$11.45 to \$16.42 σ g^{-1}cow^{-1} and \$11.88 to \$16.29 σ g^{-1}cow^{-1} for the MARC and BIO data respectively.

Koots (1994) observed mature size to have positive economic values which is consistent with the result found here. In a study of crossbreeding using specialized dams and sire lines by MacNeil et al. (1994), negative economic values for cow weight were found for the dam line.

Table 4.3a: Relative economic values of selected traits in the base scenario (cow-calf production system)[z]. ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
MS	12.37	12.57	12.43	12.63	11.19	12.41
S1AC	0.23	0.23	0.26	0.27	0.26	0.24
S1UAC	2.12	2.22	2.50	2.56	2.58	2.26
RFIG	-2.21	-2.33	-2.30	-2.29	-2.15	-2.29
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.25	0.22	0.26	0.28	0.23	0.23
FRc	0.09	0.08	0.06	0.10	-0.04	0.00
S3	-0.52	-0.58	-0.63	-0.62	-0.69	-0.59
PM	4.50	4.82	4.69	4.43	4.52	4.72

Table 4.3b: Relative economic values of selected traits in the base scenario (cow-calf production cycle). ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
MS	12.20	12.42	12.44	12.31	11.24	12.50
S1AC	0.26	0.25	0.26	0.27	0.26	0.26
S1UAC	2.34	2.45	2.47	2.57	2.50	2.45
RFIG	-2.21	-2.33	-2.30	-2.29	-2.16	-2.29
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.27	0.24	0.26	0.27	0.23	0.27
FRc	0.07	0.06	0.07	0.04	-0.03	0.09
S3	-0.57	-0.64	-0.62	-0.64	-0.67	-0.60
PM	4.46	4.81	4.68	4.66	4.51	4.64

[x] Traits include Mature Size (MS), Survival rate of calves with assisted calving (S1AC), Survival of calves from birth to weaning with unassisted calving (S1UAC), Residual feed intake in growing animals (RFIG), Residual feed intake in mature animals (RFIM), Fertility rate in heifers (FRh), Fertility rate of cows (FRc), Survival rate of cows (S3) and Peak milk (PM).
[z] Breed average performance values from Meat Animal Research Center
[y] Breed average performance values from Beef Improvement Ontario

Table 4.4a: Relative economic values of selected traits in the base scenario (integrated production cycle)[z]. ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
MS	15.38	15.11	13.99	16.42	11.45	14.90
S1AC	0.24	0.23	0.27	0.27	0.26	0.25
S1UAC	2.17	2.25	2.51	2.54	2.59	2.32
RFIG	-6.00	-6.32	-6.21	-6.25	-5.82	-6.05
RFIM	-4.36	-4.32	-4.21	-4.34	-4.32	-4.34
FRh	-0.04	-0.02	-0.05	-0.06	-0.04	-0.04
FRc	-0.02	0.04	-0.06	-0.04	-0.12	-0.08
S3	-0.55	-0.61	-0.66	-0.65	-0.71	-0.62
PM	3.55	3.96	4.09	2.15	2.21	3.65

Table 4.4b: Relative economic values of selected traits in the base scenario (integrated production cycle)[y]. ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
MS	14.48	13.17	16.29	12.53	11.88	14.30
S1AC	0.26	0.25	0.26	0.28	0.26	0.26
S1UAC	2.36	2.46	2.48	2.57	2.51	2.45
RFIG	-6.00	-6.31	-6.23	-6.15	-5.84	-6.21
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	-0.05	-0.03	-0.05	-0.06	-0.04	-0.05
FRc	-0.07	-0.01	-0.04	-0.09	-0.10	-0.04
S3	-0.59	-0.66	-0.65	-0.67	-0.69	-0.63
PM	3.74	2.51	2.44	2.38	2.23	4.06

[x] Traits include Mature Size (MS), Survival rate of calves with assisted calving (S1AC), Survival of calves from birth to weaning with unassisted calving (S1UAC), Residual feed intake in growing animals (RFIG), Residual feed intake in mature animals (RFIM), Fertility rate in heifers (FRh), Fertility rate of cows (FRc), Survival rate of cows (S3) and Peak milk (PM).
[z] Breed average performance values from Meat Animal Research Center
[y] Breed average performance values from Beef Improvement Ontario

4.2 Economic values of traits

The economic values for this trait within each production system did not have wide variations. The values were high in both systems of production indicating the relative importance of the trait in beef production under a purebreeding setting. Such results show that increasing the mature weight of the different breeds tended to increase the profit accrued from both production processes through weaning of heavier calves and also the sale of heavier animals at finishing. Animals of heavier mature sizes are known to have the potentials to be heavy throughout their growth phases unless there is an environmental interference. Although they will add higher gains, their nutritional demand may be higher than those of lighter animals.

The economic values for the mature size in the cow calf production system were lower than that of the integrated production system for all the breeds. This suggests that increase in the mature size will have greater value in the integrated production system than in the cow-calf.

The survival in calves was partitioned into 2; calf survival with assisted calving (S1AC) and calf survival with unassisted calving (S1UAC). The economic values for both survival traits were similar across the breeds within each production system. The cow-calf production system has economic values for S1AC and S1UAC ranging from \$0.23 to \$0.27$\sigma g^{-1} cow^{-1}$ and \$2.12 to 2.58$\sigma g^{-1} cow^{-1}$ respectively. The integrated production system also gave similar values ranging \$0.23 to \$0.28$\sigma g^{-1} cow^{-1}$ and \$2.17 to \$2.59$\sigma g^{-1} cow^{-1}$ for the S1AC and S1UAC respectively.

Economic values for assisted calving were consistently lower than that of unassisted calving. This reflects the relative importance of increase in the unassisted calving by cows thereby incurring minimum expenses associated with assisted calving. The values were similar in both systems of production.

There were similar economic values for residual feed intake for the breeds among the breed data sets used (MARC vs BIO) within each production system and also between the mature animals in both production systems. The economic values for the residual feed intake in the cow-calf production system range from -\$2.15 to -\$2.33 $\sigma\, g^{-1}cow^{-1}$ and -\$4.36 to -\$4.32 $\sigma\, g^{-1}cow^{-1}$ for growing animals (RFIG) and mature animals (RFIM) respectively. The integrated system has economic values for RFIG ranging from -\$6.32 to -\$5.82 $\sigma\, g^{-1}cow^{-1}$ and -\$6.31 to -\$5.84 $\sigma\, g^{-1}cow^{-1}$ for the MARC and BIO values.

The negative coefficients for the economic values of residual feed intake indicate that additional levels of feed intake causes a negative return to production. This is due to the effect of higher feed costs that accompany animals that consume more feed to meet their requirements or to attain desired market size. Such conditions are related to the biological efficiency (Ferrell and Jenkins, 1988; Notter, 2002) of the animals in utilizing the available feeds. Animals that require less net feed intake to attain a desired size are deemed to be more profitable than those that consume extra feed.

The economic values of residual feed intakes were similar for most of the breeds due to the specified time spent in the herd for the growing (RFIG) and mature (RFIM) animals. The growth phase for the growing animals (mainly steers and heifers) was fixed until the animals entered the feedlot. The average daily gains in the feedlot accounts for length of finishing the animal to attain the required market weight. Differences between the breeds were identified in the period of finishing since the time to reach desired weight varied among breeds. The economic values were higher for growing animals than mature ones in the integrated system because of the greater number of individuals in that category. Although the RFIM economic values in the integrated production system were same as those in the cow-calf production system, the values for the RFIG were lesser in the cow-calf production system. Similarities existed in RFIM because same classes of older animals are maintained for self replacing herd in both systems of production. On the other hand, the RFIG in the cow-calf is lower because the calves are sold at weaning and therefore are kept for a shorter time than the finished calves in the integrated production system. Therefore the effect of extra feeding will be greater in the integrated system than the cow-calf.

The economic values of fertility rates for the heifers (FRh) were higher than that of cows in the cow calf production system while they were generally lower in the integrated system. The economic values for the FRh and FRc ranged from $0.22 σ $g^{-1}cow^{-1}$ to $0.28 σ $g^{-1}cow^{-1}$ and -$0.04 σ $g^{-1}cow^{-1}$ to $0.10 σ $g^{-1}cow^{-1}$ respectively for the entire cow-calf system. Economic values for fertility rates of heifers and cows were generally negative in the integrated production system. The values ranged from -$0.06 σ $g^{-1}cow^{-1}$ to -$0.02 σ $g^{-1}cow^{-1}$ for FRh while FRc ranged from -$0.12 σ $g^{-1}cow^{-1}$ and $0.04 σ $g^{-1}cow^{-1}$.

The economic values for fertility rate in the cow calf system were generally higher than those in the integrated system. The results were generally lower than the values obtained by some others studies for cow fertility (Koots and Gibson, 1998a) and female fertility (MacNeil et al., 1994). The results indicate that improving the female fertility will generate more value in the cow calf system whereas in the integrated it may cause a reduction. Normally, increased fertility is expected to be associated with more calves and more income, but if the farm is not making profit or if the cost of maintaining animals is close to/ higher than the revenue, any extra cost associated with production will entail losses to the farm. In this case, the increased number of calves (as a result of increased heifer or cow fertility) will increase the management and nutritional demands.

The economic values for the survival rate of cows were negative for all breeds. The values were also similar within the two production systems and among the individual breeds. The cow-calf production system has economic values ranging from -\$0.69 to -\$0.52 σ $g^{-1}cow^{-1}$ while the integrated system has values ranging from -\$0.71 to -\$0.55 σ $g^{-1}cow^{-1}$.

The survival rate of cows gave negative economic values indicating that greater retention of old cows in the herd was detrimental to the profitability of both production systems. In practice, this may be observed for cows greater than 8 years. Such results indicate that maintenance costs for the cows were greater than the revenues. Increasing the survival of the cows meant increasing the proportions of the older cows in the herd. These cows are bigger in size and would have more nutritional demands than younger females; moreover the prices of the cows are discounted during sales. Since the revenue from their sales do not cover their management and feeding costs, any increase in the number of this class of animals will generate negative profit. The result from this study does not conform to Koots and Gibson (1998a) which gave a highly positive value of \$14.72 σ $g^{-1}cow^{-1}$ for the purebreeding system. This may be as a result of reduced cost associated with cows in his model or that the selling prices of the cows were able to offset the keeping costs of the cows.

The economic values for the peak milk production were generally higher in the cow-calf system than in the integrated production system. These values were higher than those reported by Koots and Gibson (1998a). The values ranged from \$4.43 to \$4.82 σ $g^{-1}cow^{-1}$ and \$2.15 to \$4.09 σ $g^{-1}cow^{-1}$ respectively for the cow calf and the integrated production systems. The importance of the maternal ability is reflected in the economic value of the peak milk yield. At a fixed day of peak lactation, the milk yield of a breed indicates their maternal ability in weaning heavy calves. The economic values for peak milk yield in this study were positive in both systems. The values were higher in the cow calf production system than in the feedlot. This may be due to fewer costs associated with supplementing (creep) the calves' requirements. Calves whose dams produced more milk were heavier at weaning and this also affected their weights up to finishing in the feedlot.

There was relatively little variation in the economic values for the most of the traits among the breeds within each system. The economic values for some traits were also similar across the two production systems evaluated.

Table 4.5a: Relative economic values of selected traits in the Adjusted scenario (cow-calf production system)[z]. (\$ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
Profit (\$)	17782.12	20542.54	23315.48	23852.35	22031.79	20179.94
MS	13.80	14.14	13.94	14.12	12.64	13.91
S1AC	0.26	0.25	0.29	0.31	0.29	0.27
S1UAC	2.36	2.47	2.78	2.85	2.86	2.51
RFIG	-2.21	-2.33	-2.30	-2.29	-2.15	-2.29
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.33	0.29	0.34	0.37	0.31	0.31
FRc	0.28	0.27	0.27	0.32	0.17	0.20
S3	-0.52	-0.58	-0.63	-0.62	-0.69	-0.59
PM	4.94	5.30	5.16	4.89	4.97	5.18

Table 4.5b: Relative economic values of selected traits in the Adjusted scenario (cow-calf production cycle)[y]. (\$ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
Profit (\$)	20136.86	23254.38	23024.29	23781.38	21183.85	22547.88
MS	13.63	13.98	13.95	13.80	12.69	14.00
S1AC	0.29	0.28	0.29	0.30	0.28	0.29
S1UAC	2.60	2.73	2.75	2.85	2.77	2.72
RFIG	-2.21	-2.33	-2.30	-2.29	-2.15	-2.29
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.35	0.31	0.35	0.36	0.30	0.35
FRc	0.28	0.26	0.28	0.27	0.17	0.30
S3	-0.57	-0.64	-0.62	-0.64	-0.67	-0.60
PM	4.91	5.29	5.15	5.12	4.96	5.10

[x] Traits include Mature Size (MS), Survival rate of calves with assisted calving (S1AC), Survival of calves from birth to weaning with unassisted calving (S1UAC), Residual feed intake in growing animals (RFIG), Residual feed intake in mature animals (RFIM), Fertility rate in heifers (FRh), Fertility rate of cows (FRc), Survival rate of cows (S3) and Peak milk (PM).

[z] Breed average performance values from Meat Animal Research Center

[y] Breed average performance values from Beef Improvement Ontario

Table 4.6a: Relative economic values of selected traits in the Adjusted scenario (integrated production cycle)[z]. (\$ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
Profit (\$)	18332.70	20613.89	23377.99	23634.60	22327.92	21032.30
MS	18.06	18.04	16.86	19.05	14.37	17.78
S1AC	0.27	0.26	0.30	0.31	0.30	0.28
S1UAC	2.46	2.55	2.85	2.88	2.94	2.64
RFIG	-5.99	-6.32	-6.21	-6.25	-5.82	-6.05
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.06	0.06	0.05	0.05	0.05	0.06
FRc	0.21	0.25	0.20	0.22	0.13	0.16
S3	-0.55	-0.61	-0.66	-0.65	-0.71	0.62
PM	3.70	4.15	4.24	2.45	2.50	3.78

Table 4.6b: Relative economic values of selected traits in the Adjusted scenario (integrated production cycle)[y]. (\$ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Angus	Gelbvieh	Simmental	Charolais	Limousin
Profit (\$)	20535.33	23130.68	23035.04	23895.04	21512.84	22580.97
MS	17.17	16.20	18.96	15.49	14.78	17.11
S1AC	0.29	0.28	0.30	0.31	0.29	0.30
S1UAC	2.67	2.79	2.81	2.91	2.85	2.78
RFIG	-6.00	-6.32	-6.23	-6.15	-5.84	-6.21
RFIM	-4.36	-4.32	-4.34	-4.34	-4.32	-4.34
FRh	0.05	0.06	0.05	0.05	0.05	0.05
FRc	0.19	0.23	0.21	0.18	0.14	0.21
S3	-0.59	-0.66	-0.65	-0.67	-0.69	-0.63
PM	3.88	2.83	2.74	2.67	2.52	4.21

[x] Traits include Mature Size (MS), Survival rate of calves with assisted calving (S1AC), Survival of calves from birth to weaning with unassisted calving (S1UAC), Residual feed intake in growing animals (RFIG), Residual feed intake in mature animals (RFIM), Fertility rate in heifers (FRh), Fertility rate of cows (FRc), Survival rate of cows (S3) and Peak milk (PM)
[z] Breed average performance values from Meat Animal Research Center
[y] Breed average performance values from Beef Improvement Ontario

Tables 4.5(a,b) and 4.6(a,b) indicate the economic values of the traits as a result of 10% increase in the selling prices of the steers and heifers. This translated to increased profits under both systems of production. At such market prices for the heifers and steers, the integrated production system became more profitable than the cow-calf production system although the margins varied among the breeds.

There were also changes in the economic values of the traits evaluated. There were general increases in all economic values of traits especially the fertility rates of females (which was negative in the base scenario under the integrated production system). This result was expected since increase in fertility of females would increase the number of marketed animals; in this situation of profit per individual animal sold, increased number of animals sold would increase the total profit of the farm. The economic value of residual feed intake was unaffected.

The effects of changing the mature cow size and milk production on the economic values of the traits are shown in Table 4.7a for the cow-calf system and Table 4.7b for the integrated system. Among the breeds compared, the changes were applied to the Simmental and the Hereford breeds which were the heaviest, highest milk producer and lightest, lowest milk producer according to the BIO data. While the economic values of other breeds remained constant, observations were made on the economic values of the Hereford and Simmental to which changes were made.

