THESIS

EFFECTS OF BEEF COW MILK PRODUCTION LEVELS ON LONGEVITY AND STAYABILITY

Submitted by

Miranda M Culbertson

Department of Animal Sciences

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2014

Master's Committee:

Advisor: R. Mark Enns

Milton G. Thomas
James Pritchett

ABSTRACT

EFFECTS OF BEEF COW MILK PRODUCTION LEVELS ON LONGEVITY AND STAYABILITY

The objective of this study was to determine the effects of beef cow milk potential on their ability to remain in the herd. We hypothesized that in areas with more arid climates and associated forage quantity and quality challenges, cows with higher genetic potential for milk production, measured as milk EPD, may not remain in the herd as long as in more favorable environments. Two sources of data were used to examine this effect.

The Red Angus Association of America provided breeder and herd records for stayability on 120,871 cows from 229 breeders with each herd subsequently classified into 8 different environments (biomes). In order to measure length of productive life, a score for longevity was assigned to each cow as the age at which she calved her last calf. Data were analyzed in ASREML3.0 using a mixed model with milk EPD, metabolic weight EPD and biome class as fixed effects to predict cow longevity (length of productive life). The quadratic term of milk EPD^2 was included in the model as well as an interaction between milk EPD^2 and biome. The interaction term was significant ($P<0.001$) with regression coefficients of 0.01414, 0.01693, 0.01096, 0.010504, 0.002240, 0.017331, 0.019607 and 0.014834 for the eight biomes of California Division, Subtropical Division, Prairie Division, Eastern Great Plains Division, Western Great Plains Division, Dry Domain, Rocky Mountain Province, and Hot Continental Division, respectively. The positive coefficients indicated that as levels of milk EPD increased so would longevity; however, rates were different depending upon biome.

A logistic regression was also performed using SAS 9.3 with stayability to 6 years of age (a binary outcome) as the dependent variable for milk EPD, milk EPD ^{2}, metabolic weight EPD and biome as fixed effects. An interaction term for biome with milk EPD, and biome with milk EPD^2 was also included and was significant *($P<0.0001$).* As milk EPD increased the probability of a cow remaining in the herd increased for all biomes quantified by odds ratios.

The second source of data was provided by the Colorado State University John E. Rouse Beef Improvement Center (BIC). Using SAS 9.3, the regression of longevity on the linear and quadratic effect of cow's milk EPD as a main effect was conducted resulting in a regression coefficient of 0.1002. This positive regression coefficient suggested that for higher levels of milk EPD, the positive relationship between milk EPD and longevity increased.

Logistic regressions were also conducted with the BIC data for the binary outcomes of stayability to 3 years of age and 6 years of age with those regressed on milk EPD and milk EPD^2. The resulting regression coefficient for stayability of 3 years was -0.0537 with an odds ratio of 0.948. For stayability to 6 years, the resulting regression coefficient was -0.0354 with an odds ratio of 0.965. These results suggested very little change in odds for receiving a stayability score of 1 as milk increases.

Based on our results from the data from RAAA, we would reject our hypothesis that in areas of forage restriction that cows with higher milk EPD would not remain in the herd as long as those in environments with more abundant forage. According to the results from the BIC herd, we would also reject our hypothesis that cows with high milk EPD would have an increased probability of being culled from the herd.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

The success and profitability of a beef operation is dependent on a cow's ability to remain in the herd long enough to recoup the expense of heifer development and cow maintenance in a discounted manner (Snelling et al., 1995). In order to recoup this investment, a heifer needs to calve as a 2 year old and stay in the herd long enough to produce enough calves to recapture the investment in the individual and of other individuals leaving the herd prematurely. The number of calves needed for a cow to reach a breakeven point depends on the initial investment in the cow and in the failure rate of other cows in the herd. The higher the initial investment in replacement heifers and the higher the loss of young cows, the longer a female needs to remain in the herd to recoup early-life investment (Buzanskas et al., 2010; Cammack et al., 2009).

The cow's ability to remain in the herd relies on her ability to maintain a 365 day calving interval since most commercial managers cows that fail to rebreed within a short, controlled breeding season (Short et al., 1990; Snelling et al., 1995; Frazier et al., 1999). On average, a cow has an 80 day window to recover from calving and then conceive (assuming a 285 day average gestation length) to maintain a yearly calving interval. Postpartum interval (PPI) can be a determining factor in a cow's ability to remain in the herd (Williams, 1990). If a cow has a longer postpartum anestrous, she would fail to express estrus or resume an estrous cycle late in the breeding season. Cows that are bred late in the breeding season give birth to calves later in the calving season resulting in smaller calves at weaning. In addition, these cows have limited number of days and opportunity to be rebred when compared to cows that calved early in the season (Dunn et al., 1980).

A longer PPI can be the result of many factors and can decrease reproductive efficiency. Lactation and nutritional requirements contribute to the length of PPI (Short et al., 1990). Lactation requirements following calving are high and increase the nutritional requirements of the cow thereby potentially delaying resumption of estrous. If the cow's nutritional requirements are not met during lactation, negative energy balance is perceived by the hypothalamus. This negative interpretation results in the reduction of gonadotropin releasing hormone (GnRH) secretion and therefore a reduction in anterior pituitary secretion of luteinizing hormone (LH). Low secretion of LH results in minimal ovarian activity and failed resumption of estrous cycles (Williams, 2005; Seger, 2012) and in terms of this study shortened productive life.

A calf's weaning weight is influenced by the dams milking ability. In most cow/calf operations, higher weaning weights are more desirable. Calves weaned from dams with higher milk EPD are heavier at weaning than calves from dams with lower milk EPD (Montano-Bermudez et al., 1990; Marston et al., 1992). This increase in milk production could be antagonist to a cow's ability to remain in the herd. The increase in energy demand during lactation could compromise the cow's ability to resume estrous, rebreed and remain in the herd. Providing adequate nutrition to meet the energy demands for lactation would be crucial for a cow to resume estrous cycles. Certain environments may not provide adequate nutrition to meet the energy requirements for high milking cows to resume estrous.

Since most producers sell their calves at weaning, it is more desirable for higher weaning weights. However, if the drive for higher weaning weights causes a greater culling rate of cows prior to reaching their breaking points this would be counterproductive for the overall profit of the herd.

Given the importance for both weaning weight and fertility to profitability, our objectives were to evaluate the effects of milk genetic potential of beef cows on their longevity. We hypothesized that in areas that are more arid and have forage quantity and quality challenges, cows with higher milk EPD may not remain in the herd long enough to recoup the development cost of replacement females.

CHAPTER 2

LITERATURE REVIEW

Introduction

Common management practices for cow/calf operations are to cull cows that fail to become pregnant during the breeding season (Snelling, 1994). The cow's ability to stay within a herd depends on her ability to become pregnant and maintain a 365 day calving interval (Short et al., 1990; Frazier et al., 1999). This reproductive efficiency is of great economic importance to beef cattle production systems (Buzanskas et al., 2010; Cammack et al., 2009) given the low reproductive rate (i.e. single births) of beef cattle. A beef cow must remain in production for several years to produce enough revenue through her calves to adequately offset her development and maintenance costs. Cows that remain in the herd beyond their breakeven point must also compensate for other cows that were culled prior to reaching this point in order to maintain operation profitability (Snelling et al., 1995). Lactation level can be a contributing factor to reproductive failure and can cause cows to be culled from the herd before they reach a breakeven point (Short et al., 1990).

Measures of Longevity

Hudson and Van Vleck (1981) defined stayability as the ability of a cow to remain in the herd for a specific number of years. Snelling et al. (1995) defined stayability as the probability of a cow surviving to a specific age when given the opportunity to reach this age and Rogers et al. (2004) definition was the probability that a cow wean five calves given that she weans one. Stayability is directly related to the cow's ability to produce a specific number of calves over a period of time (Buznskas et al., 2010) and therefore has a large impact on operation success.