Table 4.7a: Sensitivity of the economic values under changes in mature size and peak milk yield (Cow-calf). ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Simmental
MS	12.43	12.00
S1AC	0.24	0.30
S1UAC	2.16	2.77
RFIG	-2.21	-2.29
RFIM	-4.36	-4.34
FRh	0.26	0.28
FRc	0.14	-0.01
S3	-0.52	-0.70
PM	4.45	4.65

Table 4.7b: Sensitivity of the economic values under changes in mature size and peak milk yield (Integrated). ($ σ $g^{-1}cow^{-1}$)

Traits[x]	Hereford	Simmental
MS	15.30	12.57
S1AC	0.24	0.30
S1UAC	2.18	2.76
RFIG	-6.09	-6.09
RFIM	-4.36	-4.34
FRh	-0.04	-0.07
FRc	0.01	-0.16
S3	-0.54	-0.73
PM	3.70	2.27

[x] Traits include Mature Size (MS), Survival rate of calves with assisted calving (S1AC), Survival of calves from birth to weaning with unassisted calving (S1UAC), Residual feed intake in growing animals (RFIG), Residual feed intake in mature animals (RFIM), Fertility rate in heifers (FRh), Fertility rate of cows (FRc), Survival rate of cows (S3) and Peak milk (PM)

The reduction of the mature size and peak milk yield in the Hereford affected the total profit in both systems as well as the relative economic values of some traits. There was approximately 10% reduction in total profits of the cow-calf system ($1707) as well as in the in the integrated system ($1770). Increase in the mature size and milk yield of the Simmental increased profit by 10% in both the cow-calf production system ($1955) and the integrated production system ($1861).

Changes in the economic values of traits were observed for some traits in the cow calf production system. There were little increases in the economic values of some traits (MS, FRc and S3) the traits in the Hereford breed. The RFIG and RFIM were constant while S1AC, S1UAC, FRh and PM reduced for the breed. The Simmental breed had reduced values in the MS, FRc, S3 and PM. Economic values for S1AC, S1UAC and FRh increased in their economic values while RFIG and RFIM were constant.

The integrated production system experienced more obvious changes in the economic values of the MS in the Hereford breed. There was reduction in the economic values of both breeds for the PM while MS increased. The other traits experienced little changes as shown in Table 4.7b.

Generally, the changes in the mature size and peak milk yields had more effect on the total profit of each of the production systems. Net effect on the changes in profits was greater for the Simmental breed than the Hereford. The changes in total profit (shown in Figures 4.1a and 4.1b) of each sector as a result of the rescaling were expected because changing the milk and the mature weight of a breed will affect the revenue from the marketed product. There will be correlated changes in the weights at weaning as well as at finishing due to more/less production of milk by the dam. The cost of creep feeding would also be affected because the milk produced by the dam may not meet the needs of the calf if there is lesser milk production by the dam or there will be less cost attached to creep feeding if the dam's milk production supports all requirement of the calf.

These results indicated that the changes made to mature size and peak milk yield affect most of the individual traits in the cow-calf production system but the changes were very small. The little changes that occurred indicate that the economic values seem not be affected much by changes in the cow mature size and peak milk yield. The results were similar in the integrated system. The economic value of mature size for the Hereford was affected to a greater extent than the Simmental breed indicating that errors in the actual values of such traits of individual breeds would affect the resulting economic values. This is in agreement with the findings of Koots and Gibson (1998b).

Figure 4.1a: Changes in the profit as a result of 10% increase in mature size and peak milk yield in the Simmental breed.

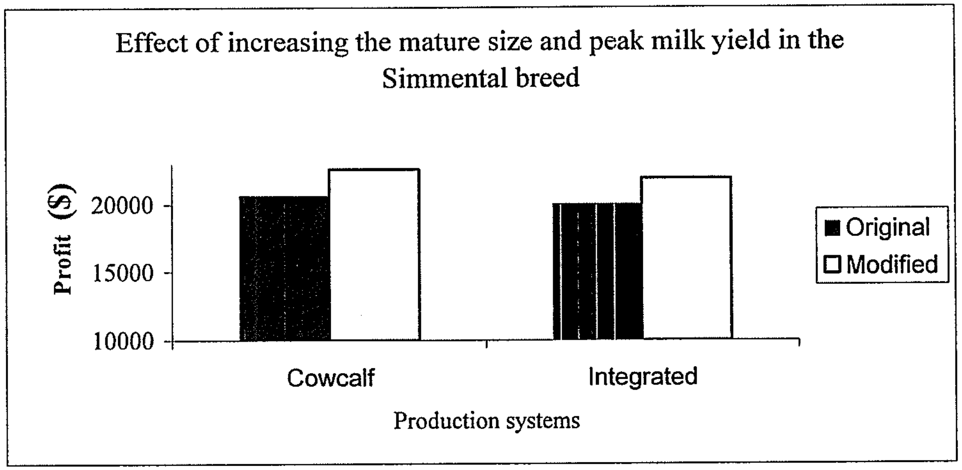
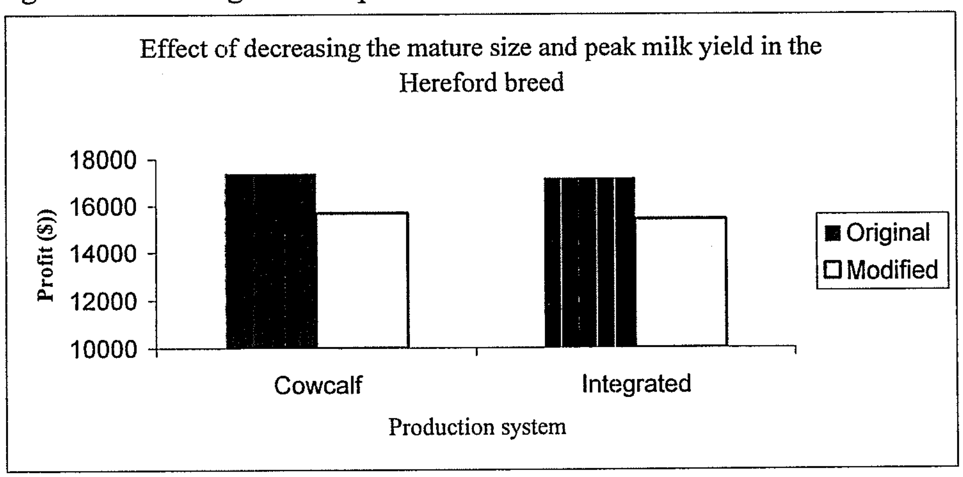


Figure 4.1b: Changes in the profit as a result of 10% decrease in mature size and peak milk yield in the Hereford breed.



4.3 Breed proportions in the optimum composite

The determinationof the optimum composite will be described in this section. The "v" matrix is a vector of the economic values for the various traits (t) to be selected and is based on the average (median) values of economic values by breeds for the various traits studied. Table 4.8 (a, b) also shows the economic values of the different traits incorporated in the optimization. The economic values of traits (per unit of measurement) under the two scenarios, the base scenario and the adjusted scenario (10% increases in the selling price of the heifers and steers) are shown. The matrix is of dimension t x 1. Figures 4.2 and 4.3 show the similarities in the relative economic values of the different traits, for clarity, the maximum and the minimum values have been indicated. The economic values of the traits to be incorporated in the optimization procedure have been expressed as dollars per unit of measurement.

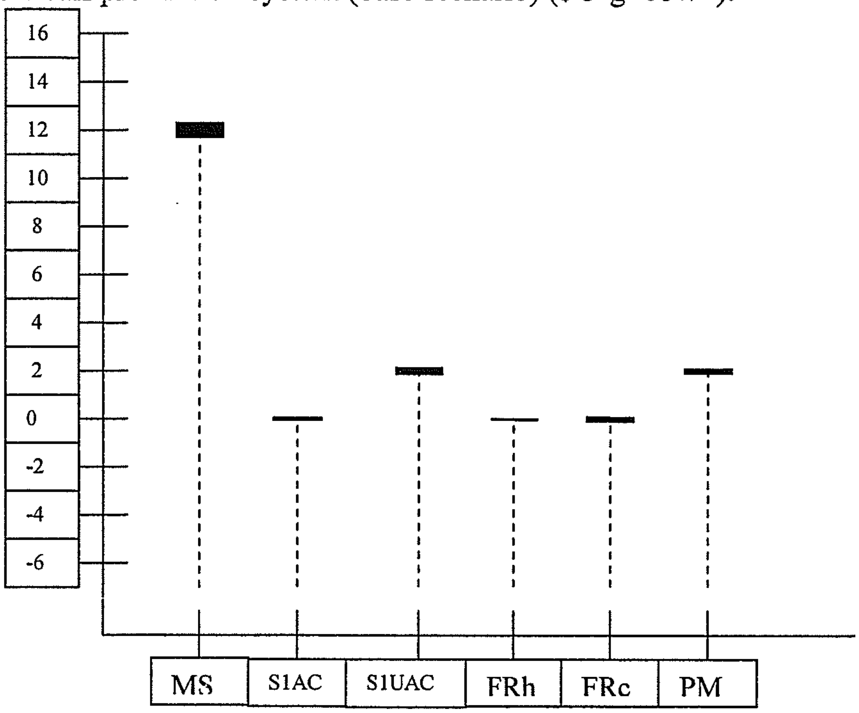
Table 4.8a: Direct heterosis estimates and mean economic values for traits in the base scenario.

			Economic values ($/Unit of trait)			
			Beef Improvement Ontario		Meat Animal Research Center	
Traits	Unit	Direct Heterosis %	Cow calf	integrated	Cow calf	integrated
Mature weight	Kg	3.0	0.32	0.36	0.33	0.39
Calf survival	%	4.0	6.46	6.48	6.25	6.34
Fertility rate of females	%	6.0	0.20	-0.10	0.20	-0.93
Peak milk yield	Kg	9.0	11.72	6.24	11.61	9.08

Table 4.8b: Direct heterosis estimates and mean economic values for traits in the adjusted scenario.

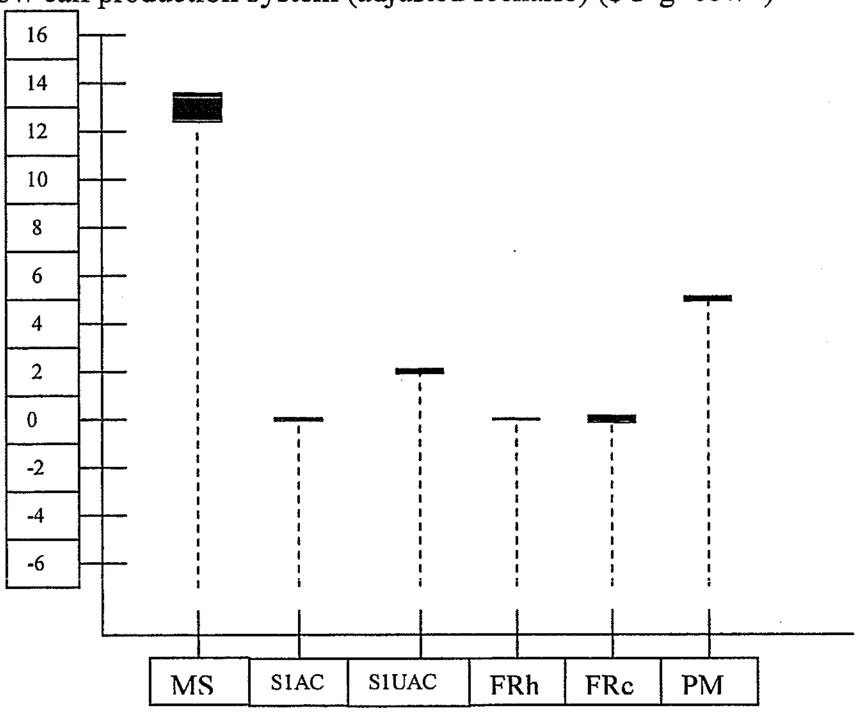
			Economic values ($/Unit of trait)			
			Beef Improvement Ontario		Meat Animal Research Center	
Traits	Unit	Direct Heterosis %	Cow calf	integrated	Cow calf	integrated
Mature weight	Kg	3.0	0.36	0.44	0.36	0.47
Calf survival	%	4.0	7.19	7.35	6.94	7.20
Fertility rate of females	%	6.0	0.56	0.33	0.54	0.34
Peak milk yield	Kg	9.0	12.88	7.02	12.77	9.43

Figure 4.2: Maximum and minimum economic values for the various traits in the BIO cow calf production system (base scenario) ($\$ \sigma g^{-1} cow^{-1}$).



Mature size (MS), Survival rate of calves with assisted calving (S1AC), Survival rate of cows with unassisted calving (S1UAC), Fertility rate of heifers (FRh), Fertility rate of cows (FRc), Peak milk yield (PM).

Figure 4.3: Maximum and minimum economic values for the various traits in the BIO cow calf production system (adjusted scenario) ($\$ \sigma g^{-1} cow^{-1}$)



Mature size (MS), Survival rate of calves with assisted calving (S1AC), Survival rate of cows with unassisted calving (S1UAC), Fertility rate of heifers (FRh), Fertility rate of cows (FRc), Peak milk yield (PM).

The T matrices are shown below. These represent deviations from the Simmental and are in units of $ per cow. The values of the purebreds are located on the diagonals and these were mostly negative values with respect to the Simmental values. The off-diagonals represent profitability of the F1 crosses and were mostly positive except the values in column 1 and 5 as well as rows 1 and 5.

For the cow calf production system, the T-matrices were:

T (BIO –base scenario) =

$$\begin{bmatrix} -60.58 & 2.08 & 0.22 & 6.49 & -17.89 & -5.48 \\ 2.08 & -8.97 & 27.54 & 33.81 & 9.43 & 21.84 \\ 0.22 & 27.54 & -12.34 & 31.95 & 7.57 & 19.98 \\ 6.49 & 33.81 & 31.95 & 0 & 13.84 & 26.25 \\ -17.89 & 9.43 & 7.57 & 13.84 & -46.10 & 1.86 \\ -5.48 & 21.84 & 19.98 & 26.25 & 1.86 & -23.33 \end{bmatrix}$$

T (MARC base scenario) =

$$\begin{bmatrix} -105.93 & 48.73 & -22.54 & -17.60 & -33.98 & -53.92 \\ 48.73 & -59.22 & 2.33 & 7.17 & -9.21 & -29.15 \\ -22.54 & 2.33 & -8.77 & 33.36 & 16.98 & -2.96 \\ -17.60 & 7.17 & 33.36 & 0 & 21.92 & 1.98 \\ -33.98 & -9.21 & 16.98 & 21.92 & -29.82 & -14.40 \\ -53.92 & -29.15 & -2.96 & 1.98 & -14.40 & -67.54 \end{bmatrix}$$

For the integrated system the T- matrices were

T (BIO base scenario) =

$$\begin{bmatrix} -52.02 & -0.07 & -0.56 & 4.42 & -15.83 & -6.49 \\ -0.07 & -9.30 & 21.88 & 26.86 & 6.62 & 15.96 \\ -0.56 & 21.88 & -10.05 & 26.37 & 6.12 & 15.46 \\ 4.42 & 26.86 & 26.37 & 0 & 11.10 & 20.44 \\ -15.83 & 6.62 & 104.20 & 11.10 & -38.54 & 0.20 \\ -6.49 & 15.96 & 15.46 & 20.44 & 0.20 & -21.51 \end{bmatrix}$$

T (MARC base scenario) =

$$\begin{bmatrix} -100.32 & -47.29 & -20.12 & -17.91 & -30.67 & -48.12 \\ -47.29 & -56.48 & 3.05 & 5.26 & -7.50 & -24.95 \\ -20.12 & 3.05 & -3.7 & 32.43 & 19.67 & 2.21 \\ -17.91 & 5.26 & 32.43 & 0 & 21.87 & 4.42 \\ -30.67 & -7.50 & 19.67 & 21.87 & -22.94 & -8.34 \\ -48.12 & -24.95 & 2.21 & 4.42 & -8.34 & -56.47 \end{bmatrix}$$

The T matrix for both methods in the optimization procedure indicated that the higher values of the Hereford and Limousin breeds resulted in negative relative to the purebred Simmental when combined with other breeds. In the MARC data set, the Hereford breed accumulated high negative performance although fewer combinations were negative. Such results may indicate shortcoming in the breed given the weighting factors (economic values) for the traits incorporated. These weights favor individual breeds with high performance for any of the traits (MS, S1, FR and PM) by assigning a high value to their outcome. In both the MARC and BIO data used, the Hereford breed consistently had the lowest performance for peak milk yield and mature weight (except in MARC data) whereas the Charolais breed had low values for the peak milk yield and also the lowest performance for the mean calf survival.

In deriving an optimum, the procedure chooses a combination which gives the highest net merit. Results of the optimum breed proportion for the six breeds (Hereford, Angus, Gelbvieh, Simmental, Charolais and Limousin) are shown in Tables 4.9(a, b). The initial results (with the BIO data set) using Lin's methodology to generate the optimum breed proportion given the values in the T matrices indicated negative proportions to two breeds (Hereford and Limousin) in the both production systems. Deleting these two breeds (Lin, 1996; Hayes et al. 2000) and a re-run of the program with the remaining breeds gave breed proportions shown in the table below for the different systems of production using the BIO and MARC data. The net profit from the optimum composition of each composite under each system is also shown in Table 4.9. These values are relative to the purebred Simmental which is the reference point. Breed proportions other than the optimum generate lower net economic merit in the composites for example a composite with 0% Hereford, 40% Simmental, 30% Gelbvieh and 10% each of the Angus, Limousin and Charolais would give a net economic value of $12.47/cow (MARC, cow calf) greater than that of the Simmental, thus less than the optimum ($24.38).