This is compared to longevity which measures the length of time a cow remains in the breeding herd (Cammack et al., 2009).

Longevity is influenced by female fertility, since the failure of a cow to become pregnant, calve and wean a live calf would, in most management systems, result in her being culled. Increased longevity means reduced requirements for replacement heifers, an increased number of mature cows and lower culling due to reproductive failure (Cammack et al., 2009). Since daughters have to produce calves and be culled before longevity can be measured, the genetic expression of longevity is late in life and difficult to include in genetic evaluations (Rogers et al., 2004; Cammack et al., 2009). Stayability, compared to longevity, is defined as a cow remaining in a reproductive herd for a given number of years. Since mature cows on average wean heavier calves, stayability has an economic influence on a herd through female reproduction and calf performance (Cammack et al., 2009).

Prediction of stayability, based on genetic merit, enables selection of parents for daughters that will likely remain in the herd for a sufficient amount of time to be profitable. It has been indicated that there is genetic influence on stayability with variability depending upon the endpoint chosen (Snelling et al., 1995). Stayability heritability has been estimated from 0.02 to 0.23 depending on the age chosen for the endpoint (Snelling et al., 1995; Cammack et al., 2009). Under the scenario where non-pregnant cows are culled, stayability traits measure continuous fertility to each age. In order for stayability evaluations to be the most useful, the trait should reflect the age that would have the greatest economic impact and also be weighted by the amount of information available for predictions. It has also been noted that "although extremely old cows may be the most profitable, genetic predictions for the probability of surviving to an extremely old age may be meaningless without sufficient information to make reliable predictions” (Snelling et al., 1995).

Martinez et al. (2005) examined two different measures of stayability. Their examination of stayability considered whether a cow had a second calf given she had a calf as a 2 year old and was presented as a measure of the cow’s ability to recover and rebreed after first parturition. Stayability to weaning, the second option, was defined as to whether a cow weaned a second calf given the cow weaned the first calf. This was an indicator of a cow’s ability to recover, rebreed and wean a calf. Stayability to relatively old ages (10 years or older) was also considered as an indicator of soundness since physical impairments can result in culling (Greer et al., 1980). Specifically, Martinez et al. (2005) found that estimates of annual environmental changes were significantly negative for all measures of stayability. They also found near zero genetic correlations between stayability and weaning and yearling weight which were used as correlated traits for genetic prediction. It was shown that stayability to calving and to weaning were genetically similar measures of stayability. Martinez et al. (2005) concluded that selection on stayability is effective and possible and selection to weaning or calving is more accurate than selection to a specific age of 6. This is due to higher estimates of heritability for stayability to calving and weaning compared to the heritability for stayability to a specific age. Any direct measure of stayability would increase the generation interval since a cow would remain in the herd longer. Selection for yearling and weaning weights has little effect on stayability (Martinez et al., 2005).

Post-partum interval and the influence of lactation

Stayability is an indicator of reproductive efficiency since failure to reproduce is the major reason for culling (Martinez et al., 2005). There is a substantial economic influence for longevity in the value of livestock. Increasing the amount of time a cow remains in the herd would do the following: reduce annual production costs associated with replacement heifers, increase the number of high producing mature cows, and decrease the amount of cows that are involuntarily culled (Rogers et al., 2004). For females who start their reproductive life earlier (i.e. calving heifers as 2 year olds versus as 3 year olds), their production costs are lower and they have more calves by 76 months of age (Buzanskas et al., 2010).

Increase the efficiency of a cow/calf herd requires improvement of fertility in both cows and yearling heifers. Female fertility in beef cattle has been measured with several variables: age at first calving, calving date, first insemination conception (non-return rate), days to first breeding (days open), pregnancy rate, calving interval, longevity, and stayability. However, within most beef production systems, there is limited data for reproductive performance analyses because of the variability of fertility measures, no agreed trait from which to evaluate fertility and select animals, and the long time interval required to measure said traits. Calving interval compared to calving date has been used has a measure of reproductive efficiency; however, sources are more biased with calving interval than with calving date since a shorter calving interval could represent cows who calved late and possibly had an older age at puberty (Cammack et al., 2009).

With an average gestation of 285 days, a cow has 80 days to conceive after calving to maintain a 365 day calving interval. Within those 80 days, a cow must go through uterine involution and resume estrous. The interval between calving and conception is considered the postpartum interval (PPI). The cow's ability to maintain a 365 day calving interval is largely determined by her postpartum interval (Williams, 1990). For cows that express estrus late during the breeding season, there are fewer chances to breed and fewer chances for conception. In addition, for those cows that show estrus late and conceived late, their calves are born later and are smaller at weaning than other calves in the herd born the same year. (Dunn et al., 1980).

During calving, estradiol levels are high causing negative feedback to the hypothalamus. After calving, the cow exhibits a period of insufficient secretion of gonadotropin releasing hormone (GnRH) to stimulate a sufficient amount of luteinizing hormone (LH) secretion. The low levels of LH secretion result in a lack of ovarian activity. Circulating estrogens decline after calving resulting in the re-accumulation of the anterior pituitary LH stores over the following 2 to 3 weeks. After the re-accumulation of the anterior pituitary LH stores, pulsatile secretion of LH increases resulting in the resumption of follicular development and ovulation (Williams, 2005).

Lactation and nutritional requirements contribute to the negative feedback to the hypothalamus. Cows with a lower body condition score are more sensitive to this negative energy balance. Immediately after calving, the cow's lactation requirements are higher and increase her basic nutritional requirements. These requirements all add to the negative energy balance interpretation by the hypothalamus which results in a reduction of GnRH secretion to the anterior pituitary and therefore a reduction of LH secretion. The result of low LH is a "quiet" ovary and anestrous

As time progresses from calving, lactation and nutrition requirements change. The feedback to the hypothalamus changes from negative to positive. This causes enhanced tonic secretion of GnRH to the anterior pituitary which results in an increase of LH pulses. These changes in lactation and nutrition with the addition of bio stimulation (i.e. bull presence or removal of the calf) contribute to the positive feedback of the hypothalamus. With increased LH pulses, the ovary becomes active and ovulation occurs.

Short et al. (1990) discussed major factors influencing the length of PPI. Two of the most influential factors are suckling and nutrition. After calving, the cow enters a period of high nutritional demand. Feed quantity and quality, stored nutrient reserves within the body and competition for nutrients from other physiological systems other than reproduction can affect PPI. Nutrients are allocated to various body functions, first to the maintenance of the cow then to the propagation of the species. Short et al. (1990) prioritized the partitioning of nutrients under these biological systems as follows (from top priority to lowest priority):

1. Basal metabolism
2. Activity
3. Growth
4. Basic Energy Reserves
5. Pregnancy
6. Lactation
7. Additional Energy Reserves
8. Estrous Cycle and Initiation of Pregnancy
9. Excess Reserves

The effects of nutrition on PPI depend on the nutritional status of the cow before and after calving. The above factors can prevent a cow from having an estrous cycle postpartum until her nutrient requirements are met.

Body condition scores (BCS) can be a useful tool for judging body reserves. Studies have evaluated BCS at calving and its relationship with PPI as lower BCS leads to longer PPI and vice versa. When managing for a BCS at calving of 5 to 7, there is the potential of optimizing reproduction (Short et al., 1990). The decision of an optimum BCS can be dictated by herd characteristics such as breed, amount of milk production and dystocia. Pre-calving BCS should be adjusted according to these characteristics (Short et al., 1990). High BCS allow the cow to have the required body stores to be used for fetal development compared to cows with a low BCS who have to use their body tissue stores for fetal development. Those with low BCS will have a longer PPI as they have less body stores after calving than those cows with higher BCS who calved with sufficient body reserves (Dunn et al, 1980). The nutritional restriction of cows with low BCS will decrease the secretion of the necessary hormones needed for a successful estrous cycle (Wettemann et al., 2003).