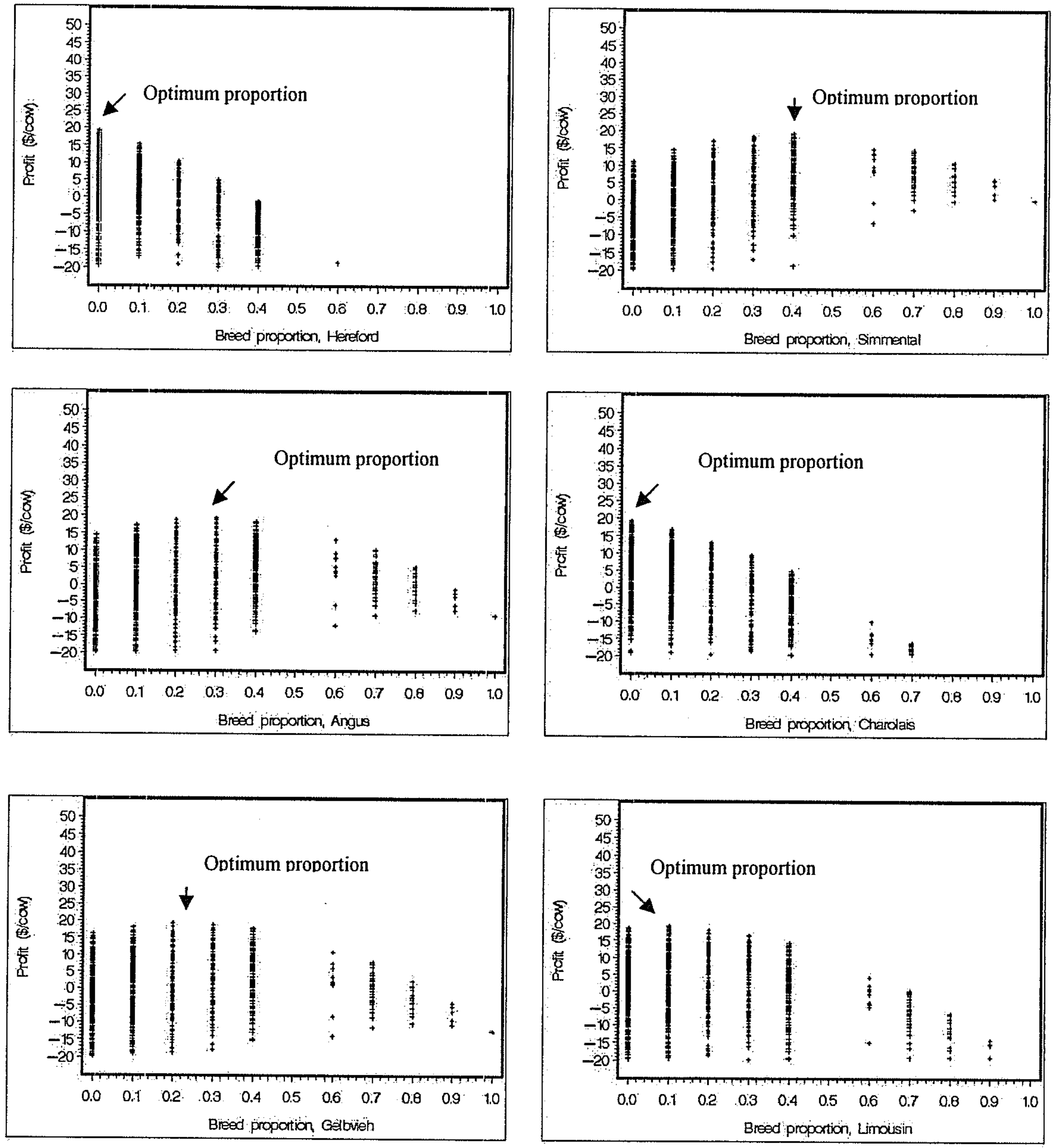
Table 4.9a: Breed proportions in the composite line (base scenario).

	Cow calf		Integrated	
Breed	BIO	MARC	BIO	MARC
Hereford	0.00	0.00	0.00	0.00
Angus	0.28	0.00	0.27	0.00
Gelbvieh	0.23	0.43	0.25	0.44
Simmental	0.40	0.36	0.41	0.34
Charolais	0.00	0.21	0.00	0.22
Limousin	0.09	0.00	0.07	0.00
Net value ($\$cow^{-1}$)	19.27	24.38	15.21	23.53
Breed additive value ($\$cow^{-1}$)	-7.45	-10.03	-3.52	-6.68
Heterosis value ($\$cow^{-1}$)	26.72	34.41	18.73	30.21

Table 4.9b: Breed proportions in the composite line (adjusted scenario).

	Cow calf		Integrated	
Breed	BIO	MARC	BIO	MARC
Hereford	0.00	0.00	0.00	0.00
Angus	0.29	0.00	0.27	0.00
Gelbvieh	0.22	0.51	0.23	0.52
Simmental	0.40	0.46	0.43	0.44
Charolais	0.00	0.03	0.00	0.04
Limousin	0.09	0.00	0.07	0.00
Net value ($\$cow^{-1}$)	21.99	24.37	17.28	23.76
Breed additive value ($\$cow^{-1}$)	-8.77	-6.87	-8.65	-3.90
Heterosis value ($\$cow^{-1}$)	30.76	31.24	25.93	27.66

Figure 4.4: Effect of breed proportion on the profit of the composite the cow-calf production system. Each of the six breeds are shown here and the optimum point for each breed is shown with an arrow. With each proportion for a breed, there is a vertical range in profit, which is the result of other breeds that are present. The optimum solution here is Hereford (0.0), Angus (0.28), Gelbvieh (0.23), Simmental (0.40), Charolais (0.0) and Limousin (0.09).



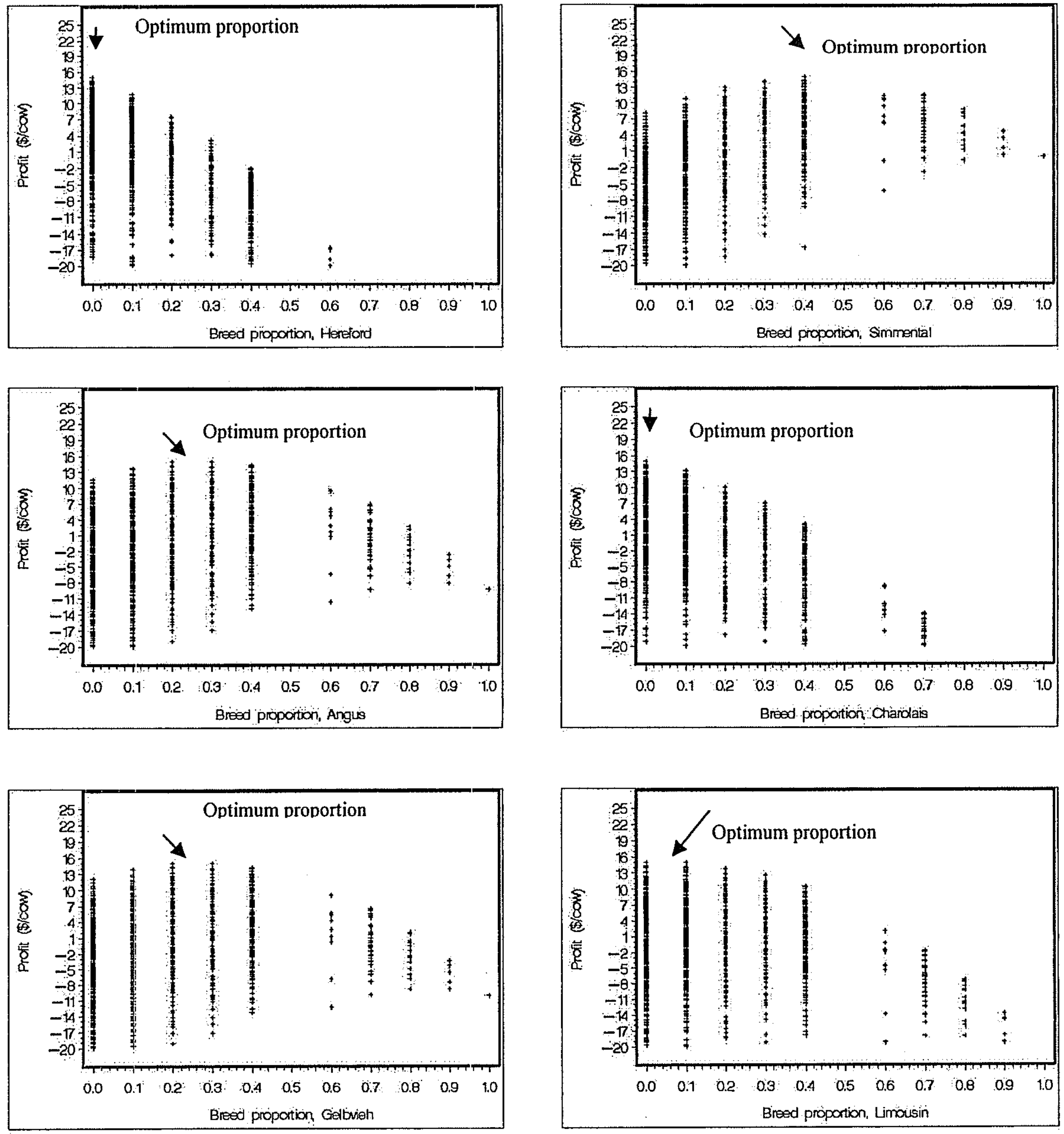


Figure 4.5: Effect of breed proportion on the profit of the composite in the integrated production system.
Each of the six breeds is shown here and the optimum point for each breed is shown with an arrow. With each proportion for a breed, there is a vertical range in profit, which is the result of other breeds that are present. The optimum solution here is
Hereford (0.0), Angus (0.27), Gelbvieh (0.25), Simmental (0.41), Charolais (0.0), and Limousin (0.07).

The optimum breed proportions in the composite for both sets of data (MARC vs BIO) were different even though similar reproductive parameters and survival rates for both sets of data. Use of the MARC data indicated that only three of the breeds (Gelbvieh, Simmental and Charolais) would produce the maximum net merit in the composite. The BIO data produced a maximum net merit with four breeds comprised of Angus, Gelbvieh, Simmental and Limousin.

In both data sets, the major component breed in the composite is the Simmental while the least was Charolais or Limousin. This is due to the high weight assigned to peak milk. Simmental was consistently the highest milking breed while the Hereford had the least size as well as milking ability. This would also contribute to consistent placement of a breed above others in both data sets.

Validation of the Lin's method involved calculating profit from all possible combinations of the six breeds. The results of this are shown in Figure 4.4 and 4.5. Each of the six graphs in a set shows the relationship between profit and the proportion of a given breed. Optimum points are indicated with arrows. This could be a useful tool for breeders who may intend some compromise either in profit or in heterosis. It will be noted that in some breeds e.g. Gelbvieh and Angus, the net profit is almost the same over a range of proportions, 0.1 to 0.3 (as shown in the graphs). The results shown in Figures 4.4 and 4.5 then avail the producer some flexibility in terms of choice of breed proportions in the composite that would give him similar profit level as the optimum breed proportion.

Tables 4.9a and 4.9b also indicate the breed additive and heterosis effects on profits for the optimum composite. The values are relative to the Simmental breed. The negative signs indicate lower performance than the Simmental breed. The contribution of the hybrid vigor was deduced from the T matrix given the optimum breed composition in the composite. For instance, in the cow calf system (base scenario) using the MARC data, the contribution of the breed additive effects (located in the diagonals of the T-matrix) in the composite excluding hybrid vigor would be $10.03 per cow lower than the value of the Simmental whereas the composite value incorporating the hybrid vigor gives $24.38 above the Simmental. It is important to note that heterosis for profit was a major part of the net value of the composite.

The degree of heterosis is proportional to the level of heterozygosity. Deviation from equal proportion of breeds in a composite reduces the hybrid vigor. The procedure thus makes a "choice" to have a higher level of heterozygosity with a lesser profit from the optimum or capitalize on the profit due to breed additive effects. This also fosters the retention of the maximum (F1) heterosis when more breeds are included. For example in the cow-calf production system, a producer intending to include Angus in less than 50% of the composite would be ready to lose some part of the profit.

The results in both procedures in the cow-calf system indicate that the Simmental or Gelbvieh breed forms the major breed in the composite that would maximize the net merit. This may be due to its high performance milking ability and also given that the economic value of the trait in the system is higher than other traits. The optimum composite would have combined effects of calf survival (Angus), size (Simmental and Charolais) and milking abilities (Simmental, Gelbvieh). These are important traits in both the cow-calf production system and the integrated production system.

Shrestha (2005) gave the illustration of the development of the 2-breed and 3-breed composites. In both cases, the crossings in the third generation of crossings were used to produce the composites. These conclusions about the best combination of breeds are based on the assessed value for breed mean performance. For the present study, the composite would be formed from animals that are breed average. There is much genetic variation within each breed (Cundiff, 2004) and the specific animals chosen to represent a breed could be much different than average. The results shown here give some indicators of the types of animals that may produce better results. For example, within limits of size dictated by market for slaughter animals, larger size seems to be better.

5. CONCLUSIONS

Two production systems were considered in the development of the economic values for traits of importance in beef production. Six breeds of beef cattle were evaluated for these traits and the profitability of the breeds under the two production systems were estimated. Given the costs and returns used in this study, the integrated system of production may not be favorable for such beef production environment. This is as a result of the losses in the value of the animals at finishing compared to the cow calf operations. The cow calf operation seems more profitable for this environment.

There is some influence of milk yield in the profitability of the beef industry especially the cow-calf production sector given the results of this study. Breeds with higher milking abilities were more profitable in the cow-calf system than in the integrated production system. Mature size alone does not determine profitability but contributes to it. Therefore selection of individuals for replacements should be based on total merit of the desired traits.

The economic values of traits among breeds were very much similar to one another under each production system. Such similarities suggest that the same economic value can be used for traits when comparing breeds or making selection of individuals for the development of a composite line. The mature size and calf survival as well as residual feed intake were observed to have high economic values indicating that improvement in these traits will be of high incentives to producers. The changes in the genotypes (mature size and peak milk yield) had significant effects on the profitability of the different production systems. The economic values of the most beef traits studied were not affected by changes in mature size and peak milk. The prices of products also have high influence on the outcomes of the economic values of the traits.

Breed means for various breeds from two studies were used to obtain the optimum composition of a composite line of beef cattle. Two scenarios were considered, the integrated production system (birth to feedlot-finish) and the cow-calf production system. Each system used economic values of important traits affecting the system which were contributors to the selection process of breeds that would maximize the net profit in the composite line.

The Angus, Gelbvieh, Simmental, Limousin and Charolais were found to give the maximum net merit in the composite using both systems of production using Lin's method and affirmed by the verification procedure. It can also be observed that hybrid vigor plays an important role in the formation of a composite by adding more value to the mix of breeds.

The results of the optimum breeds indicate that breeds with high milking ability had greater proportion in the composite due to the high economic value of the trait.

5.1 Future research

1. There is need for collation of more information on breeds that will suit the estimation models as those contained in later editions of the Beef Nutrient Requirements (NRC, 2000).
2. Additional research is required in development of programs that will model composite formations or crosses as well as indicating the number of individuals and generations required to achieve such results.

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APPENDIX

Appendix 1: Yearly averages for production costs (2000-2005)

parameters	2000	2001	2002	2003	2004	2005	Average
calf market price($/cwt) (575lbs)	145	152	120	100	100	130	124.5
Cost of straw @1ton/cow	15	20	22	22	18	20	19.5
Cost of straw @1ton/bull	15	20	22	22	18	20	19.5
Calf medication $/head	0.55	0.55	0.55	0.63	0.42	0.48	0.53
Cow medication $/head	13.06	13.34	13.34	13.84	13.84	12.68	13.35
Breeding costs $/bull	69	64	70	70	58	65	66
Bull replacement $/bull	2200	2500	2500	1800	1800	2200	2166.67
Pasture cost $/bull	52.36	51.59	50.14	48.53	51.55	60.86	52.51
Salvage value	1500	1800	1600	300	250	600	1008.33
Commission on calves $/head	15.75	15.75	15.75	15.75	15.75	15.75	15.75
Commission on cows $/head	18.25	18.25	18.25	18.25	18.25	18.25	18.25
Replacement cost of heifer	1200	1200	1000	800	800	1000	1000
Average cost of cow	1400	1400	1100	700	700	900	1033.33
Cull cow price (1350 lbs)	850	900	700	250	200	375	545.83
Community pasture grazing							
Cost/cow/day	0.35	0.36	0.36	0.36	0.36	0.36	0.36
Cost/calf/season	15	17	20	20	20	20	18.67

Yearly average slaughter prices for grades of beef carcass.
From Agriculture and Agri-Food Canada (2006)

Appendix 2: Prices of slaughter animals on liveweight basis.