Suckling and the presence of the calf has been shown to lengthen PPI (Stevenson et al., 1994; Short et al., 1990; Williams 1990) through a complex set of biological interactions. Stevenson et al. (1994) demonstrated that the actual presence of a calf would prolong PPI. Several sensory cues between the cow and the calf were likely to be associated with normal suckling-induced hormones. Chronic milking and the presence of a calf with the absence of suckling had no effect on the LH release and mastectomy and denervation of the udder have been shown not to shorten PPI (Williams, 2005). Cows that develop a maternal bond with their calf in addition to the physical stimulation of suckling resulted in neural changes causing anestrous.

This suppressed hypothalamic sensitivity to estradiol suppresses GnRH-LH secretions, and therefore prevents ovulation. When calves are weaned, the cow-calf bond ceases, the suckling stimulation is removed and the cows return to estrus in a few days. Postpartum interval can be shortened by complete weaning, short-term weaning (48 hours) or partial weaning with restricted, short, suckling periods (Short et al., 1990). A possible management option would be to regulate suckling in order to shorten PPI.

Lactation can influence reproduction and reproductive efficiency (Short et al., 1990; Lucy, 2001). Declines in female fertility have been occurring in the dairy industry due to heavy selection pressure on milk production traits (Lucy, 2001; Cammack et al., 2009). Lucy (2001) stated that "the reproductive physiology of dairy cows has changed over the past 50 years, and physiological adaptations to high milk production may explain part of the reproductive decline." Lactation and gestation overlap resulting in an inherent requirement for dairy cows to establish pregnancy while lactating (Lucy 2001). In DHIA records, it was noted that there was an increase in days to conception as the amount of milk produced increased (Lucy 2001). There is an antagonistic genetic correlation between milk production and fertility and females are considered to be sub-fertile during lactation (Cammack et al., 2009; Lucy, 2001; Frazier et al., 1999).

In modern dairy cows, the delay to ovulation following parturition can be explained by a negative energy balance. Dairy cows, when lactating, are generally in a negative energy balance during early post-partum interval (PPI) because they cannot consume sufficient energy in their diet. That negative energy balance will reduce LH surges and thus delay ovarian activity. The negative energy balance results in weight loss, in turn producing an inhibitory effect on ovarian follicular growth and development. With genetic improvements in milk production in the dairy industry, female fertility has declined by 25% since 1951 with a 0.45% per annum decline in the

United States from 1975 to 1997 (Lucy, 2001). Alternatively, higher producing dairy herds have improved reproduction but these improvements may be due to improved feed and management strategies (Lucy, 2001).

Unlike dairy operations where cows are managed in concentrated feeding operations, the majority of beef cows are maintained on pasture in a less intensive management system. Milk production influences the feed requirements for beef cows and nursing calves which introduce challenges in grazing environments. The maintenance requirements for a cow vary depending on activity, lactation demand and environmental conditions. These effects of environment on maintenance requirements vary with environmental stresses such as extreme weather conditions, reduction of forage, terrain, hair condition and skin condition (Fox et al., 1988; Hawkins et al. 2000). Short et al. (1990) stated that due to varying environments, different genes are likely activated. Genetic variation could be truncated if 1) some gene effects are zero in poor environments or 2) if average gene effects are reduced in herds in poorer environments. Management differences could be associated with environmental differences (Short et al., 1990).

Net energy and protein requirements are at their highest during peak lactation (Adams et al., 1996; NRC, 2010). The Nutrient Requirements of Beef Cattle (NRC, 2010) estimated the lactation curve of beef cattle in Figure 1. The net energy for maintenance and net protein required for milk production are presented in Tables 1 and 2, respectively.

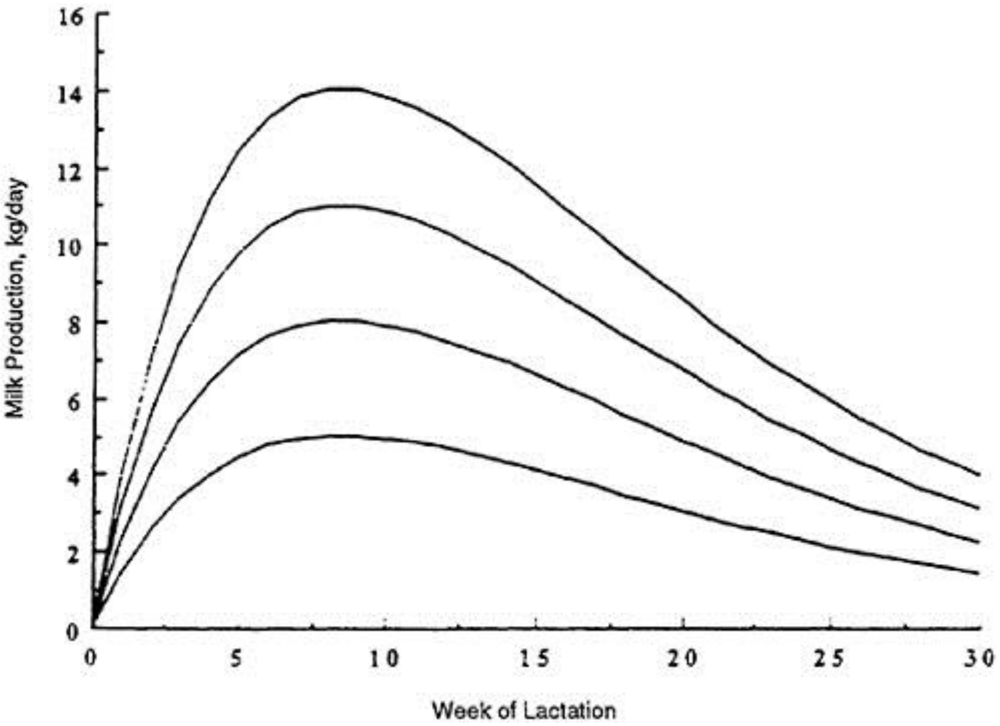


Figure 1. Generalized lactation curves for cows producing 5, 8, 11, or 14 kilograms of milk at peak milk production (NRC, 2010).

Table 1. Net Energy (NE_m, Mcal/day) Required for Milk Production (NRC, 2010).

Week of Lactation	Peak Milk Yield, kg/day			
	5	8	11	14
3	2.42	3.87	5.32	6.77
6	3.4	5.44	7.48	9.52
9	3.58	5.73	7.88	10.03
12	3.36	5.37	7.39	9.4
15	2.95	4.72	6.49	8.26
18	2.49	3.98	5.47	6.96
21	2.04	3.26	4.48	5.71
24	1.64	2.62	3.6	4.58
27	1.29	2.07	2.85	3.62
30	1.01	1.46	2.19	2.83

NOTE: Requirement assumes milk contains 4.0% fat, 3.4% protein, 8.3% SNF, and 0.72 Mcal/kg.

Table 2. Net Protein (g/day) Required for Milk Production (NRC, 2010).

Week of Lactation	Peak Milk Yield, kg/day			
	5	8	11	14
3	115	183	252	321
6	161	258	354	451
9	170	272	373	475
12	159	254	350	445
15	140	223	307	391
18	118	188	259	330
21	97	154	212	270
24	68	124	170	217
27	61	98	135	172
30	48	77	105	134

NOTE: Requirement assumes milk contains 3.4% protein.

When feed resources are limited and protein and energy requirements are not met, the cow's body reserves are utilized to meet the nutritional requirements (Jenkins and Ferrell, 1992). Cows that graze dormant native range are gazing forage that is low in dietary quality and may not receive the nutrients needed for reproduction (Hawkins et al., 2000). Adams et al. (1996) stated that a cow should receive the needed nutrients from grazed forages when the range resources are matched to the cow's stage of parturition or lactation. Two determining factors were referred to for matching an animal to its environments: genetic potential for milk production and synchronizing the highest nutrient value of the forage to the nutrient requirements for lactation.

Roger et al. (2004) proposed "matching the genetic potential of cows to the production environment, such that rebreeding performance is not compromised by concurrent lactation." Rogers et al. (2004) reported cows with higher breeding values for maternal pre-weaning gain were more likely to be culled. They attributed this to cows with lower milk production maintaining and accumulating energy reserves more successfully during lactation as compared to cows with higher milk production. Cows with higher milk production expend more energy reserves during lactation and are lighter at weaning and lack body condition to rebreed.

Calves suckling high-milk cows have heavier 205-d weights than calves suckling from low milking cows (Clutter and Nielsen, 1987; Minick et al., 2001), yet there are higher energy costs from milk versus other feed sources in addition to higher milk production resulting in higher maintenance requirements. Requirements for maintenance per unit of metabolic body weight (MW= $kg^{0.75}$) were positively related to production potential (Ferrell and Jenkins, 1985). Montano-Bermudez et al. (1990) and Minick et al. (2001) both reported that cows with low milk production had higher BCS compared to cows with medium to high milk production resulting in cows with low milking production being heavier than medium and heavy milk producing cows. During gestation, cows with lower milk production had higher BCS than cows in the medium to high milk production groups.

Montano-Bermudez et al. (1990) reported higher energy maintenance per MW for medium and high milk producing groups (16% and 11%, respectively) compared to low milk producing cows. Subsequently, during lactation, BCS for cows with low milk production were higher than cows with medium to high milk production. Body condition score changes for all levels of milk producing cows during gestation through lactation remained the same. Montano-Bermudez et al. (1990) found that the energy required during lactation to gain 1 kg of weight was 1.05 ± 0.83 MCal. When weight was lost the amount of energy required to regain the lost weight was estimated to be 2.94 ± 0.52 MCal per kg lost. Energy required to produce 1 kg of milk was estimated to be 1.0 ± 0.13 MCal. The study illustrated the increase in energy demands required by a cow during lactation and the amount of energy needed to improve BCS during lactation. In addition, cows with a decline in BCS while lactating would need a threefold increase in the amount of energy in order to gain the weight back.

Montano-Bermudez et al. (1990) also examined the difference in feedlot performance in calves from dams of different milk production levels. For growing cattle, the initial weight of calves was different between groups of low, medium and high milk producing dams. Estimated energy maintenance requirements per unit MW were 9 to 12% and 4 to 16% higher for medium and high groups, respectively, than those from the low milk producing groups. Montano-Bermudez et al. (1990) reported that the energy requirements for non-lactating cows to be 83 to 90% of what is required during gestation for their first trial and 73 to 83% for their second trial. Neville and McCullough (1969), Neville (1974) and Patle and Mudgal (1977) cumulatively reported that energy requirements for non-lactating Hereford cows were 70 to 76% of those who were lactating. Results from Montano-Bermudez et al. (1990) showed that medium and high milk producing cows required about 12% more energy per unit MW than low milk producing cows to maintain body weight. Maintenance requirements are positively related to milk production potential and therefore cattle with higher milk production have higher energy requirements (Montano-Bermudez et al., 1990).

Positive phenotypic relationship between cow body weight and milk production for both beef and dairy cows has been reported (Sieber et al., 1988; Lewis et al., 1990; Freking and Marshall, 1992). In other words, larger framed cattle produce more milk. However, the genetic relationship has been inconsistent in dairy cattle (Badinga et al., 1985; Lin et al., 1985). Negative genetic correlations between weight at calving and first lactation milk yield ranged from -0.22 to -0.24 for Holsteins and -0.29 to -0.33 for Ayrshires were reported by Moore et al. (1991) and -0.10 for polled Herefords was reported by Meyer et al. (1994).

Milk EPD

Frazier et al. (1999) defined milk EPD as a combined predictor of genetic merit for milk production and maternal ability. Milk EPD was developed to predict the genetic differences in milk production in beef cattle (Benysheck et al., 1988, Marson et al., 1992; Minick et al., 2001) since milk production is a major component of maternal effects on calf growth prior to weaning (Meyer, et al., 1994). These EPD have been used by producers to change the milking ability of their herd and to tailor the milking ability to match their environment. Through selection on milk production, there is an opportunity for a herd to increase milk production to increase weaning weight (Marston et al., 1992).

In a studies conducted by Marston et al. (1992) and Minick et al. (2001), a positive relationship between milk EPD, actual milk production and weaning weight was shown. Marston et al. (1992) suggested that milk production can be estimated by measuring a single lactation. It was reported that a 1 kg change in milk EPD resulted in an increase in actual milk yield of 42.1 ± 16.6 kg for Angus and 69.3 ± 16.0 kg for Simmental. There was a 2 unit change in calf weaning weight per unit change in dam's milk EPD which was expected since the breeding value is ½ the milk EPD which passed from parent to progeny. Calves with larger birth weights resulted in dams producing more milk. Both EPD for weaning weight and dam's milk were related to weaning weight. The total intake of milk fat and protein influenced pre-weaning growth and weaning weights compared to the percentage of constituents (i.e. fat, protein, lactose and total solids) which had little or no effect. Total milk yield and adjusted weaning weights were correlated and suggested that the total milk production had a strong influence on calf performance (Marston et al., 1992, Meyer et al., 1994; Minick et al. 2001). However, Marston et al. (1992) and Minick et al. (2001) argued that milk EPD were conservative in predicting the differences in calf weaning weight and true genetic differences.

The beef industry is challenged with balancing genetics and production profitability. Maintaining a calving interval of less than 365 days is critical for maintaining an efficient beef production system (Frazier et al., 1991). Short et al. (1990) reported a negative relationship between milk yield and reproduction in Holstein cattle. In a study conducted with beef cows by Brink and Kniffen (1996), cows with high milk EPD had a longer calving interval; however, calving intervals were not consistently affected by milk EPD. Frazier et al. (1991) found that milk EPD and sire marbling EPD were significant predictors of age at first calving. They also found an increase of 113-kg of milk EPD decreased age at first calving by 21 days. In addition, daughters from sires with high milk EPD (sires in the top quartile) had a decrease in age at first calving by 8.5 ± 0.4 days when compared to low milk EPD sires (sires in the lower quartile). Frazier et al. (1999) found a statistical significance in their results for calving interval but the biological significance was minimal. They concluded that the use of sire milk EPD was not a significant predictor of calving intervals. Frazier et al. (1999) concluded that selection for either of these traits would not have detrimental effects on calving interval.

CHAPTER 3

MATERIALS AND METHODS

Two sources of data were available for the investigation of the objectives of this study. The first was provided by the Red Angus Association of America (RAAA) and the second was provided by Colorado State University's John E. Rouse Beef Improvement Center (BIC). The Red Angus Association of America provided pedigrees, performance information and breeder addresses in order to examine the effects of milk production on length of productive cow life across different environments. In order to examine the relationship of length of productive life and milk production in a commercial herd in a single environment, records from BIC for milk EPD, dam birth dates and calving dates were provided. The following provides a description of the data used in this study as well as the methodology to address the objectives of the study in the context of each data source.

Red Angus

Data

The Red Angus Association of America (RAAA) provided animal identification, sex, breeder, sire, dam and the dam's date of birth for 3,095,722 individual registered Red Angus cattle. Milk expected progeny differences on 3,185,914 individual animals, metabolic weight EPD for 120,884 animals, stayability records for 313,352 animals and a pedigree containing 3,149,414 was also provided. This information was used to create data on females with lifetime calf production records.

Stayability records that were provided are coded as either 0 or 1. A stayability score of 0 was defined as an animal that did not wean 5 calves by the time she reached the age of six given calving as a 2 year old. A stayability score of 1 represented a cow that weaned 5 calves by the time she has reached the age of six. Cows with stayability scores of 1 were considered by RAAA to have reached the breakeven point on the initial investment of the cow and to compensate for the failure rate of other cows in the herd. With this coding, 91,692 animals had stayability scores of 1 and 221,660 animals had scores of 0.