Slaughter	2005 ($/cwt)	2004 ($/cwt)	2003 ($/cwt)	2002 ($/cwt)	2001 ($/cwt)	2000 ($/cwt)	Total ($/cwt)	$/lb	$/kg
Steers	80.47	71.74	90.22	96.91	103.45	95.28	89.68	0.90	1.97
Heifers	79.20	71.25	89.76	96.90	103.45	95.31	89.31	0.89	1.96
Cows D1,2	27.61	22.31	39.26	58.65	66.43	61.55	45.97	0.46	1.01
D3	18.30	14.58	32.47	53.04	57.81	53.26	38.24	0.38	0.84
Bulls	26.69	20.75	44.08	74.84	78.78	73.20	53.06	0.53	1.17

Yearly average slaughter prices for grades of beef carcass.
From Agriculture and Agri-Food Canada (2006)

Appendix 3: Feed material costs

Feed Material	$/tonne	$/kg	$/ME
Timothy hay[a]	81.47	0.08147	0.0395
Timothy hay	39.4[b]	0.039	0.0191
Barley grain[c]	120	0.12	0.0432
Alfalfa grass hay[c]	75	0.075	0.0371
Oats[c]	130.56	0.13056	0.0495

a Blawat et al. (2004)

b Rob Berry, Dairy cattle specialist, Manitoba Agriculture Food and Rural Initiatives.

c Manitoba Agriculture Food and Rural Initiatives, 2006.

Appendix 4: The profit equations

Total profit is generated from 5 classes of animals on the farm namely cows (Profc), bulls (Profb), steers (Profs) heifers (Profh) and replacement heifers (Profr). The total profit from a herd is the sum of profits from all the classes. The profit equations shown below are based on those used by Koots and Gibson (1998).

$$\text{Total profit} = \text{Profc} + \text{Profb} + \text{Profs} + \text{Profh} + \text{Profr}$$

Profits from cows (Profc): The profit from the cows is dependent on the returns from non-fertile and non-surviving cows less the cost of feeding for maintenance, lactation, gestation and costs of management and marketing.

$$\text{Profc} = (1 - \text{RR}) \times \text{NCw} \times \text{S3CS} \times ((1 - \text{FRc})\text{Rcwc} - \text{ES} \times \text{CEccw} - \text{CF4gm} - \text{CF5rf} - \text{ES} \times \text{CF6gr} - 0.5 \times (1 - \text{S3CS}) \times (\text{Rcwc} - \text{ES} \times \text{CEccw} - \text{CF4gm} - \text{CF5rf} - \text{ES} \times \text{CF6gr} - 0.5 \times (1 + \text{S1BW}) \times \text{ES} \times \text{CF7lr} - \text{Chm})$$

Profit from bulls (Profb): Profit from bulls depends on the returns from the bulls, cost of feed for maintenance and growth of the bulls as well as cost of purchasing the bulls and cost of bull management and marketing.

$$\text{Profb} = ((\text{NCw}/\text{FR})/25) \times (0.5 \times \text{Rcwb} - \text{Chmb} - \text{CF12gmb} - 0.5 \times \text{Cbp})$$

Profit from steers (Profs): The profit from steers depends on the number of steers, feed costs for growth and maintenance as well as management and marketing costs.

$$\text{Profs} = (0.5 \times \text{NCw} \times \text{ES} \times \text{S1BW} \times \text{S2WS}) \times (\text{Rcws} - \frac{\text{CEcclf}}{\text{S1BW} \times \text{S2WS}} - \frac{(1 + \text{S1BW}) \times \text{CF1nnmlk}}{2 \times \text{S1BW} \times \text{S2WS}} - \frac{(1 + \text{S2WS}) \times (\text{CF2gf} + \text{CF3rfig} + \text{Chg})}{2 \times \text{S2WS}})$$

Profit from heifers (Profh): The profit from heifers depends on the number of heifers sold, including replacement heifers that don't conceive and excluding the older replacement heifers, the feed costs for maintenance and growth as well as management and marketing costs.

$$Profh = (0.5 \times NCw \times ES \times S1BW \times S2WS - RR \times NCw) \times [Rcwh - \frac{CEcclf}{S1BW \times S2WS} - \frac{(1+S1BW) \times CF1nnmlk}{2 \times S1BW \times S2WS} - \frac{(1+S2WS) \times (CF2gf + CF3rfig + Chg)}{2 \times S2WS}] + RR \times Ncw \times (((1-FRh) \times Rcwh8) - \frac{CEcclf}{S1BW \times S2WS} - \frac{(1+S1BW) \times CF1nnmlk}{2 \times S1BW \times S2WS} - \frac{(1+S2WS)(CF2gf + CF3rfig + Chg)}{2 \times S2WS}]$$

Profit from replacement heifers (Profr): The profit for replacement heifers depends on the number of replacement heifers culled after their first calf, their feed costs for growth, maintenance, gestation and lactation. Other costs include management as well as marketing costs.

$$Profr = RR \times NCw \times S3CS \times [((FRc) \times Rcwr) - (\frac{CEcclf}{(S1BW \times S2WS)} + \frac{(1+S1BW) \times CF1nnmlk}{(2 \times S1BW \times S2WS)} + \frac{(1+S2WS) \times (CF8 + Chg)}{(2 \times S2WS)}) - (CF5rf + CF9gm + ES \times (CEccw + CF10gr) + 0.5 \times (1+S1BW) \times ES \times CF11lr + Chmr)]$$

$$+ 0.5 \times RR \times NCw \times (1 - S3CS) \times [Rcwr - 2 \times (\frac{CEcclf}{(S1BW \times S2WS)} + \frac{(1+S1BW) \times CF1nnmlk}{(2 \times S1BW \times S2WS)} + \frac{(1+S2WS) \times (CF8 + Chg)}{(2 \times S2WS)}) - (CF5rf + CF9gm + ES \times (CEccw + CF10gr) + 0.5 \times (1+S1BW) \times ES \times CF11lr + Chmr)]$$

Where Ncw is number of pregnant cows in the fall in the herd.
The animal traits related to fertility, survival and replacement are as follows:

FRh, FRc, FR are fertility rate of heifers, cows and mean herd fertility respectively
ES is embryonic survival rate
S1BW is calf survival from birth to weaning

S2WS is calf survival from weaning to slaughter
S3CS is average yearly cow survival
RR is replacement rate

Costs are as follows, feeding costs are calculated based on nutritional requirements of animals. Husbandry costs are given in Table 3.2

CEcclf, CEccw are cost of calving ease on calf and dam respectively
CF1nnmlk is cost for preweaning non-milk energy requirement (creep feed)
CF2gf, CF4gm, CF8, CF9gm are costs of energy requirements of stocker to finisher calves, cows, replacement heifers (weaning to18 months, and 18 to 13 months) for growth and maintenance
CF10gr, CF11lr are cost of energy requirements of cow for gestation and lactation respectively
CF3rfig, CF5rm are cost of residual energy intake in growing and mature animals
Chm8, Chg, Chm are husbandry costs in replacement heifers, growing and mature animals respectively

Returns from individual animals within each class are expressed as Rcwc (cows), Rcwb (bulls), Rcws (steers), Rcwh (heifers) and Rcwr (replacement heifers)

Appendix 5: Weight measures and average daily gains for the steers and heifers in both systems[x]

	Birth weight	Preweaning ADG	205 day Weaning weight	Growth phase ADG[z]	Growth phase ADG	296 day Growth Endweight	Finishing ADG[y]	Finishing ADG	Finish Endweight	Days on feedlot
Hereford										
Heifer	44.85	1.02	254.71	0.77	0.87	334.17	1.42	1.32	459.59	95
Steer	46.24	1.10	270.97	0.82	0.93	355.5	1.51	1.42	540.70	130
R.Angus										
Heifer	45.27	1.08	265.77	0.78	0.79	337.30	1.43	1.42	463.90	89
Steer	46.67	1.15	282.73	0.83	0.84	358.83	1.52	1.51	545.77	124
Gelbvieh										
Heifer	51.69	1.20	296.98	0.89	0.97	385.12	1.63	1.55	529.67	93
Steer	53.29	1.28	315.94	0.95	1.03	409.71	1.74	1.67	623.14	128
Simmental										
Heifer	51.58	1.23	303.70	0.89	0.89	384.30	1.63	1.62	528.54	89
Steer	53.17	1.32	323.09	0.95	0.94	408.83	1.74	1.73	621.82	123
Charolais										
Heifer	54.72	1.21	302.63	0.94	1.15	407.68	1.73	1.53	560.70	100
Steer	56.41	1.30	321.95	1.00	1.23	433.71	1.84	1.69	659.65	134
Limousin										
Heifer	49.48	1.08	269.99	0.85	1.08	368.64	1.56	1.36	507.00	102
Steer	51.01	1.15	287.23	0.91	1.15	392.17	1.66	1.49	596.47	137

Average Daily Gain (ADG)

[z] Derived from the growth curve given the actual weaning weights without maternal effects.

[y] Derived by adjusting the average daily gain using the Brody growth curve.

[x] Breed average performance values from Meat Animal Research Center

Appendix 6: Weight measures and average daily gains for the steers and heifers in both systems[x]

	Birth weight	Preweaning ADG	205 day Weaning weight	Growth phase ADG[z]	Growth phase ADG	296 day Growth Endweight	Finishing ADG[y]	Finishing ADG	Finish Endweight	Days on feedlot
Hereford										
Heifer	48.97	1.12	278.11	0.84	0.95	364.88	1.55	1.44	501.82	95
Steer	50.49	1.20	295.86	0.90	1.01	388.17	1.65	1.56	590.38	130
R.Angus										
Heifer	49.83	1.18	291.31	0.86	0.88	371.29	1.58	1.55	510.64	90
Steer	51.37	1.26	309.90	0.91	0.94	394.99	1.68	1.66	600.76	124
Gelbvieh										
Heifer	50.73	1.19	293.95	0.87	0.92	377.99	1.60	1.54	519.86	92
Steer	52.30	1.27	312.71	0.93	0.98	402.12	1.71	1.66	611.60	126
Simmental										
Heifer	53.39	1.22	397.8	0.92	1.03	397.80	1.69	1.57	547.11	95
Steer	55.04	1.31	323.31	0.98	1.10	423.19	1.80	1.71	643.66	129
Charolais										
Heifer	52.83	1.18	293.70	0.91	1.10	393.66	1.67	1.49	541.41	99
Steer	54.47	1.26	312.45	0.97	1.17	418.78	1.78	1.64	636.95	133
Limousin										
Heifer	50.10	1.18	291.08	0.86	0.90	373.31	1.58	1.54	513.43	91
Steer	51.65	1.26	309.66	0.92	0.96	397.14	1.69	1.64	604.03	126

Adjusted Hereford (Hereford3); Adjusted Simmental (Simmental3); Average Daily Gain (ADG)
[z]Derived from the growth curve given the actual weaning weights without maternal effects.
[y] Derived by adjusting the average daily gain using the Brody growth curve.
[x] Breed average performance values from Beef Improvement Ontario

Appendix 7: The FORTRAN codes for calculation

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!Program for the Simmental breed in integrated production system where steers
!and the heifers are sold at finish time.
Program All1

Implicit none

Real :: A, B, k, NCw, CFPasture, Chm, Chmb, Chmr, Frac, &
        NEmCreep,NEmGrow, NEmFL, NEmWinter,NEmPasture, &
        NEgCreep, NEgGrow, NEgFL,NEgWinter,NEgPasture, &
        MECreep, MEGrow, MEFL, MEWinter, MEPasture, &
        TotMEP18,
TotMEPast18,TotMEWinter,TotMEPasture,TotMELactW,TotMEPregW,TotMELactP,TotMEPreg
P, &
        TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR, &
        NCw, ES, S1BW, S2WS, S3, S3CS, RR, FR, FRh, FRc,  &
        Rcwh, Rcws,Rcwr,Rcwb,Rcwc, MCs, MCh, MCr,MCc,MCb, PValue, AValue,
MilkYield, W540, &
        DaystoPeak,PeakMilk,MilkEnValm,MilkEnValg,MEMilk,MilkEnVal,&
        CF1nnmlk, CF2gf, CF3rfig,CF4gm,CF5rf, CF6gr,CF7lr, CF8gm, CF9gm,
CF10gr,CF11lr,&
        Chg, CEcclf, CEccw, DP, DPr,DPc,Cbp,CcsPb,CcsPh, CcsPs,
CcsPr,CcsPc,CcsPh8,MCh8,Chg8, &
        RFIG, RFIM,CF1,CFGrow,CFPasture,
CFWinter,CFFdlot,BirthWts,BirthWth,MBirthWt, &
        PROFh, PROFs,PROFr,PROFb,PROFc, Profit, PrChange, PrChPerGSD,
PrChGSDCow, &
        ACalvh, ACalvc, S1AC, S1UAC,FinishADGh

Character(Len=10), Dimension(10) :: TraitName
Real, Dimension(10) ::  TraitMean, Herit, PSD, GSD, ProfList(0:10)

!Age distribution is returned from cow subroutines and is calculated from
fertility
! rates of cows and heifers
Real :: AgeDist(9),coweight(9)

Integer IT, NT

Open(22,File='all1detail.out', Status='REPLACE',Access='SEQUENTIAL',
Action='WRITE')

!Breed size parameters
       A=845.7; k=0.0022; DP=0.613 !DP is that of steers and heifers
       BirthWts=0.0667*A;BirthWth=0.064699*A;MBirthWt=(BirthWts+BirthWth)/2
       B=(A-MBirthWt)/A
!Assisted calving in cows and heifers
       ACalvh=0.25; ACalvc=0.06
!Survival and fertility rates
       ES=.98
       S1AC=0.83; S1UAC=0.9011   ! Survival rates of calves from assisted and
unassisted calvings
       S2WS=1.00; S3=.98; RR=0; FRh=.817;FRc=.908
       CEcclf=6.23; CEccw=0.86
!Milk parameters
       DaystoPeak=70; PeakMilk=10.5; MilkEnValm=0.5256
       MilkEnValg=0.4444; MEMilk=0.6348;MilkEnVal=0.7031
!Herd size
       NCw=50.
!Feed characteristics
       NEmCreep=1.85; NEgCreep=1.22; MECreep=2.78
       NEmPasture=1.54; NEgPasture=0.94; MEPasture=2.42
```

```
       NEmGrow=1.436; NEgGrow=0.848; MEGrow=2.314
       NEmFL=1.904; NEgFL=1.262; MEFL=2.858
!       NEmFL=2.06; NEgFL=1.4; MEFL=3.04
       NEmWinter=1.456; NEgWinter=0.866; MEWinter=2.334
!Feed and husbandry costs
       CF1=0.0495; CFGrow=0.0239; CFFdlot=0.0384;
       CFWinter=0.0275; CFPasture=0.0048; Cbp=2166.67
       Chm=43.38; Chg=46.82; Chmb=76.00; Chmr=43.38; RFIG=0.; RFIM=0.
!Carcass and marketing prices
       CcsPh=1.965; CcsPs=1.973;
CcsPr=1.965;CcsPc=0.890;CcsPb=1.096!;CcsPc=1.011;CcsPb=1.221
       MCh=0.025; MCs=0.025; MCr=0.025; MCc=0.030; MCb=0.030
       CcsPh8=1.965; MCh8=0.030; Chg8=48.00

       CcsPh=CcsPh*1.1; CcsPs=CcsPs*1.1

!  Calculate genetic standard deviation for each trait
!
NT=10
TraitName(1)='A'; TraitName(2)='S1AC'; TraitName(3)='S1UAC';
TraitName(4)='RFIG'; TraitName(5)='RFIM'
TraitName(6)='FRh'; TraitName(7)='FRc'
TraitName(8)='S1BW' ; TraitName(9)='S3';TraitName(10)='PeakMilk'

TraitMean(1)=A; TraitMean(2)=S1AC; TraitMean(3)=S1UAC
TraitMean(4)=RFIG; TraitMean(5)=RFIM
TraitMean(6)=FRh; TraitMean(7)=FRc
TraitMean(8)=S1BW; TraitMean(9)=S3
TraitMean(10)=PeakMilk

Herit(1)=0.5; Herit(2)=.14; ; Herit(3)=.14; Herit(4)=.35
Herit(5)=0.35; Herit(6)=.27; Herit(7)=.27
Herit(8)=.14; Herit(9)=0.04; Herit(10)=0.13

PSD(1)=54.; PSD(2)=0.01; PSD(3)=0.01; PSD(4)=1.3
PSD(5)=1.3; PSD(6)=0.01
PSD(7)=0.01; PSD(8)=0.01; PSD(9)=0.01; PSD(10)=1.10
Do IT=1, NT
  GSD(IT)=Sqrt( Herit(IT)*PSD(IT)*PSD(IT) )
EndDo

Frac=.05
!----------------------------------------
!----------------------------------------
! Loop for each trait to evaluate for effect on profit

Do IT=0, NT
  If (IT.eq.1) then
    A=A+(Frac*PSD(1))
  EndIf
  If (IT.eq.2) then
    A=A-(Frac*PSD(1))
    S1AC=S1AC+(Frac*PSD(2))
  EndIf
  If (IT.eq.3) then
    S1AC=S1AC-(Frac*PSD(2))
    S1UAC=S1UAC+(Frac*PSD(3))
  EndIf
  If (IT.eq.4) then
    S1UAC=S1UAC-(Frac*PSD(3))
    RFIG=RFIG+(Frac*PSD(4))
  EndIf
  If (IT.eq.5) then
```