A contemporary group was defined as a group of animals experiencing similar environments (Bourdon, 1997). Contemporary groups for stayability were defined as breeder of the dam, dam birth year and breeder of the calf. Once contemporary groups were constructed, these were filtered with observations from contemporary groups with no variation deleted (e.g. all stayability observations within contemporary group are 0 or 1). The number of contemporary groups per breeder ranged from 2 to 5558 with an average of 88 contemporary groups per breeder. An additional requirement was applied where the breeder must have a minimum of 150 usable stayability records. The final data set represented 229 breeders with an average of 454 contemporary groups reported per breeder.

Using addresses provided by RAAA, the location of the 229 breeders were identified using Google Earth (https://**earth.google**.com/*; see* Figure 2). Based on these locations, each breeder was assigned to a biome according to the Marietta College Department of Biology and Environmental Science's biome map (http://www.marietta.edu/~biol/biomes/bioregion_map.htm; Figure 3) where biome was defined as geographical areas with similar climates and vegetation (Campbell (1996)). The biome map listed 52 different biomes throughout the United States with breeders located within 29 of the 52 biomes. The biome map also lists the 52 biomes by general biome classifications. Subsequently the 229 breeders from the final data were classified into 8 general biomes:

California Division (CA), Dry Domain (DD), Eastern Great Plains Division (GPE), Western Great Plains Division (GPW), Hot Continental Division (HC), Prairie Division (PR), Rocky Mountain Province (RM), and Subtropical Division (ST). The process for going from 29 biomes to 8 is described and justified below per the general biome classifications of the Marietta College Department of Biology and Environmental Science's biome map.

Southeastern mixed forest province, outer coastal plain mixed forest province, lower Mississippi riverine forest province, Ouachita mixed forest-meadow province were located in the southeastern region of the United States and was designated Subtropical Division. Prairie Division included prairie parkland (temperate) and prairie parkland (subtropical) provinces. California coastal chaparral forest and shrub province, California dry steppe province, California coastal steppe-Redwood forest province, sierra steppe-mixed forest, California coastal range open woodland were assigned to the California Division. Dry Domain was comprised of the deserts of the United States which included great plains steppe and shrub province, Colorado plateau semi desert province, southwest plateau and plains dry steppe and shrub province, Chihuahuan semi desert province, Arizona-New Mexico mountain semi desert and American semi desert and desert province. Great Plains Palouse dry steppe province and Great Plains steppe province were assigned to Western Great Plains Division and Eastern Great Plains Division, respectively. The biome Black Hills coniferous forest province was also included in the Western Great Plains Division. The entire Rocky Mountain region which included southern Rocky Mountain steppe, middle Rocky Mountain steppe, and northern Rocky mountain steppe were designated as Rocky Mountain Province. The Hot Continental Division contained the eastern broadleaf forest (oceanic) province, the eastern broadleaf forest (continental) province, central Appalachian broadleaf-coniferous forest-meadow province and Ozark broadleaf forest-meadow province.

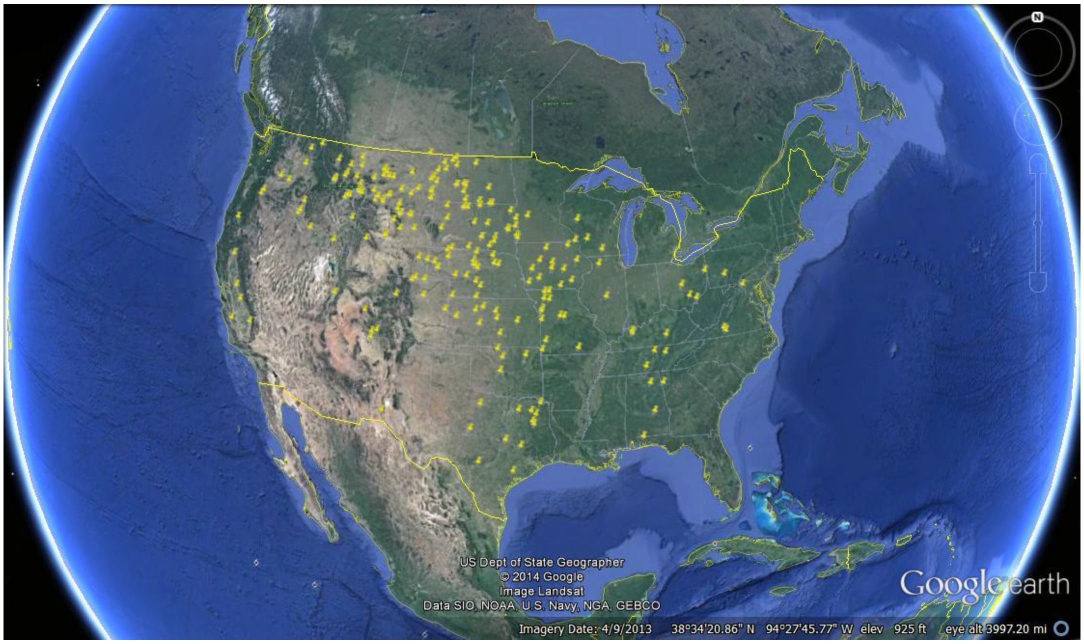


Figure 2. Map of the United States illustrating the location of Red Angus breeders (https://**earth**.**google**.com/).

Figure 3. Marietta College Department of Biology and Environmental Science's biome map (http://www.marietta.edu/~biol/biomes/bioregion_map.htm).

The California Division encompassed the coastal, central and northern California and southern area of Oregon. The Dry Domain covered the desert areas of western Texas, non-mountainous areas of New Mexico, Arizona and Nevada and southeastern California. Due to the large number of animals located in the Great Plains, the Great Plains was split into two groups, eastern and western. The Eastern Great Plains (GPE) stretched from central North Dakota to central Oklahoma while the Western Great Plains spanned from western North Dakota and the non-mountainous areas of Montana south through eastern Colorado and the panhandle of Oklahoma. The Hot Continental (HC) was located in Kentucky, Tennessee, Indiana, Michigan, southern Wisconsin, southern Illinois, southern Missouri, Ohio, West Virginia, western Virginia and the Appalachian Mountain range. The Prairie Domain encompassed the Midwestern United States. The Rocky Mountain ranges are represented in the Rocky Mountain Province (RM). The south eastern portion of the United States from the southern Virginia to Florida coasts to eastern Texas was considered the Subtropical Division (ST). Figure 4 illustrates the locations of the 8 biomes and summary statistics of data in each are presented in Table 3.

Additional environmental information besides biome classification was developed. The average maximum and minimum temperatures for January and July as well as average annual precipitation were determined for each breeder location using data collected from the Weather Channel website (*www.weather.com/).*

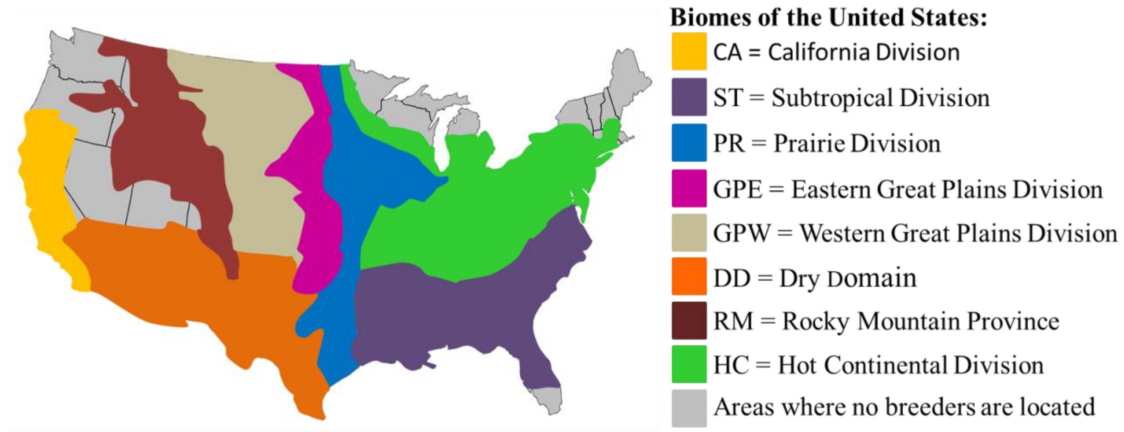


Figure 4. Map of the United States illustrating the location of 8 biomes highlighted by color (http://www.marietta.edu/~biol/biomes/bioregion_map.htm).

Table 3. Summary statistics for cow longevity in years, milk EPD in kg, metabolic weight EPD in kg and annual precipitation in mm for each biome.

Biome[1]	N[3]	No. of Breeders	Longevity[2]		Milk EPD		Metabolic Weight EPD		Annual Precipitation	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
CA	4544	6	6.68	3.30	6.50	2.89	6.12	1.63	442.63	83.93
DD	2691	10	6.18	3.27	6.92	2.64	6.66	1.56	428.14	144.08
GPE	14673	32	6.43	3.38	6.97	2.98	7.13	1.66	610.79	105.12
GPW	38105	57	6.25	3.36	7.16	3.11	6.95	1.49	435.39	51.24
HC	8630	26	6.37	3.20	7.04	3.01	7.14	1.58	1121.94	131.81
PR	12529	34	6.71	3.38	7.48	2.98	6.07	1.60	910.38	138.15
RM	36853	55	6.10	3.48	7.51	2.86	6.22	1.53	361.17	107.15
ST	2859	9	6.33	3.42	8.85	2.81	4.28	1.89	1264.37	163.58

[1] Biome was a geographical area with similar climates and vegetation

[2] Longevity was the age at which a cow had her last calf and was calculated from the difference in the cow's date of birth and year in which she produced her last calf

[3] N=The number of cows located within each biome.

The final Red Angus data set included 120,871 cows, 8674 sires, in 8 biomes. The average milk EPD was 7.28 kilograms of calf weaned with a range of -9.89 kilograms to34.81kilograms and a variance of 19.74 kilograms^2. There was an average longevity of 6.3 years with a variance of 11.5 year^2 and a range in the observations of 2 years to 29 years. Metabolic weight EPD was a prediction of cow mature weight. It was calculated using the cow's mature weight adjusted to a body condition score of 5 and raising it to the power of 0.75 per NRC guidelines (NRC, 2010). The average metabolic weight EPD was 2.98 kilograms with a minimum of -2.86 kilograms and a maximum of 13.15 kilograms and a variance of 5.5 kilograms^2. A length of productive life score (longevity) was calculated for each cow using the cow's date of birth and year in which she produced her last calf. Animals with biologically impossible longevity scores were removed from the file (i.e. >40 years). The average longevity, milk EPD and metabolic weight EPD per biome are presented in Table 1.

Of the 120,871 cows; 86,799 had a stayability score of 0, accounting for 71.8% of cows in the dataset. Further examination of the data resulted in 22, 375 cows with a stayability observation of 0 but a longevity score of greater than 6 indicating that these cows missed calving at least one year. Interpretation of the two measures of longevity and the results of this study must be made with care due to these differences. The largest age group of cows with stayability scores of 0 were 2 year olds, which was expected (17,577 cows).

Statistical Analysis

The analysis of the data for longevity as the dependent variable was conducted with ASREML 3.0 (Gilmour (2009)) using the following three models:

Model 1

$Y_{tijko} = \mu + MILK_{ti} + MILK_{ti}^{2} + MWT_{tj} + BIOME_{tk} + MILK_{ti}*BIOME_{tk} + MILK_{ti}^{2}*BIOME_{tk} + \varepsilon_{tijkmo}$

Where:

Y_{tijko} = record of trait *t* for longevity measured in years of the cow,

μ = overall population mean,

$MILK_{ti}$ = the cow's milk EPD *i* for trait *t,*

MWT_{tj} = the cow's metabolic weight EPD *j* for trait *t*,

$BIOME_{tk}$ = the fixed effect of biome *k* for trait *t,*

ε_{tijko} = random residual effects.

A quadratic term for milk EPD was included in model 1 as well as an interaction between the linear and quadratic milk EPD term and biome. The quadratic term was included to model a non-linear effect where, at some point, the direction of the relationship between longevity and milk EPD could change. The inclusion of an interaction allowed for the investigation of differences in the effects of milk EPD in each biome on longevity. Metabolic weight EPD was included in the model as a fixed effect to account for cow mature size and nutrient requirements.

Model 2

$Y_{tijko} = \mu + MILK_{ti} + MILK_{ti}^{2} + MWT_{tj} + MWT_{tj}^{2} + BIOME_{tk} + MILK_{ti}*BIOME_{tk} + MILK_{ti}^{2}*BIOME_{tk} + MWT_{tj}*BIOME_{tk} + MWT_{tj}^{2}*BIOME_{tk} + \varepsilon_{tijko}$

Where:

Y_{tijko} = record of trait *t* for longevity measured in years of the cow,

μ = overall population mean,

$MILK_{ti}$ = the cow's milk EPD *i* for trait *t*,

MWT_{tj} = the cow's metabolic weight EPD *j* for trait *t*,

$BIOME_{tk}$ = the fixed effect of biome *k* for trait *t*,

ε_{tijko} = random residual effects.

In model 2, a quadratic term for metabolic weight EPD and the interaction of biome with the linear and quadratic term for metabolic weight EPD was included in the model. The inclusions of the additional terms were to study the effect of MWT on cow longevity and to also account for these genetic differences in individual cows so as to better evaluate the effects of milk production levels.

Since stayability is nonlinear and results in a binomial distribution, a logistic regression was conducted with SAS 9.3 (SAS Institute Inc., Cary, NC) using the following model (model 3) for the stayability traits:

Model 3

$$Y_{tijko} = \mu + MILK_{ti} + MILK_{ti}^{2} + MWT_{tj} + BIOME_{tk} + MILK_{ti}*BIOME_{tk} + MILK_{ti}^{2}*BIOME_{ti} + \varepsilon_{tijkmo}$$

Where:

Y_{tijko} = record of stayability t ($t = 0, 1$) of the cow,

μ = overall population mean,

$MILK_{ti}$ = the cow's milk EPD i for trait t,

MWT_{tj} = the cow's metabolic weight EPD j for trait t,

$BIOME_{tk}$ = the fixed effect of biome k for trait t,

ε_{tijko} = random residual effects.

Beef Improvement Center

The second set of data used to meet our objectives was that from Colorado State University's John E. Rouse Beef Improvement Center (BIC). The herd data from BIC was representative of a commercial herd in a single environment.

Data

Herd data collected from the BIC was used to examine the effects of milking ability on stayability and longevity on the Angus based cow herd in a single environment. The ranch is located in Carbon County, Wyoming which is found in the Rocky Mountain biome at an elevation of 2,200 m. The average annual precipitation for BIC is 354 mm with an average temperature of -6^{0}C in January and an average temperature of 17^{0}C in July.

Cows are maintained on pasture year round and are supplemented with hay during the winter. During the summer, cows are grazed on pastures comprised of Wyoming big sagebrush

(*Artemisia* tridentate), western wheatgrass (*Agopyron smithii),* and needle-and-thread grass (*Stipa comate)* (Bastian et al., 1995). The rest of the year, cows are grazed on timothy (*Phleum pratense)* and brome *(Bromus inermis Leyss)* pastures. Calving season begins in February with the majority of the calves born by the end of May and therefore, the cows are grazing on pasture during peak lactation.