```
    RFIG=RFIG-(Frac*PSD(4))
    RFIM=RFIM+(Frac*PSD(5))
  EndIf
  If (IT.eq.6) then
    RFIM=RFIM-(Frac*PSD(5))
    FRh=FRh+(Frac*PSD(6))
  EndIf
  If (IT.eq.7) then
    FRh=FRh-(Frac*PSD(6))
    FRc=FRc+(Frac*PSD(7))
  EndIf
  If (IT.eq.8) then
    FRc=FRc-(Frac*PSD(7))
    S1BW=S1BW+(Frac*PSD(8))
  EndIf
  If (IT.eq.9) then
    S1BW=S1BW-(Frac*PSD(8))
    S3=S3+(Frac*PSD(9))
  EndIf
  If (IT.eq.10) then
    S3=S3-(Frac*PSD(9))
    PeakMilk=PeakMilk+(Frac*PSD(10))
  EndIf
!----
! Use Fertility rates of heifers (FRh) and cows (FRc) to calculate
! proportion of cows in each of 9 age groups, (2,3, ... 10)
! Replacement Rate (RR) becomes the proportion of animals in the youngest age
group
  Call CowAge(FRh, FRc, AgeDist, IT)
  RR=AgeDist(1)
  Write(*,295) IT, FRh, FRc, AgeDist, RR
295 Format(/'Trait#',I4,' FRh=',F8.4,'
FRc=',F8.4,/'AgeDist=',9F8.4,/'RR=',F8.4)

! Calculate S1BW = S1Prime from KG32
!
  S1BW=RR*(ACalvh*S1AC+(1-ACalvh)*S1UAC) + (1-RR)*(ACalvc*S1AC+(1-
ACalvc)*S1UAC)

! Calculate S3CS as the weighted average of S3 and 0 (zero for proportion of
the herd
! that is 10-year-old cows)
  S3CS=S3*(1-AgeDist(9))

!FR is calculated as the weighted mean fertility of the herd from the FRc and
FRh
  FR=(1-RR)*FRc+RR*FRh

Write (*,296) S3CS,S1BW
296 Format (' S3prime and S1prime are=', 2F8.2)
!-------
  Call Cow1 (A, B, k,FRh,FRc,NEmWinter, NEgWinter, MEWinter,NEmPasture,
NEgPasture, MEPasture,&
            DP, DPc, RR, NCw, CEcclf,S1BW, S2WS, S3CS, Chg,Chm, ES, CEccw,
MCc,CcsPc,&
            DaystoPeak, PeakMilk, MilkEnVal,coweight,&

TotMEWinter,TotMEPasture,TotMELactW,TotMEPregW,TotMELactP,TotMEPregP,&

AgeDist,TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR,&
            CFWinter,CFPasture,CF4gm,CF5rf,CF6gr,CF7lr,RFIM,Rcwc,PROFc,IT)
  Write (*,205) CF4gm,CF5rf,CF6gr,CF7lr,Rcwc,PROFc
205   Format (/'For cows: gromain resid gest lact returns profit'/6f12.2)
```

```
  Call Bull1 (A, B, k, FR, NEmPasture, NEgPasture, MEPasture, NCw, DP, Cbp,
CcsPb,&
           CFPasture,NEmWinter, NEgWinter, MEWinter, Chmb, Rcwb, PROFb,
MCb,CF5rf,RFIM, IT)
  Write(*,200) Rcwb,PROFb
200   Format(/'For Bulls: rqmt Totals for CF12, Rcwb and Profit:'/ &
           46x,2F8.2,4x,F8.2)

  Call RepHeifer1 (A, B, k,NEmCreep, NEgCreep, MECreep,NEmPasture, NEgPasture,
MEPasture,&
                    NEmGrow, NEgGrow, MEGrow,NEmWinter, NEgWinter, MEWinter, &
                    RR, NCw, FRc, CEcclf,S1BW, S2WS, S3CS, Chg,Chmr, ES, CEccw, &
                    DaystoPeak, PeakMilk, MilkEnValm,MilkEnValg, MEMilk,&

TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR, W540, &
                    CF5rf, CF8gm, CF9gm, CF10gr, CF11lr, CF1nnmlk,RFIM, &
                    CF1, CFWinter, CFPasture, CFGrow, DPr, DP,
CcsPr,CcsPc,MCr,TotMEP18, TotMEPast18, &
                    PROFr, Rcwr, IT,BirthWth)

  Write(*,203) CF1nnmlk, CF5rf, CF8gm, CF9gm, CF10gr,CF11lr, Rcwr, PROFr
203   Format(/'For RHeifers: profit inputs: nnmlk rfi fdbf18  afta18 preg  lact
returns profit'/ &
            10x,7F8.2,2x,F8.2)

  Call Heifer1 (A, B, k, RFIG, NEmCreep, NEgCreep, MECreep,
NEmPasture,NEgPasture, &
                 MEPasture, NEmGrow, NEgGrow, MEGrow,NEmFL, NEgFL, MEFL,  DP, &
                 DaystoPeak, PeakMilk, MilkEnValm,MilkEnValg, MEMilk,
W540,FinishADGh, &
                 NCw, ES, S1BW, S2WS, RR, FRh, CEcclf,CF1nnmlk, CF2gf, CF3rfig,
CF8gm, &
                 CcsPh8,MCh8,Chg8,Chg,CcsPh, MCh, CF1, CFPasture,CFFdlot,CFGrow,
PROFh, Rcwh, IT,BirthWth)
  Write(*,201) Rcwh, CF1nnmlk, CF3rfig, CF2gf, PROFh
201   Format(/'For Heifers: totals are Rcwh CF1nnmlk CF3rfig CF2gf PROFh :'/ &
            46x,4F8.2,2x,F8.2)

  Call Steer1 (A, B, k,NEmCreep, NEgCreep, MECreep,NEmPasture, NEgPasture,
MEPasture,&
                 NEmGrow, NEgGrow, MEGrow,NEmFL, NEgFL, MEFL,NCw, ES, S1BW, S2WS,
RR, FRh,&
                 DaystoPeak, PeakMilk, MilkEnValm,MilkEnValg, MEMilk,
Chg,FinishADGh,&
                 CF3rfig, CEcclf, CF8gm, DP,CcsPs, MCs, CF1, RFIG, CFPasture,
CFFdlot,&
                 CFGrow, PROFs,Rcws, IT,BirthWts)
  Write(*,202) Rcws, CF1nnmlk, CF3rfig, CF2gf,  PROFs
202   Format(/'totals are Rcws CF1nnmlk CF3rfig CF2gf PROFs :'/ &
            46x,4F8.2,2x,F8.2)

  Profit=PROFc+PROFs+PROFr+PROFb+PROFh
  Write(*,126) IT, Profit
126  Format(/'IT=',I3,' Profit=PROFc+PROFs+PROFr+PROFb+PROFh=',F20.4)

  ProfList(IT)=Profit

EndDo

Write(*,127) Frac
127   Format('Fractional change used to increment traits to evaluate
Ec.Val.=',f6.4, &
```

```
              /'Traits and change in profit per Frac*PSD unit' &
              /'then per GSD unit and per GSD unit per cow' &
              /' TrNum     Trait Name   NewProf    OldProf', &
               '  ProfCh10      GSD       PSD  ProfChGSD  PrChGSDCow')
Do IT=1, NT
  PrChange=ProfList(IT)-ProfList(0)
  PrChPerGSD=PrChange*(sqrt(Herit(IT))/Frac)
  PrChGSDCow=PrChPerGSD/NCw

  Write(*,128) IT,TraitName(IT), ProfList(IT),ProfList(0),PrChange,GSD(IT),
PSD(IT), &
         PrChPerGSD,PrChGSDCow
128  Format(I6,5x,A10,3F10.2,2F10.4,2F10.4)
EndDo

Stop
End Program All1
!-----------------------------------------------------------------------
Subroutine Bull1 (A, B, k, FR, NEmPasture, NEgPasture, MEPasture, NCw, DP, Cbp,
CcsPb, &
           CFPasture,NEmWinter, NEgWinter, MEWinter, Chmb, Rcwb, PROFb,
MCb,CF5rf,RFIM, IT)

Implicit none

Real :: A, B, k, TNEm=0., TNEg=0., &
        NEmWinter, NEgWinter, MEWinter, &
        NEmPasture, NEgPasture, MEPasture

Real :: TNEm, TNEg, TotMEPasture, TotPasture,TotMEWinter, TotWinter, &
        Weight, InitialWeight, EndWeight, ADG, Weight

!important inputs for profit
Real :: CFWinter, CFPasture, Rcwb, PROFb, CF12gmb=0.,&
        Chmb, Cbp,CF5rf,RFIM

!Perculiar inputs
Real :: NCw, FR, DP, DPb,CcsPb, MCb

! Significant days
Real :: BullStartDay=365, BullEndDay=900, PastureStartDay=62, PastureEndDay=244

Integer :: I, J, JJ, BullAge, IT
Real, Dimension(550) :: NEm, NEg, DMIPasture, DMIWinter

NEm=0.; NEg=0.; DMIPasture=0.; DMIWinter=0.

BullAge=BullStartDay;J=0.

DPb=DP-0.03

If (IT.eq.0) Write(22,100) PastureStartDay, PastureEndDay, BullStartDay,
BullEndDay
100 Format('Bull1'/'Significant days:'/, &
            '  PastureStartDay=',F6.0/, &
            '  PastureEndDay=  ',F6.0/, &
            '  BullStartAge=   ',F6.0/, &
            '  BullEndAge=     ',f6.0)

Do I=1,2
  If (I.eq.1) then
    BullAge=BullStartDay
    InitialWeight=A*0.78*1.5
```

```
!     InitialWeight=A*1.5*(1.0-B*exp(-k*BullAge))
    Weight=InitialWeight
    EndWeight=A*1.5*(1.0-B*exp(-k*(BullAge+365)))
    ADG=(EndWeight-Weight)/365.
  EndIf
  If (I.eq.2) then
    BullAge=BullStartDay+365
    InitialWeight=A*1.5*(1.0-B*exp(-k*BullAge))
    Weight=InitialWeight
    EndWeight=A*1.5*0.8595    !KG34
!     EndWeight=A*1.5*(1.0-B*exp(-k*BullEndDay))
    ADG=(EndWeight-Weight)/(BullEndDay-BullAge)
  EndIf

  If(IT.eq.0) Write(22,101) I, BullAge, InitialWeight, EndWeight, ADG
101 Format('Significant days, weights and ADG:'/, &
            '  Year=             ',I6/, &
            '  BullStartAge=     ',I6/, &
            '  StartWeight=      ',F8.2/, &
            '  EndWeight=        ',F8.2/, &
            '  ADG=              ',F8.4)
  If (IT.eq.0) Write(22,200)
!           123412341234123456781234567812345678123456781234567812345678
200 Format(/'Year Day Age   Weight    NEm     NEg  DMIPasture  DMIWinter')

  Do JJ=1,365
    BullAge=BullAge+1
    J=J+1
    If ((I.gt.1).and.(BullAge.gt.BullEndDay)) exit
    If ((JJ.ge.PastureStartDay).and.(JJ.LE.PastureEndDay)) then
      NEm(J)=(0.077*Weight**0.75)*1.1  !increase in 10% during pasture
      NEg(J)=(0.0493*(Weight**0.75)*ADG**1.097)
      DMIPasture(J)=NEm(j)/NEmPasture+NEg(J)/NEgPasture
      Weight=Weight+ADG
    EndIf

    If ((JJ.lt.PastureStartDay).or.(JJ.GT.PastureEndDay)) then
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0493*(Weight**0.75)*ADG**1.097)
      DMIWinter(J)=NEm(J)/NEmWinter+NEg(J)/NEgWinter
      Weight=Weight+ADG
    EndIf

    If(IT.eq.0)Write(22,201)
I,JJ,BullAge,Weight,NEm(J),NEg(J),DMIPasture(J),DMIWinter(J)
201 Format(3I4,F8.2,4F8.4)

  EndDo
EndDo

TNEm=Sum(NEm); TNEg=Sum(NEg); TotPasture=Sum(DMIPasture);
TotWinter=Sum(DMIWinter)
TotMEWinter=TotWinter*MEWinter; TotMEPasture=TotPasture*MEPasture

      CF5rf= (RFIM*((364*CFWinter)+(366*CFPasture))*1.5)/1.466
      CF12gmb=(((TotMEWinter*CFWinter)+(TotMEPasture*CFPasture))*1.5)/1.466
      Rcwb = (Weight*(CcsPb-MCb))/1.466
      PROFb= ((NCw/FR)/25)*(0.5*Rcwb-Chmb-CF12gmb-0.5*Cbp)

If (IT.eq.0) Write(22,202)
!           12341234567812345678123456781234567812345678123456781234567 8
202 Format('Bull1'/'                          NEm     NEg  DMIPasture DMIWinter')
```

```
If (IT.eq.0) Write(22,203) TNEm, TNEg, TotPasture, TotWinter

!            1234567 101234567 20
203 Format(/'DMI and NE Totals:'/,20x,4F8.2/)

If (IT.eq.0) Write(22,204) TotMEPasture, TotMEWinter
204 Format(/'ME Totals:'/ &
           36x,2F8.2)

Return
End subroutine bull1
!------------------------------------------------------------------------
Subroutine Heifer1 (A, B, k, RFIG, NEmCreep, NEgCreep, MECreep,
NEmPasture,NEgPasture, &
               MEPasture, NEmGrow, NEgGrow, MEGrow,NEmFL, NEgFL, MEFL,  DP, &
               DaystoPeak, PeakMilk, MilkEnValm, MilkEnValg, MEMilk,
W540,FinishADGh, &
               NCw, ES, S1BW, S2WS, RR, FRh, CEcclf,CF1nnmlk, CF2gf, CF3rfig,
CF8gm, &
               CcsPh8,MCh8,Chg8,Chg,CcsPh, MCh, CF1, CFPasture,CFFdlot,CFGrow,
PROFh, Rcwh, IT,BirthWth)

Implicit none

Real :: A, B, k, TNEm=0., TNEg=0., &
        NEmCreep, NEgCreep, MECreep, &
        NEmPasture, NEgPasture, MEPasture, &
        NEmGrow, NEgGrow, MEGrow, FinishADGh,&
        NEmFL, NEgFL, MEFL, ADJ=1.25

! Milk production parameters
Real :: DaystoPeak, PValue, AValue, PeakMilk, MilkYield
Real :: MilkEnValm     !Calculate as 5.29 Mcal ME/kg DM (12%DM) (KG34)
                               ! 0.828 efficiency of use for
maintenance(.6348*.828)
Real :: MilkEnValg     ! 0.700 efficiency of use for gain (0.6348*.700)
Real :: MEMilk

!important inputs for profit - values are received from the main calling
program
Real :: NCw, ES, S1BW, S2WS, RR, FRh, CF1nnmlk, &
        Rcwh, CF2gf, CF3rfig, Chg, CEcclf, CF8gm, DP, W540, &
        CcsPh, MCh, CF1, RFIG, CFPasture, CFFdlot, &
        CFGrow, PROFh, &
        CcsPh8,Rcwh8,MCh8,Chg8

Real :: WeaningDay=205, PastureStartDay=62, PastureEndDay=244, &
          GrowEndDay=296, FinishEndDay=600
Real :: BirthWt, WeaningWt,WeaningWti, NnMlk, PreWeanADG,BirthWth, &
          GrowEndWt, GrowADG,FinishEndWt, FinishADG,FinishADGi, Weight,
MeanFLWt, ADG,  &
          FinalDay, FFM, FFG, DMI, WE, TNEm, TNEg, TotMilk, TotCreep,
TotPasture, TotGrow, &
          TotFeedlot, TotMEMilk, TotMECreep, TotMEPasture, TotMEGrow,
TotMEFeedlot, &
          x1, DiffNEm, DiffNEg

Integer :: J, IT, FinalDayi
Real, Dimension(700) :: NEm, NEg, Wt,wtw, DMIMilk, DMICReep, DMIPasture,
DMIPast, &
                         DMIGrow, DMIFeedlot

PValue=1./DaystoPeak
```

```
AValue=DaystoPeak/(exp(1.)*PeakMilk)

BirthWt=BirthWth
Weight=BirthWt

WeaningWt=(87.7+0.202*A+6.04*PeakMilk)*0.94 !(KG33)
WeaningWti=(A*(1.0-B*exp(-k*WeaningDay)))*0.94
PreWeanADG=(WeaningWt-BirthWt)/WeaningDay

GrowEndWt=(A*(1.0-B*exp(-k*GrowEndDay)))*0.94   !as compared with the value got
from KG43
!GrowEndWt=A*0.47 !if heifers attain 47% of A at this time.
GrowADG=(GrowEndWt-WeaningWti)/(GrowEndDay-WeaningDay)
FinishEndWt=0.663*A