In June, the cows are synchronized and bred by artificial inseminated (AI) to either registered bulls or within herd bulls. Any cows that are not bred by AI are bred by natural service to a within herd bull. As a result, the herd is comprised of cows that are sired by either registered Angus bulls or within herd unregistered Angus bulls. Any cows who were sired by any breed other than an Angus bull was removed from this study. No selection pressure was placed on milk for this herd. Yet, this herd was chosen because of the use of registered American Angus Association (AAA) sires from outside the herd. Historically, the AAA trend for milk has been upward (http://www.angus.org/nce/genetictrends.aspx; Figure 5). Given the trend for milk in those outside sires, this herd was especially suited to evaluate the effect of milk on cow productivity in the restrictive environment of this location comparing within-herd to AAA sires.

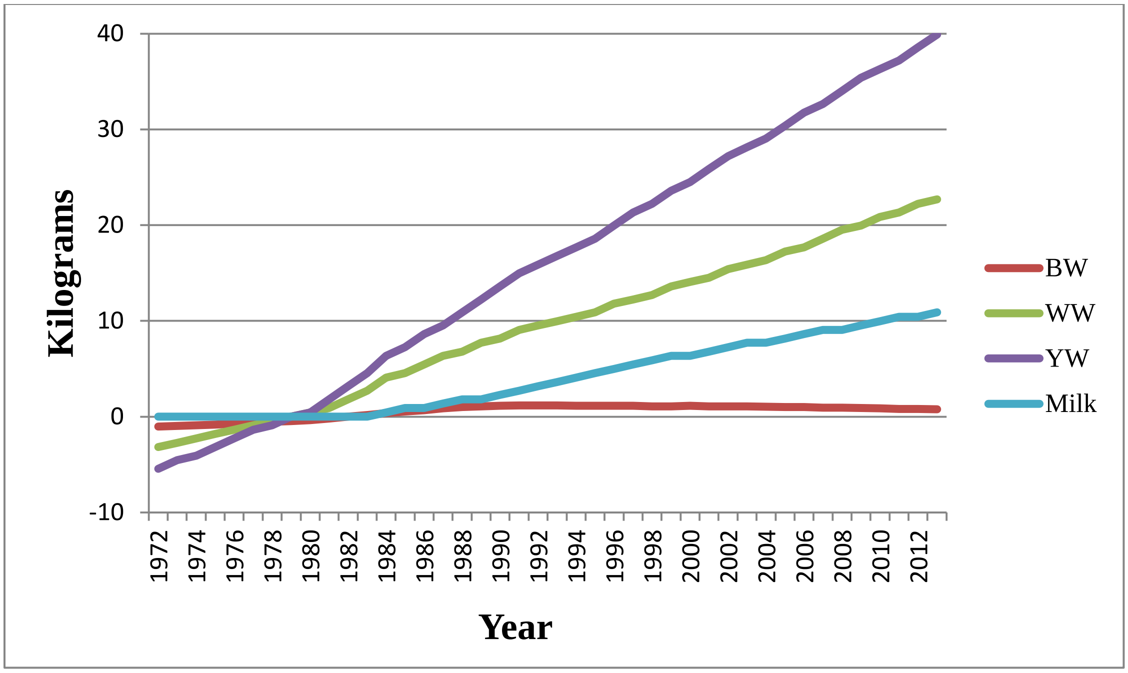


Figure 5. Genetic trends of birth weight (BW), weaning weight (WW), yearling weight (YW) and milk EPD (MILK) for American Angus Association from 1972 to 2013

This data set included 8,347 calf records collected from 1994 to 2013 with dam birth dates ranging from 1979 to 2011. Using this data, the dam's age at which she last calved was calculated and throughout is referred to as longevity. After calculating longevity, each animal received a score for stayability to 3 years of age and stayability to 6 years of age based on the longevity. As with Red Angus, a score of 0 represented an animal that failed to reach the respective year of stayability and a score of 1 if she succeeded. The frequency of success and failure are reported in Table 4 by the dam's birth year. Only animals having sufficient time to reach the required endpoint age for stayability were included for each age. For instance, stayability to 3 years of age included only animals born prior to 2010. Accordingly, only animals that were born prior to 2007 were used for stayability scores of 6 years as younger animals had not had the opportunity for stayability to 6 observations. When longevity was used as the dependent variable, cows that were born after 2000 were removed from the data set to prevent bias for cows that were still in production past 6 years of age. In essence this puts a maximum limit on longevity of 13 for cows born in 2000. Cows with unknown sires were also removed from the data set which accounted for 0.05% of the observations.

The data set containing stayability to 3 years contained records for 1097 cows. The average milk EPD for cows within this data set was 1.3 kilograms of calf weaned with a standard deviation of 2.0 kilograms, a minimum of -7.3 kilograms and a maximum of 6.6 kilograms. When examining the cow’s sire’s milk EPD, the mean was 1.3 kilograms of calf weaned with maximum milk EPD of 13.7 kilograms, a minimum of -7.5 kilograms and a standard deviation of 2.1 kilograms.

When stayability is considered to 6 years of age, 906 cow records were used. For the cow’s milk EPD, the average was 1.4 kilograms of calf weaned with a minimum of -7.3 kilograms and a maximum of 6.6 kilograms. The standard deviation was 2.1 kilograms. The average for the cow’s sire’s milk EPD was 1.5 kilograms of weaned calf with a standard deviation of 2.6 kilograms, a maximum of 6.2 kilograms and a minimum of -7.5 kilograms.

The resulting data set for longevity was comprised of 507 cows that were born1993 to 2000. The average longevity for BIC was 7 years with a minimum age of 2 years and a maximum age of 16 years with a variance of 16.767 years^2. In addition, the average milk EPD for cows in this data set was 1.5 kilograms of calf weaned with a minimum of -5.3 kilograms and a maximum of 6.1 kilograms and a standard deviation of 1.9 kilograms. When considering the milk EPD for the cow’s sire, the average is 1.9 kilograms of calf weaned with a standard deviation of 2.1 kilograms. The minimum milk EPD for the sires was -4.1 kilograms and a maximum of 6.2 kilograms.

Table 4. Average longevity measures and frequency of failure and success for stayability for BIC cow herd

[1]Year	[2]Longevity	[3]Score	3 Year Stayability		6 Year Stayability	
	Mean		Frequency	Percent	Frequency	Percent
[4]Overall	7.2	0	152	13.9%	360	39.4%
		1	945	86.1%	554	60.6%
1993	6.7	0	8	12.3%	35	53.8%
		1	57	87.8%	30	46.2%
1994	6.6	0	22	31.9%	35	50.0%
		1	47	68.1%	35	50.0%
1995	6.7	0	8	12.9%	31	50.0%
		1	54	87.1%	31	50.0%
1996	7.1	0	5	8.5%	27	45.0%
		1	54	91.5%	33	55.0%
1997	7.2	0	11	15.5%	30	42.3%
		1	60	84.5%	41	57.7%
1998	7.7	0	13	16.5%	27	34.2%
		1	66	83.5%	52	65.8%
1999	7.4	0	6	11.3%	22	41.5%
		1	47	88.7%	31	58.5%
2000	8.3	0	5	10.2%	13	26.5%
		1	44	89.8%	36	73.4%
2001		0	3	4.8%	14	22.2%
		1	59	95.2%	49	77.7%
2002		0	9	18.0%	21	42.0%
		1	41	82.0%	29	58.0%
2003		0	9	18.4%	16	32.7%
		1	40	81.6%	33	67.3%
2004		0	2	4.7%	10	23.3%
		1	41	95.3%	33	76.7%
2005		0	14	18.4%	35	43.8%
		1	62	81.6%	45	56.3%
2006		0	7	11.7%	25	41.0%
		1	53	88.3%	36	59.0%
2007		0	3	5.1%	19	32.2%
		1	56	94.9%	40	67.8%
2008		0	12	19.7%		
		1	49	80.3%		
2009		0	11	15.9%		
		1	58	84.1%		
2010		0	4	6.6%		
		1	57	93.4%		

Longevity was reported from 1993 to 2000 as these were the years used for the analysis.