!-----------we need a do loop to get the average finishADG before adjustment
Do J=297,700
      wtw(J)=(A*(1.0-B*exp(-k*(J))))*0.94
   If (wtw(J).ge.FinishEndWt) then
    FinalDayi=J; Exit
   EndIf
EndDo
Write(*,600) FinalDayi,wtw(297),wtw(FinalDayi)
600 Format (/'the final day for heifers is ='/ I4, 2F8.3)
FinishADGi=(wtw(FinalDayi)-wtw(297))/(FinalDayi-GrowEndDay)
!-----------------
FinishADGh=FinishADGi*2.6
FinishADG=FinishADGh

!FinishEndDay=GrowEndDay+(FinishEndWt-GrowEndWt)/FinishADG

MeanFLWt=(FinishEndWt+GrowEndWt)/2.
!234567 101234567 201234567 301234567 401234567 501234567 601234567 701234567
80
If (IT.eq.0) Write(22,190) PastureStartDay, WeaningDay, PastureEndDay, &
          GrowEndDay, FinishEndDay
190 Format('Heifer1'/'Significant days (should form a progression):'/, &
            '  Calving Day=       0.'/, &
            '  PastureStartDay=',F6.0/, &
            '  WeaningDay=      ',F6.0/, &
            '  PastureEndDay=   ',F6.0/, &
            '  GrowEndDay=      ',F6.0/, &
            '  FinishEndDay=    ',F6.0, ' or when target weight is reached')

If (IT.eq.0) Write(22,191) BirthWt, WeaningWt, PreweanADG, GrowEndWt, GrowADG,
FinishEndWt, FinishADG
191 Format(/'Significant weights:' &
           /' BirthWt=      ',F8.2, &
           /' WeaningWt=    ',F8.2,' PreweanADG=   ',F8.4, &
           /' GrowEndWt=    ',F8.2,' GrowADG=      ',F8.4, &
           /' FinishEndWt= ',F8.2,' FinishADG=    ',F8.4)

NEm=0.; NEg=0.; DMIMilk=0.; DMICReep=0.; DMIPasture=0.; DMIGrow=0.;
DMIFeedlot=0.
CF1nnmlk=0.
If (IT.eq.0) Write(22,200)
!            1234123456781234567812345678123456781234567812345678
200 Format('Heifer1'/'IDay  Weight    ADG     NEm     NEg  DMIMilk DMICree', &
                '  DMIPast DMIGrow DMI-FL')

Do J=1,FinishEndDay

    If (J.LT.PastureStartDay) then
```

```
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0686*(Weight**0.75)*PreWeanADG**1.119)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm              ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMICreep(J)=0.
         Else
            DMIMilk(J)=MilkYield*0.12
            DMICreep(J)=(NEg(J)-DiffNEg)/NEgCreep
         EndIf
      Else
        DMIMilk(J)=MilkYield*0.12
        DiffNEm=(x1-MilkYield)*MilkEnValm
        DMICreep(J)=DiffNEm/NEmCreep+NEg(J)/NEgCreep
      EndIf
      ADG=PreWeanADG
      Weight=Weight+ADG
    EndIf

    If ((J.GE.PastureStartDay).and.(J.LE.WeaningDay)) then
      NEm(J)=(0.077*Weight**0.75)*1.1  !increase in 10% during pasture
      NEg(J)=(0.0686*(Weight**0.75)*PreWeanADG**1.119)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm              ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMIPasture(J)=0.
         Else
            DMIMilk(J)=MilkYield*0.12
            DMIPasture(J)=(NEg(J)-DiffNEg)/NEgPasture
         EndIf
      Else
        DMIMilk(J)=MilkYield*0.12
        DiffNEm=(x1-MilkYield)*MilkEnValm
        DMIPasture(J)=DiffNEm/NEmPasture+NEg(J)/NEgPasture
      EndIf
      ADG=PreWeanADG
      Weight=Weight+ADG
    EndIf

    If ((J.GT.WeaningDay).and.(J.LE.PastureEndDay)) then
      NEm(J)=(0.077*Weight**0.75)*1.1  !increase in 10% during pasture
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      DMIGrow(J)=NEm(j)/NEmPasture+NEg(J)/NEgPasture
      ADG=GrowADG
      Weight=Weight+ADG
    EndIf

    If ((J.GT.PastureEndDay).and.(J.LE.GrowEndDay)) then
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      DMIGrow(J)=(NEm(j)/NEmGrow+NEg(J)/NEgGrow)
      ADG=GrowADG
      Weight=Weight+ADG
    EndIf
```

```
    If ((J.GT.GrowEndDay).and.(J.LE.FinishEndDay)) then
      NEm(J)=(0.077*Weight**0.75)     ! Equations from KG34
      ADG=FinishADG
      NEg(J)=0.0686*Weight**0.75*ADG**1.119
      DMIFeedlot(J)=NEm(J)/NEmFL+NEg(J)/NEgFL
      Weight=Weight+ADG
      If (Weight.ge.FinishEndWt) then
       FinalDay=J; Exit
      EndIf
    EndIf

    If (IT.eq.0) Write(22,201)
J,Weight,ADG,NEm(J),NEg(J),DMIMilk(J),DMICreep(J),DMIPasture(J),&
                    DMIGrow(J), DMIFeedlot(J)
201 Format(I4,F8.2,F8.4,7F8.4)

EndDo

TNEm=Sum(NEm); TNEg=Sum(NEg);TotMilk=Sum(DMIMilk); TotCreep=Sum(DMICreep)
TotPasture=Sum(DMIPasture); TotGrow=Sum(DMIGrow+DMIPast);
TotFeedlot=Sum(DMIFeedlot)
TotMEMilk=Sum(DMIMilk)*MEMilk; TotMECreep=TotCreep*MECreep;
TotMEPasture=TotPasture*MEPasture
TotMEGrow=TotGrow*MEGrow; TotMEFeedlot=TotFeedlot*MEFL

Rcwh = (Weight*(CcsPh-MCh))/(FinalDay/365)
Rcwh8 = W540*(CcsPh8-MCh8)/(540/365)
CF1nnmlk=TotMECreep*CF1*1
CF3rfig=
(RFIG*((61*CF1)+(144*CFPasture)+(91*CFGrow)+(85*CFFdlot))*1)/(FinalDay/365)
CF2gf=(TotMEPasture*CFPasture+TotMEGrow*CFGrow+TotMEFeedlot*CFFdlot)/(FinalDay/
365)

PROFh = (0.5*NCw*ES*S1BW*S2WS-RR*NCw)* &
         (Rcwh-CEcclf/(S1BW*S2WS)-((1+S1BW)*CF1nnmlk)/(2*S1BW*S2WS)- &
                        ((1+S2WS)*(CF2gf+CF3rfig+Chg))/(2*S2WS))+ &
         RR*Ncw*(((1-FRh)*Rcwh8)-CEcclf/(S1BW*S2WS)-
((1+S1BW)*CF1nnmlk)/(2*S1BW*S2WS)- &
                        ((1+S2WS)*(CF8gm+CF3rfig+Chg8))/(2*S2WS))

If (IT.eq.0) Write(22,202)
!            12341234567812345678123456781234567812345678123456780
202 Format('Heifer1'/'                             NEm     NEg  DMIMilk DMICree', &
                ' DMIPast DMIGrow DMI-FL')

If (IT.eq.0) Write(22,203) TNEm, TNEg, TotMilk, TotCreep, TotPasture, TotGrow,
TotFeedlot, FinalDay, &
              FinishEndDay-GrowEndDay
!             1234567 101234567 20
203 Format(/'DMI and NE Totals:'/,20x,7F8.2/ &
             'Final Feedlot Day=',F8.1,' Days on Feed=',F8.1)

If (IT.eq.0) Write(22,204) TotMEMilk, TotMECreep, TotMEPasture, TotMEGrow,
TotMEFeedlot
204 Format(/'ME Totals:'/ &
           36x,5F8.2)

Return
End subroutine heifer1
!-----------------------------------------------------------------------
Subroutine Steer1 (A, B, k,NEmCreep, NEgCreep, MECreep,NEmPasture, NEgPasture,
MEPasture,&
```

```
                    NEmGrow, NEgGrow, MEGrow,NEmFL, NEgFL, MEFL,NCw, ES, S1BW,
S2WS, RR, FRh,&
                    DaystoPeak, PeakMilk, MilkEnValm, MilkEnValg, MEMilk,
Chg,FinishADGh,&
                    CF3rfig, CEcclf, CF8gm, DP,CcsPs, MCs, CF1, RFIG, CFPasture,
CFFdlot,&
                    CFGrow, PROFs,Rcws, IT,BirthWts)

Implicit none

Real :: A, B, k, TNEm=0., TNEg=0., &
        NEmCreep, NEgCreep, MECreep, &
        NEmPasture, NEgPasture, MEPasture, &
        NEmGrow, NEgGrow, MEGrow,FinishADGh, &
        NEmFL, NEgFL, MEFL, ADJ=1

! Milk production parameters
Real :: DaystoPeak, PValue, AValue, PeakMilk, MilkYield
Real :: MilkEnValm     !Calculate as 5.29 Mcal ME/kg DM (12%DM) (KG34)
                               ! 0.828 efficiency of use for
maintenance(.6348*.828)
Real :: MilkEnValg     ! 0.700 efficiency of use for gain (0.6348*.700)
Real :: MEMilk

!important inputs for profit
Real :: NCw, ES, S1BW, S2WS, RR, FRh, CF1nnmlk=0., &
        Rcws, CF2gf=0., CF3rfig, Chg, CEcclf, CF8gm, DP, &
        CcsPs, MCs, CF1, RFIG, CFPasture, CFFdlot, &
        CFGrow, PROFs

Real :: WeaningDay=205, PastureStartDay=62, PastureEndDay=244, &
          GrowEndDay=296, FinishEndDay=600
Real :: BirthWt, WeaningWt,WeaningWts, NnMlk, PreWeanADG, BirthWts,  &
          GrowEndWt, GrowADG,FinishEndWt, FinishADG,FinishADGs, Weight,
MeanFLWt, ADG,  &
          FinalDay, FFM, FFG, DMI, WE, TNEm, TNEg, TotMilk, TotCreep,
TotPasture, TotGrow, &
          TotFeedlot, TotMEMilk, TotMECreep, TotMEPasture, TotMEGrow,
TotMEFeedlot, &
          x1, DiffNEm, DiffNEg

Integer :: J, IT, FinalDays
Real, Dimension(800) :: NEm, NEg, Wt,wtw, DMIMilk, DMICReep, DMIPasture,
DMIPast, &
                          DMIGrow, DMIFeedlot

PValue=1./DaystoPeak
AValue=DaystoPeak/(exp(1.)*PeakMilk)

BirthWt=BirthWts
Weight=BirthWt

WeaningWt=(87.7+0.202*A+6.04*PeakMilk)
WeaningWts=(A*(1.0-B*exp(-k*WeaningDay)))
PreWeanADG=(WeaningWt-BirthWt)/WeaningDay

GrowEndWt=(A*(1.0-B*exp(-k*GrowEndDay)))
GrowADG=(GrowEndWt-WeaningWts)/(GrowEndDay-WeaningDay)

FinishEndWt=0.78*A
FinishADG=FinishADGh/0.94
MeanFLWt=(FinishEndWt+GrowEndWt)/2
```

```
If (IT.eq.0) Write(22,190) PastureStartDay, WeaningDay, PastureEndDay, &
        GrowEndDay, FinishEndDay
190 Format('Steer1'/'Significant days (should form a progression):'/, &
            '  Calving Day=       0.'/, &
            '  PastureStartDay=',F6.0/, &
            '  WeaningDay=     ',F6.0/, &
            '  PastureEndDay=  ',F6.0/, &
            '  GrowEndDay=     ',F6.0/, &
            '  FinishEndDay=   ',F6.0, ' or when target weight is reached')

If (IT.eq.0) Write(22,191) BirthWt, WeaningWt, PreweanADG, GrowEndWt, GrowADG,
FinishEndWt, FinishADG
191 Format(/'Significant weights:' &
          /' BirthWt=      ',F8.2, &
          /' WeaningWt=    ',F8.2,' PreweanADG=   ',F8.4, &
          /' GrowEndWt=    ',F8.2,' GrowADG=      ',F8.4, &
          /' FinishEndWt= ',F8.2,' FinishADG=    ',F8.4)

NEm=0.; NEg=0.; DMIMilk=0.; DMICReep=0.; DMIPasture=0.; DMIGrow=0.;
DMIFeedlot=0.

If (IT.eq.0) Write(22,200)
!             12341234567812345678123456781234567812345678l2345678
200 Format('Steer1'/'IDay  Weight    ADG     NEm     NEg  DMIMilk DMICree', &
                ' DMIPast DMIGrow DMI-FL')

Do J=1,FinishEndDay

    If (J.LT.PastureStartDay) then
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0557*(Weight**0.75)*PreWeanADG**1.097)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm                ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMICreep(J)=0.
         Else
            DMIMilk(J)=MilkYield*0.12
            DMICreep(J)=(NEg(J)-DiffNEg)/NEgCreep
         EndIf
      Else
        DMIMilk(J)=MilkYield*0.12
        DiffNEm=(x1-MilkYield)*MilkEnValm
        DMICreep(J)=DiffNEm/NEmCreep+NEg(J)/NEgCreep
      EndIf
      ADG=PreWeanADG
      Weight=Weight+ADG
    EndIf

    If ((J.GE.PastureStartDay).and.(J.LE.WeaningDay)) then
      NEm(J)=(0.077*Weight**0.75)*1.1  !increase in 10% during pasture
      NEg(J)=(0.0557*(Weight**0.75)*PreWeanADG**1.097)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm                ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMIPasture(J)=0.
```

```
          Else
             DMIMilk(J)=MilkYield*0.12
             DMIPasture(J)=(NEg(J)-DiffNEg)/NEgPasture
          EndIf
       Else
         DMIMilk(J)=MilkYield*0.12
         DiffNEm=(x1-MilkYield)*MilkEnValm
         DMIPasture(J)=DiffNEm/NEmPasture+NEg(J)/NEgPasture
       EndIf
       ADG=PreWeanADG
       Weight=Weight+ADG
     EndIf

     If ((J.GT.WeaningDay).and.(J.LE.PastureEndDay)) then
       NEm(J)=(0.077*Weight**0.75)*1.1  !increase in 10% during pasture
       NEg(J)=(0.0557*(Weight**0.75)*GrowADG**1.097)
       DMIGrow(J)=NEm(j)/NEmPasture+NEg(J)/NEgPasture
       ADG=GrowADG
       Weight=Weight+ADG
     EndIf

     If ((J.GT.PastureEndDay).and.(J.LE.GrowEndDay)) then
       NEm(J)=(0.077*Weight**0.75)
       NEg(J)=(0.0557*(Weight**0.75)*GrowADG**1.097)
       DMIGrow(J)=(NEm(j)/NEmGrow+NEg(J)/NEgGrow)
       ADG=GrowADG
       Weight=Weight+ADG
     EndIf

     If ((J.GT.GrowEndDay).and.(J.LE.FinishEndDay)) then
       Wt(J)=(A*(1.0-B*exp(-k*J)))
       NEm(J)=(0.077*Weight**0.75)     ! Equations from KG34
       ADG=FinishADG
       NEg(J)=0.0557*Weight**0.75*ADG**1.097
       DMIFeedlot(J)=NEm(J)/NEmFL+NEg(J)/NEgFL
       Weight=Weight+ADG
       If (Weight.ge.FinishEndWt) then
         FinalDay=J; Exit
       EndIf
     EndIf

     If (IT.eq.0) Write(22,201)
J,Weight,ADG,NEm(J),NEg(J),DMIMilk(J),DMICreep(J),DMIPasture(J),&
                  DMIGrow(J), DMIFeedlot(J)
201 Format(I4,F8.2,F8.4,7F8.4)

EndDo

TNEm=Sum(NEm); TNEg=Sum(NEg);TotMilk=Sum(DMIMilk); TotCreep=Sum(DMICreep)
TotPasture=Sum(DMIPasture); TotGrow=Sum(DMIGrow+DMIPast);
TotFeedlot=Sum(DMIFeedlot)
TotMEMilk=Sum(DMIMilk)*MEMilk; TotMECreep=TotCreep*MECreep;
TotMEPasture=TotPasture*MEPasture
TotMEGrow=TotGrow*MEGrow; TotMEFeedlot=TotFeedlot*MEFL

Rcws = (Weight*(CcsPs- MCs))/(FinalDay/365)
CF1nnmlk=TotMECreep*CF1*1
CF3rfig=
(RFIG*((61*CF1)+(144*CFPasture)+(91*CFGrow)+(118*CFFdlot))*1)/(FinalDay/365)
CF2gf=(TotMEPasture*CFPasture+TotMEGrow*CFGrow+TotMEFeedlot*CFFdlot)/(FinalDay/
365)

 PROFs = (0.5*NCw*ES*S1BW*S2WS)*(Rcws-CEcclf/(S1BW*S2WS)- &
```

```
           ((1+S1BW)*CF1nnmlk)/(2*S1BW*S2WS)- &
            ((1+S2WS)*(CF2gf+CF3rfig+Chg))/2*S2WS)

If (IT.eq.0) Write(22,202)
!            1234123456781234567812345678123456781234567812345678
202 Format(/'                          NEm     NEg  DMIMilk DMICree', &
               ' DMIPast DMIGrow DMI-FL')

If (IT.eq.0) Write(22,203) TNEm, TNEg, TotMilk, TotCreep, TotPasture, TotGrow,
TotFeedlot, FinalDay, &
              FinishEndDay-GrowEndDay
!             1234567 101234567 20
203 Format(/'DMI and NE Totals:'/,20x,7F8.2/ &
             'Final Feedlot Day=',F8.1,' Days on Feed=',F8.1)

If (IT.eq.0) Write(22,204) TotMEMilk, TotMECreep, TotMEPasture, TotMEGrow,
TotMEFeedlot
204 Format(/'ME Totals:'/ &
           36x,5F8.2)
Return
End Subroutine steer1
!-----------------------------------------------------------------------------
------------
Subroutine RepHeifer1 (A, B, k,NEmCreep, NEgCreep, MECreep,NEmPasture,
NEgPasture, MEPasture,&
                      NEmGrow, NEgGrow, MEGrow,NEmWinter, NEgWinter, MEWinter,
&
                      RR, NCw, FRc, CEcclf,S1BW, S2WS, S3CS, Chg,Chmr, ES,
CEccw, &
                      DaystoPeak, PeakMilk, MilkEnValm, MilkEnValg, MEMilk,&

TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR, W540, &
                      CF5rf, CF8gm, CF9gm, CF10gr, CF11lr, CF1nnmlk,RFIM, &
                      CF1, CFWinter, CFPasture, CFGrow, DPr, DP, CcsPr,CcsPc,
MCr,TotMEP18, TotMEPast18, &
                      PROFr, Rcwr, IT,BirthWth)

 Implicit none

 Real :: A, B, k, TNEm=0., TNEg=0., &
         NEmCreep, NEgCreep, MECreep, &
         NEmPasture, NEgPasture, MEPasture, &
         NEmGrow, NEgGrow, MEGrow, &
         NEmWinter, NEgWinter, MEWinter

 ! Milk production parameters
 Real :: DaystoPeak, PValue, AValue, PeakMilk, MilkYield
 Real :: MilkEnValm     !Calculate as 5.29 Mcal ME/kg DM (12%DM) (KG34)
                                ! 0.828 efficiency of use for
 maintenance(.6348*.828)
 Real :: MilkEnValg     ! 0.700 efficiency of use for gain (0.6348*.700)
 Real :: MEMilk

 !significant days
 Integer :: WeaningDay=205, PastureStartDay1=62, PastureEndDay1=244, &
            PastureStartDay2=427, PastureEndDay2=609, BreedingDay=448, &
            GrowEndDay=296, RHEndDay=729

 Real :: DayPreg, BirthWt, WeaningWt,WeaningWti, PreWeanADG,BirthWth, &
            GrowEndWt, GrowADG,FinishEndWt, FinishADG, Weight, ADG, W540,  &
            FinalDay, FFM, FFG, DMI, TNEm, TNEg,TotNEPreg,TotMilk, TotCreep,
 TotPasture,  &
```

```
          TotGrow, TotFeedlot, TotMEMilk, TotMECreep, TotMEPasture, TotMEGrow,
TotWinter1, TotPast1,  &
          TotWinter2,TotMEWinter1, TotMEPast1, TotMEWinter2, TotMEPast2,
TotPast2,  &
          x1, DiffNEm, DiffNEg, &
          TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR

!important inputs for profit
Real :: RR, NCw, FRc, CEcclf,S1BW, S2WS, S3CS, Chg, &
        Chmr, ES, CEccw, &
        CF5rf, CF8gm, CF9gm, CF10gr, CF11lr, CF1nnmlk,RFIM, &
        CF1, CFWinter, CFPasture, CFGrow,DPrc, DPr, DP, CcsPr,CcsPc, MCr, &
        TotMEWinter1=0., TotMEP18, TotMEPast18, TotMEWinter2=0.,TotCostr=0., &
        PROFr, Rcwr,MEPreg1=0., MEPreg2=0.

Integer :: J, IT
Real, Dimension(729) :: NEm, NEma, NEg, NEPreg, DMIMilk, DMICReep, DMIPasture,
&
                        DMIGrow, DMIWinter, MEPreg

PValue=1./DaystoPeak
AValue=DaystoPeak/(exp(1.)*PeakMilk)

BirthWt=BirthWth
Weight=BirthWt
WeaningWt=(87.7+0.202*A+6.04*PeakMilk)*0.94 !(KG33)
WeaningWti=(A*(1.0-B*exp(-k*WeaningDay)))*0.94
PreWeanADG=(WeaningWt-BirthWt)/WeaningDay
DPr=DP-0.03
DPrc=DP-0.06
GrowEndWt=(A*(1.0-B*exp(-k*GrowEndDay)))*0.94
!GrowEndWt=A*0.47 !if heifers attain 47% of A at this time.
GrowADG=(GrowEndWt-WeaningWti)/(GrowEndDay-WeaningDay)

FinishEndWt=(A*(1.0-B*exp(-k*RHEndDay)))
FinishADG=(FinishEndWt-GrowEndWt)/(RHEndDay-GrowEndDay)   !RHEndDay-GrowEndDay
(729-296)=433

If (IT.eq.0) Write(22,190) WeaningDay, PastureStartDay1, PastureEndDay1,
GrowEndDay, &
             PastureStartDay2, PastureEndDay2,  RHEndDay
190 Format('RepHeifer1'/'Significant days (should form a progression):'/, &
           '  Calving Day=       0.'/, &
           '  Weaning Day=     ',I6/, &
           '  PastureStartDay=',I6/, &
           '  PastureEndDay=  ',I6/, &
           '  GrowEndDay=     ',I6/, &
           '  PastureStartDay=',I6/, &
           '  PastureEndDay=  ',I6/, &
           '  RHEndDay=       ',I6)

If (IT.eq.0) Write(22,191) BirthWt, WeaningWt, PreweanADG, GrowEndWt, GrowADG,
FinishEndWt, FinishADG
191 Format(/'Significant weights:' &
          /' BirthWt=     ',F8.2, &
          /' WeaningWt=   ',F8.2,' PreweanADG=  ',F8.4, &
          /' GrowEndWt=   ',F8.2,' GrowADG=     ',F8.4, &
          /' FinishEndWt= ',F8.2,' FinishADG=   ',F8.4)

DMIMilk=0.; DMICReep=0.; DMIPasture=0.; DMIGrow=0.; DMIWinter=0.
NEPreg=0.;NEm=0.; NEg=0.

If (IT.eq.0) Write(22,200)
```

```
!            12341234567812345678123456781234567812345678123456781234567812345678
200 Format('RepHeifer1'/'IDay   DayPreg Weight    ADG     NEm     NEg  NEPreg
MEPreg  DMIMilk', &
                'DMICree DMIPast DMIGrow DMIWin')

Do J=1,RHEndDay
DayPreg=0.
    If (J.LT.PastureStartDay1) then
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0686*(Weight**0.75)*PreWeanADG**1.119)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm               ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMICreep(J)=0.
         Else
            DMIMilk(J)=MilkYield*0.12
            DMICreep(J)=(NEg(J)-DiffNEg)/NEgCreep
         EndIf
      Else
        DMIMilk(J)=MilkYield*0.12
        DiffNEm=(x1-MilkYield)*MilkEnValm
        DMICreep(J)=DiffNEm/NEmCreep+NEg(J)/NEgCreep
      EndIf
      ADG=PreWeanADG
      Weight=Weight+ADG
    EndIf

    If ((J.GE.PastureStartDay1).and.(J.LE.WeaningDay)) then
      NEma(J)=(0.077*Weight**0.75)
      NEm(J)=NEma(J)+(NEma(J)*0.1)  !increase in 10% during pasture
      NEg(J)=(0.0686*(Weight**0.75)*PreWeanADG**1.119)
      MilkYield=J/(AValue*exp(PValue*J))
      x1=NEm(J)/MilkEnValm               ! Meet maintenance requirements from
milk?
      If (MilkYield.ge.x1) then
         DiffNEg=(MilkYield-x1)*MilkEnValg
         If (DiffNEg.ge.NEg(J)) then
            DMIMilk(J)=NEm(J)/MilkEnValm+NEg(J)/MilkEnValg
            DMIPasture(J)=0.
         Else
            DMIMilk(J)=MilkYield*0.12
            DMIPasture(J)=(NEg(J)-DiffNEg)/NEgPasture
         EndIf
      Else
        DMIMilk(J)=MilkYield*0.12
        DiffNEm=(x1-MilkYield)*MilkEnValm
        DMIPasture(J)=DiffNEm/NEmPasture+NEg(J)/NEgPasture
      EndIf
      ADG=PreWeanADG
      Weight=Weight+ADG
    EndIf

    If ((J.GT.WeaningDay).and.(J.LE.PastureEndDay1)) then
      NEma(J)=(0.077*Weight**0.75)
      NEm(J)=NEma(J)+(NEma(J)*0.1)  !increase in 10% during pasture
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      DMIGrow(J)=NEm(J)/NEmPasture+NEg(J)/NEgPasture  !!!!!!
      ADG=GrowADG
      Weight=Weight+ADG
```

```
    EndIf

    If ((J.GT.PastureEndDay1).and.(J.LE.GrowEndDay)) then
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      DMIGrow(J)=(NEm(j)/NEmGrow+NEg(J)/NEgGrow)
      ADG=GrowADG
      Weight=Weight+ADG
    EndIf

    If ((J.GT.GrowEndDay).and.(J.LT.PastureStartDay2)) then
      NEm(J)=(0.077*Weight**0.75)    ! Equations from KG34
      NEg(J)=0.0686*Weight**0.75*ADG**1.119
      DMIWinter(J)=NEm(J)/NEmWinter+NEg(J)/NEgWinter
      ADG=FinishADG
      Weight=Weight+ADG
    EndIf

    If ((J.GE.PastureStartDay2).and.(J.LE.PastureEndDay2)) then
      If (J.GE.449.) then            ! so Breeding occurs at day 448
          DayPreg=J-448.                   ! NEPreg see NRC43, corrected from
latest edition
          NEPreg(J)=(0.576*BirthWt*(0.4504-0.000766*DayPreg)* &
                      exp((0.03233-0.0000275*DayPreg)*DayPreg))/1000.
          MEPreg(J)=(NEPreg(J)/NEmPasture)*MEPasture
      EndIf
      NEma(J)=(0.077*Weight**0.75)
      NEm(J)=NEma(J)+(NEma(J)*0.1)  !increase in 10% during pasture
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      DMIPasture(J)=NEm(j)/NEmPasture+NEg(J)/NEgPasture+NEPreg(J)/NEmPasture
      If (J.eq.540) then
      W540=Weight
      EndIf
      ADG=FinishADG
      Weight=Weight+ADG
    EndIf

    If ((J.GT.PastureEndDay2).and.(J.LE.RHEndDay)) then
      DayPreg=J-448.                  ! NEPreg see NRC43, corrected from latest
edition
      NEm(J)=(0.077*Weight**0.75)
      NEg(J)=(0.0686*(Weight**0.75)*GrowADG**1.119)
      NEPreg(J)=(0.576*BirthWt*(0.4504-0.000766*DayPreg)* &
                  exp((0.03233-0.0000275*DayPreg)*DayPreg))/1000.
      MEPreg(J)=(NEPreg(J)/NEmWinter)*MEWinter
      DMIWinter(J)=NEm(J)/NEmWinter+NEg(J)/NEgWinter+NEPreg(J)/NEmWinter
      ADG=FinishADG
      Weight=Weight+ADG
    EndIf

    If (IT.eq.0) Write(22,201) J, DayPreg, Weight,
ADG,NEm(J),NEg(J),NEPreg(J),MEPreg(J),DMIMilk(J),&
                  DMICreep(J),DMIPasture(J),DMIGrow(J),DMIWinter(J)
201 Format(I4,F8.0, 2x, 2F8.4,F8.4,14F8.4)

EndDo

TNEm=Sum(NEm); TNEg=Sum(NEg);TotNEPreg=Sum(NEPreg);TotMilk=Sum(DMIMilk);
TotCreep=Sum(DMICreep); TotPasture=Sum(DMIPasture)
TotGrow=(Sum(DMIGrow(WeaningDay+1:GrowEndDay)))
TotPast1=Sum(DMIPasture(PastureStartDay1:WeaningDay))
TotWinter1=Sum(DMIWinter(GrowEndDay+1:PastureStartDay2-1))
TotPast2=Sum(DMIPasture(PastureStartDay2:PastureEndDay2))
```

```
TotWinter2=Sum(DMIWinter(PastureEndDay2+1:RHEndDay))
TotMEMilk=Sum(DMIMilk)*MEMilk; TotMECreep=TotCreep*MECreep
TotMEPasture=TotPasture*MEPasture
TotMEGrow=((Sum(DMIGrow(WeaningDay:PastureEndDay1)))*MEPasture)+((Sum(DMIGrow(P
astureEndDay1+1:GrowEndDay)))*MEGrow)
TotMEWinter1=TotWinter1*MEWinter    !total feed for first winter after growing
from 297 to 426
TotMEPast1=TotPast1*MEPasture
TotMEWinter2=TotWinter2*MEWinter !total feed for winter stage after 18months
from 610-729
TotMEPast2=TotPast2*MEPasture
TotMEP18=(Sum(DMIPasture(PastureStartDay2:540)))*MEPasture   !total feed for
pasture from 427 to 540(18months)
TotMEPast18=(Sum(DMIPasture(540:PastureEndDay2)))*MEPasture !total feed on
pasture after 18 months from 541-609,610-729

CF1nnmlk = CF1*TotMECreep*1
CF5rf= RFIM*((182*CFWinter)+(183*CFPasture))*1
CF8gm= (CFGrow*TotMEGrow+CFWinter*TotMEWinter1+CFPasture*TotMEP18)/(540/365)
CF9gm= ((TMEIPastureR*CFPasture)+(TMEIWinterR*CFWinter))*1 !other component
must come from cow
MEPreg1=(Sum(MEPreg(BreedingDay+1:PastureEndDay2)))
MEPreg2=(Sum(MEPreg(PastureEndDay2+1:RHEndDay)))
CF10gr=
((MEPreg1*CFPasture)+(MEPreg2*CFWinter)+(TMEPregPR*CFPasture)+(TMEPregWR*CFWint
er))*1
CF11lr= ((TMELactWR*CFWinter)+(TMELactPR*CFPasture))*1 !Must come from cows
TotCostr=CF1nnmlk+CF5rf+CF8gm+CF9gm+CF10gr+CF11lr
Rcwr = Weight*(CcsPc-MCr)/(540/365)
PROFr= RR*NCw*S3CS*(((1-FRc)*Rcwr)-(CEcclf/(S1BW*S2WS)+(1+S1BW)*CF1nnmlk/ &
           (2*S1BW*S2WS)+(1+S2WS)*(CF8gm+Chg)/(2*S2WS))-(CF5rf+CF9gm+ES*
&
           (CEccw+CF10gr)+0.5*(1+S1BW)*ES*CF11lr+Chmr))+ &
       0.5*RR*NCw*(1-S3CS)*(Rcwr-2*(CEcclf/(S1BW*S2WS)+(1+S1BW)*CF1nnmlk/ &
           (2*S1BW*S2WS)+(1+S2WS)*(CF8gm+Chg)/2*S2WS)-(CF5rf+CF9gm+ES* &
           (CEccw+CF10gr)+0.5*(1+S1BW)*ES*CF11lr+Chmr))

If (IT.eq.0) Write(22,202)
!            1234123456781234567812345678123456781234567812345678
202 Format('RepHeifer1'/'                          NEm     NEg  NEPreg DMIMilk
DMICree', &
                ' DMIPast DMIGrow DMIWin1 DMIPast1 DMIWin2 DMIPast2')

If (IT.eq.0) Write(22,203) TNEm, TNEg,TotNEPreg, TotMilk, TotCreep, TotPasture,
TotGrow,    &
              TotWinter1,TotPast1,TotWinter2,TotPast2,FinalDay,RHEndDay-
GrowEndDay
!             1234567 101234567 20
203 Format(/'DMI and NE Totals:'/,20x,12F8.2/ &
             'Final Feedlot Day=',F8.1,' Days on Feed=',I8)

If (IT.eq.0)Write(22,204) TotMEMilk, TotMECreep, TotMEPast1, TotMEGrow,
TotMEWinter1, &
              TotMEPast2,
TotMEWinter2,MEPreg1,MEPreg2,TotMEP18,TotMEPast18,TotMEPasture,Weight
204 Format(/'ME Totals& weight:'/ &
           36x,16F8.2)
Write (*,215) W540
215 Format('weight at 540 is' F8.2)
End Subroutine RepHeifer1
!------------------------------------------------------------------------------
-----
```

```
Subroutine Cow1 (A, B, k,FRh,FRc,NEmWinter, NEgWinter, MEWinter,NEmPasture,
NEgPasture, MEPasture,&
                DP, DPc, RR, NCw, CEcclf,S1BW, S2WS, S3CS, Chg,Chm, ES, CEccw,
MCc,CcsPc,&
                DaystoPeak, PeakMilk, MilkEnVal,coweight,&

TotMEWinter,TotMEPasture,TotMELactW,TotMEPregW,TotMELactP,TotMEPregP,&

AgeDist,TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR,&
                CFWinter,CFPasture,CF4gm,CF5rf,CF6gr,CF7lr,RFIM,Rcwc,PROFc, IT)

Implicit none

!NOTES: KG33 refers to Koots and Gibson paper, page 33;
!       NRC117 is NRC publication, page 117; and K196 is Koots thesis, page
196.

! Growth curve parameters
Real :: A, B, k       !KG34 top

! Feed characteristics
Real :: NEmWinter, NEgWinter, MEWinter, &
        NEmPasture, NEgPasture, MEPasture

Real :: DP, DPc, RR, NCw, CEcclf,S1BW, S2WS, S3CS, Chg, &
        Chm, ES, CEccw, MCc,CcsPc,&
        CFWinter,CFPasture, &
        TMEIWinterR,TMEIPastureR,TMELactWR,TMELactPR,TMEPregWR,TMEPregPR

! Fertility rates of heifers and cows, and herd age distribution vector
! The values of FRh=.764 and FRc=.874 can be calculated from values on K235.
! These values reproduce the cow age proportions shown in K244.
Real :: FRh, FRc
Real, Dimension(9) :: AgeDist, AgeList=(/2,3,4,5,6,7,8,9,10/)

! Ages, weights, annual gain, and totals for each of the nine cow ages
Real, Dimension(9) :: Age=(/730,1095,1460,1825,2190,2555,2920,3285,3650/)
Real, Dimension(9) :: Weight, Gain, TNEm, TNEg, &
                      TDMIWinter,coweight, &
                      TMEIWinter,TMEIPasture,TMEI, &
                      TMELactW, TMELactP,TMEPregW,TMEPregP

Real :: TotMEWinter, TotMEPasture, TotMELactW, TotMEPregW,TotMELactP,
TotMEPregP,&
        CF4gm,CF5rf,CF6gr,CF7lr,RFIM,Rcwc,PROFc,ACwWt

! Age distribution of cows is calculated from FRh and FRc by the subroutine,
CowAge
! and this is done in the main program. The values in the AgeDist vector are
passed
! to this Cow1 subroutine from the main program.

! AOCMilk Age of Cow adjustments for Peak milk yield, KG33 top
Real, Dimension(9) :: AOCMilk=(/0.78,0.88,0.96,1.00,1.00,1.00,1.00,1.00,0.98/)

! Milk production parameters
Real :: DaystoPeak, PValue, AValue, PeakMilk
Real :: MilkEnVal             !Calculate as 0.092*MilkFat+0.049*SNF-0.0569
(NRC117)
                              ! with MilkFat=4 and SNF=8 passed from main
program
! Arrays to hold Daily amounts of NE, DMI and MEI
Real, Dimension(365) :: NEm, NEg, NELact, NEPreg, DMI, MEI, NEma
```

```
! Significant days of the year
Integer :: WeaningDay=205, BreedingDay=79, PastureStartDay=62,
PastureEndDay=244

! Calculating variables
Real :: CowWt, CowADG, BirthWt, DayofPreg
Integer :: I, J, IT

! Calculate cow weight at the beginning of each year,
! and the weight gain to be made each year
!  2 year-olds are 730 days of age
! 10 year-olds are 3650 days of age

Do I=1,9
  Weight(I)=A*(1.0-B*exp(-k*Age(I)))
EndDo

BirthWt=0.0667*A              !K192 middle, for steers
coweight=0.
Gain=0.
Do I=1,8
  Gain(I)=Weight(I+1)-Weight(I)
EndDo
! Calculate for each cow age group
!             12345612345612345612345612345678123456781234567812345678123456 78
If (IT.eq.0) Write(22,200)
200 Format('Cow1'/'Average ages, weights, and totals for energy and dry matter
needs', &
            /'   Age  Prop  Wt    Gain  TNEm   TNEg', &
                                  '   TMEIPast TMEIWint', &
                                  'TmeLactW TmeLactP', &
                                  'TmePregW TmePregP')
Do I=1, 9
! Assume equal ADG throughout the year from the given start point, Weight(I)
!
  CowWt=Weight(I); CowADG=Gain(I)/365.
coweight(I)=Weight(I)+Gain(I)
!
! Parameters for the milk production curve
  PValue=1./DaystoPeak; AValue=DaystoPeak/(exp(1.)*AOCMilk(I)*PeakMilk)

  NEm=0.; NEg=0.; NELact=0.; NEPreg=0.  ! Zero the 365-length arrays
!----------
  Do J=1,365
    If ((J.ge.1).and.(J.lt.PastureStartDay)) then
      NEma(J)=0.077*(CowWt**0.75)
      NEg(J)=0.0635*(CowWt**0.75)*(CowADG**1.097)
      NEm(J)=NEma(J)*1.15              ! Increase NEm by 15% during lactation,
KG34
      NELact(J)=MilkEnVal*(J/(Avalue*(exp(Pvalue*J))))
      DMI(J)=NEm(J)/NEmWinter+NEg(J)/NEgWinter
      MEI(J)=DMI(J)*MEWinter
      CowWt=CowWt+CowADG
    EndIf
                                      ! Gestation length is 286 days, K196
    If (J.gt.BreedingDay) then        ! so Breeding occurs at 365-286=79
      DayofPreg=J-79.                 ! NEPreg see NRC43, corrected from
latest edition
      NEPreg(J)=(0.576*BirthWt*(0.4504-0.000766*DayofPreg)* &
                exp((0.03233-0.0000275*DayofPreg)*DayofPreg))/1000.
    EndIf
```

```
     If ((J.ge.PastureStartDay).and.(J.le.WeaningDay)) then
       NEma(J)=0.077*(CowWt**0.75)
       NEg(J)=0.0635*(CowWt**0.75)*(CowADG**1.097)
       NEm(J)=NEma(J)+NEma(J)*0.1+NEma(J)*0.15     ! Increase NEm by 10% and 15%
 when on pasture, K199
       NELact(J)=MilkEnVal*(J/(Avalue*(exp(Pvalue*J))))
       DMI(J)=NEm(J)/NEmPasture+NEg(J)/NEgPasture
       MEI(J)=DMI(J)*MEPasture
       CowWt=CowWt+CowADG
     EndIf

     If ((J.ge.WeaningDay).and.(J.le.PastureEndDay)) then
       NEma(J)=0.077*(CowWt**0.75)
       NEg(J)=0.0635*(CowWt**0.75)*(CowADG**1.097)
       NEm(J)=NEma(J)+NEma(J)*0.1+NEma(J)*0.15     ! Increase NEm by 10% when on
 pasture, K199
       DMI(J)=NEm(J)/NEmPasture+NEg(J)/NEgPasture
       MEI(J)=DMI(J)*MEPasture
       CowWt=CowWt+CowADG
     EndIf

     If ((J.gt.PastureEndDay).and.(J.le.365.)) then
       NEma(J)=0.077*(CowWt**0.75)
       NEg(J)=0.0635*(CowWt**0.75)*(CowADG**1.097)
       NEm(J)=NEma(J)+NEma(J)*0.15
       DMI(J)=NEm(J)/NEmWinter+NEg(J)/NEgWinter
       MEI(J)=DMI(J)*MEWinter
       CowWt=CowWt+CowADG
     EndIf

!--------
     If ((IT.eq.0).and.(I.eq.4)) Write(22,210) J,
NEm(J),NEg(J),NELact(J),NEPreg(J),DMI(J),MEI(J)
210 Format('CowDay=',I4,' NEm=',F10.2,' NEg=',F10.2,' NELact',F10.2,'
NEPreg',F10.2, &
                ' DMI=',F10.2,' MEI=',F10.2)
  EndDo
  DPc=DP-0.06
  TNEm(I)=Sum(NEm); TNEg(I)=Sum(NEg); TMEI(I)=Sum(MEI)
  TMEIPasture(I)=Sum(MEI(PastureStartDay:PastureEndDay))  !needed for
replacement heifers
  TMEIWinter(I)=Sum(MEI(1:(PastureStartDay-1)))+Sum(MEI((PastureEndDay+1):365))
!needed for replacement heifers
  TMELactW(I)=(Sum(NELact(1:(PastureStartDay-
1)))+Sum(NELact((PastureEndDay+1):365))/NEmWinter)*MEWinter
  TMELactP(I)=(Sum(NELact(PastureStartDay:PastureEndDay))/NEmPasture)*MEPasture
  TMEPregW(I)=(Sum(NEPreg(1:(PastureStartDay-
1)))+Sum(NEPreg((PastureEndDay+1):365))/NEmWinter)*MEWinter
  TMEPregP(I)=(Sum(NEPreg(PastureStartDay:PastureEndDay))/NEmPasture)*MEPasture

  If (IT.eq.0) Write(22,201)
Age(I),AgeDist(I),Weight(I),coweight(I),Gain(I),TNEm(I),TNEg(I), &
                 TMEIPasture(I),TMEIWinter(I),TMELactW(I),TMELactP(I),&
                 TMEPregW(I),TMEPregP(I)
201 Format(F6.0,F6.3,3F6.1,11F8.2)

!/'Year Day Coweight NEm NEg NElact Dayofpreg NEpreg DMI MEI'/
!--------------
EndDo

TMEIWinterR=TMEIWinter(1); TMEIPastureR=TMEIPasture(1); TMELactWR=TMELactW(1);
TMELactPR=TMELactP(1); TMEPregWR=TMEPregW(1); TMEPregPR=TMEPregP(1)
```

```
TotMEWinter=Sum(AgeDist(2:9)*TMEIWinter(2:9))
TotMEPasture=Sum(AgeDist(2:9)*TMEIPasture(2:9))
TotMELactW=Sum(AgeDist(2:9)*TMELactW(2:9))
TotMELactP=Sum(AgeDist(2:9)*TMELactP(2:9))
TotMEPregW=Sum(AgeDist(2:9)*TMEPregW(2:9))
TotMEPregP=Sum(AgeDist(2:9)*TMEPregP(2:9))
ACwWt=(Sum(coweight(2:9)*AgeDist(2:9)))/(1-AgeDist(1))

If (IT.eq.0) Write (22,204) (AgeDist (I),
I=1,9),TotMEWinter,TotMEPasture,TotMELactW,TotMELactP,&
                                TotMEPregW,TotMEPregP
204 Format(/' Weighted averages across cow age groups excluding age group 1'/ &
           /'AgeDist(1-9) Mewint Mepast MelactW MelactP MepregW
MepregP'/9f8.4/6F12.2)

CF4gm=((TotMEWinter*CFWinter)+(TotMEPasture*CFPasture))*1
CF5rf= RFIM*((61*CFWinter)+(183*CFPasture)+(121*CFWinter))*1
CF6gr=((TotMEPregW*CFWinter)+(TotMEPregP*CFPasture))*1
CF7lr= ((TotMELactW*CFWinter)+(TotMELactP*CFPasture))*1
Rcwc = ACwWt*(CcsPc- MCc)
PROFc= (1-RR)*NCw*S3CS*((1-FRc)*Rcwc- &
        ES*CEccw-CF4gm-CF5rf-ES*CF6gr-0.5* &
        (1+S1BW)*ES*CF7lr-Chm)+0.5*(1-RR)*NCw* &
        (1-S3CS)*(Rcwc-ES*CEccw-CF4gm-CF5rf- &
        ES*CF6gr-0.5*(1+S1BW)*ES*CF7lr-Chm)
write(*,209) ACwWt
209 Format(/'the weight of cow=' F8.4)
End Subroutine Cow1
!========================================================================
      Subroutine CowAge(FRh, FRc, AgeDist, IT)
!========================================================================
Implicit none

! Subroutine to calculate stable age distribution of cow herd,
! uses subroutine Invrt to invert the M matrix.

Real :: FRh, FRc
Real, Dimension(9,9) :: M
Real, Dimension(9) :: PVec, AgeDist

Integer :: I, J, IT, N=9

! Fill M matrix, as defined in Azzam et al.(1990) JAS 68:5-14
! Koots and Gibson only use heifer and cow fertility values, FRh, FRc
! instead of having different values for each age group.
M=0.
Do I=1,N
  If (I.eq.1) then
    M(I,I)=FRh
  ElseIf (I.eq.N) then
    M(I,I)=1.
  Else
    M(I,I)=FRc
  EndIf
  M(N,I)=1.
  If (I.gt.1) M(I-1,I)=-1.
EndDo

If (IT.eq.0) Write(22,201) FRh,FRc
201 Format(' Fertility Rates:'/'Heifers (FRh)=',F8.2/'Cows (FRc)=',F8.2)
PVec=(/0., 0., 0., 0., 0., 0., 0., 0., 1./)
If (IT.eq.0) Write(22,202) PVec
202 Format('PVec=',9f5.1/)
```

```
If (IT.eq.0) Write(22,203)
203 Format('M Matrix')
Do I=1,N
  If (IT.eq.0) Write (22,204) (M(I,J),J=1,N)
204 Format(9F8.4)
EndDo

Call Invrt(M, N, N)

AgeDist=MatMul(M,PVec)

End Subroutine CowAge
!========================================================================
      Subroutine Invrt(A, IA, N)
!========================================================================
! This program is from K Meyer's DFREML package
! A contains the matrix to be inverted, and is replaced by its inverse
!    upon completion of the subroutine.
! IA is the number of rows/columns of the matrix A
! N is dimension of the actual matrix to be inverted, may be equal to IA
!
! Removed references to double precision variables, eg, real(8) and dabs(XX)

      real,dimension(ia,ia), intent(inout) :: a
      integer, intent(in)                     :: ia,n

      real, dimension(:,:), allocatable    :: b
      real, dimension(:), allocatable      :: vec
      integer, dimension(:), allocatable      :: iflag
      integer                                 :: ii,imax,i,j,k
      real                                 :: zero=1.e-8,diag,off,xx,zz
      allocate(b(n,n),vec(n),iflag(n),stat=ii)
      if(ii>0)stop 'alloc invrt'

      DIAG=0.D0
      OFF=0.D0
      iflag=(/ (i,i=1,n) /)
      B=A(:n,:n)

      DO 2 I=1,N

!     FIND MAXIMUM ELEMENT IN THE COLUMN (START AT I-TH EL. ONLY)
      XX=ABS(A(I,I))
      IMAX=I
      DO 3 J=I+1,N
      ZZ=ABS(A(J,I))
      IF(ZZ.GT.XX)THEN
         XX=ZZ
         IMAX=J
      END IF
 3    CONTINUE

!     CHECK FOR SINGULARITY
      IF(XX.LT.ZERO)THEN
          WRITE(*,*)'"INVRT" : MATRIX IS SINGULAR'
          STOP
      END IF

!     INTERCHANGE ROW I AND ROW WITH MAX. ELEMENT IN THE COLUMN
      IF(IMAX.GT.I)THEN
         DO  K=1,N
         SAVE=A(I,K)
         A(I,K)=A(IMAX,K)
```

```
         A(IMAX,K)=SAVE
         end do
         ISAVE=IFLAG(I)
         IFLAG(I)=IFLAG(IMAX)
         IFLAG(IMAX)=ISAVE
      END IF

!     TRANSFORM THE MATRIX
      SAVE=1.D0/A(I,I)
      A(:n,I)=A(:n,I)*SAVE
      A(I,I)=SAVE
      DO K=1,N
      IF(K.ne.I)then
         DO  J=1,N
         IF(J.NE.I)A(J,K)=A(J,K)-A(J,I)*A(I,K)
         end do
         A(I,K)=-A(I,K)*SAVE
      end if
      end do

 2    CONTINUE

!     INTERCHANGE COLUMNS (ANALOGOUS TO PREVIOUS ROW CHANGES )
      DO I=1,N
      vec( (/ (iflag(k),k=1,n) /) ) =a(i,:n)
      A(I,:n)=VEC
      end do

!     MULTIPLY MATRIX WITH ITS INVERSE, CHECK ELEMENTS
      DO I=1,N
      DO J=1,N
      XX=dot_product(a(:n,j),b(i,:))
      IF(I.EQ.J)THEN
!        IF(ABS(XX-1.D0).GT.ZERO)PRINT *,I,XX
         DIAG=DIAG+XX
      ELSE
!        IF(ABS(XX).GT.ZERO)PRINT *,I,J,XX
         OFF=OFF+XX
      END IF
      end do
      end do
!     XX=DIAG/N
!     PRINT *,'DIAGONAL : SUM =',DIAG,'     AVERAGE =',XX
!     XX=OFF/(N*(N-1))
!     PRINT *,'OFF-DIAG : SUM =',OFF ,'     AVERAGE =',XX

      deallocate( b,vec,iflag,stat=ii)
      if(ii>0)stop 'dealloc invrt'

      RETURN
      END subroutine invr
```