[1] Year = the cow's birth year

[2] Longevity = The average length of productive life for cows born within the specific year.

[3] Score = stayability score of either 0 for failure and 1 for success

[4] Overall = the frequency and percent for all the animals

Statistical Analysis

Data were analyzed with the MIXED procedure in SAS 9.3 (SAS Institute Inc., Cary, NC) using the following mixed model.

Model 1

$Y_{tijl} = \mu + MILK_{ti} + (MILK_{ti})^2 + YEAR_{tj} + \varepsilon_{tijl}$

Where:

Y_{tijl} = record of trait *t* for longevity measured in years of the cow,

μ = overall population mean,

$MILK_{ti}$ = the milk EPD *i* for trait *t*,

$YEAR_{tj}$ = the cow's birth year *j* for trait *t*,

ε_{tijl} = random residual effects,

The same mixed model was used for analyses of BIC data. The initial analysis was conducted using the cow's milk EPD. Subsequent analysis was conducted using the milk EPD of the cow's sire as these had higher accuracy. A final analysis was conducted using only cows from registered American Angus Association sires using the sire's milk EPD reported by American Angus Association. This final analysis was conducted to evaluate the effects milking ability of the daughters of registered Angus sires and their ability to remain in the herd since historically there has been an increase in milk EPD for these sires.

Since stayability is nonlinear and is a binomial distribution, a logistic regression was conducted using the following model:

Model 2

$$Y_{tijm} = \mu + MILK_{ti} + (MILK_{ti})^2 + YEAR_{tj} + \varepsilon_{tijm}$$

Where:

Y_{tijm} = record of stayability *t* (*t* = 0, 1) of the cow,

μ = overall population mean,

$MILK_{ti}$ = the cow's milk EPD *i* for trait *t*,

$YEAR_{tj}$ = the cow's birth year *j* for trait *t*,

ε_{tijm} = random residual effects.

The same model was used for stayability to 3 years and 6 years.

These models were used to illustrate the effects on milk EPD on the length of productive life of the cow be it measured through longevity or stayability. Using a regression model we can see the amount of change in milk EPD in relation to the change in longevity. The logistic regression models measured the degree of association between the probability of the receiving a stayability score of 1 and the value of milk EPD.

CHAPTER 4

RESULTS

The results of the study evaluating the effects of level of milk production on cow stayability and longevity are presented in the following text. The results will be presented first for RAAA, followed by the results for the BIC herd. For both sources of data, the results from the analysis with longevity as the dependent variable will be presented first followed by the results for the logistic regression approach with stayability as the dependent variable. The discussion is found at the end of this chapter, following the results for both Red Angus and BIC.

Red Angus Analysis

The main effects and their significance in all three models are presented in Table 5 with longevity as the outcome. The interaction of biome and milk EPD and EPD^2 were found to be significant ($P<0.05$). The parameter estimates and regression coefficients for model 1 with longevity as the dependent variable are presented in Tables 6 and 7, respectively. These results represent a non-linear equation with marginal effects that are not constant and vary with each level of milk EPD. The marginal effect can be seen by differentiating y (the dependent variable) with regards to x (independent variable). Consider the regression equation: $y = b_0 + b_1 x + b_2 x^2$, the differential of this equation was: $y' = b_1 + 2b_2 x$. This first derivative gave the rate of change (b_1) when x = 0 and whether the function was increasing or decreasing. The second derivative of the above equation: $y'' = 2b_2$, produces b_2 as the direction and steepness of the curvature. When the first derivative was set to zero ($0 = b_1 + 2b_2 x$) the local minimum for x can determined identifying the lowest point of the quadratic curve. Therefore, for higher levels of milk EPD (beyond the local minimum), as the milk EPD increased so did the longevity of the cows when holding all other variables in the model constant. However, the regression coefficients are small (<0.02) indicating that a large difference in milk would be necessary to see a significant difference in longevity (Figure 6). For example, in order to increase longevity for a cow within the Subtropical biome by 1 year, milk EPD would need to increase by 17.6 kilograms.

Table 5. Wald-F statistics and P-values for the main effects for the 3 regression models for longevity and milk EPD for Models 1 and 2 and stayability and milk EPD for Model 3.

[1]Main Effect	Model 1		Model 2		Model 3	
	[2]F	P-value	[2]F	P-value	[2]F	P-value
Intercept	24888.44	<.001	19844.31	<.001	834.38	<.001
milk EPD	93.23	<.001	100.97	<.001	3.04	0.081
milk EPD^2	380.68	<.001	389.02	<.001	18.92	<.001
Biome	71.03	<.001	70.21	<.001	383.35	<.001
Metabolic Weight EPD	778.22	<.001	261.18	<.001	22.82	<.001
Metabolic Weight EPD^2	[3]NA	[3]NA	63.09	<.001	[3]NA	[3]NA
Biome*milk EPD	2.35	0.022	2.16	0.034	61.23	<.001
Biome*milk EPD^2	6.07	<.001	5.89	<.001	29.22	0.001
Biome*Metabolic Weight EPD	[3]NA	[3]NA	17.50	<.001	[3]NA	[3]NA
Biome*Metabolic Weight EPD^2	[3]NA	[3]NA	14.20	<.001	[3]NA	[3]NA

[1] Main Effect = the main effects of the regression model

[2] F= Wald F statistic

[3] NA= Terms not included in mod

Table 6. Parameter estimates for the regression of longevity (years) on milk EPD (kilograms) by biome class

[1]Biome	[2]Milk EPD Estimates	Standard Error	[2]Milk EPD^2 Estimates	Standard Error
Milk EPD	-0.2414	0.0935	0.0169	0.0053-
Subtropical Division	0.0000	0.0000	0.0000	0.0000
Rocky Mountain Division	0.0990	0.0958	0.0027	0.0054
Western Great Plains Division	0.1834	0.0949	-0.0083	0.0054
Eastern Great Plains Division	0.1449	0.0976	-0.0005	0.0056
Prairie Division	0.1577	0.0987	-0.0004	0.0056
Dry Domain	0.0971	0.1227	0.0004	0.0076
Hot Continental	0.0800	0.1003	-0.0021	0.0059
California Division	0.1576	0.1060	-0.0028	0.0065

[1]Biome = the parameter of the interaction of biome by milk EPD

[2]Milk EPD Estimates = the parameter estimates for the regression of longevity (years) on milk EPD (kilograms)

[3]Milk EPD^2 Estimates = the parameter estimates for the regression of longevity (years) on the quadratic of milk EPD (kilograms^2)

All P-values were significant at α=0.05 (*P<0.001)*

Table 7. Regression coefficient estimates for the regression of longevity (years) on milk EPD (kilograms) by biome class

[1]Biome	[3]Milk EPD	[2]Milk EPD^2
Subtropical Division	-0.2414	0.0169
Rocky Mountain Division	-0.1965	0.0175
Western Great Plains Division	-0.1582	0.0152
Eastern Great Plains Division	-0.1757	0.0168
Prairie Division	-0.1699	0.0157
Dry Domain	-0.1974	0.0170
Hot Continental	-0.2051	0.0165
California Division	-0.1699	0.0164

[1]Biome = the parameter of the interaction of biome by milk EPD

[2]Milk Weight EPD = the regression coefficients for the interaction of linear milk EPD and biome for the regression of a cow's longevity on milk EPD

[3]Milk EPD^2 = the regression coefficients for the interaction of biome and the quadratic of milk EPD for the regression of a cow’s longevity (years) on the quadratic of milk EPD

All p-values were significant at α=0.05 (*P<0.001)*

Figure 6 illustrates the resulting quadratic regressions for biome when holding all other variables constant. For each biome, the regression coefficients were different resulting in an intersection of lines and a significant interaction. This is not the case with biome and milk EPD. The regression coefficients are different for each biome illustrating an interaction. Figure 7 shows the estimated values for longevity when regressed on milk EPD for all biomes combined. Figures 8 through 15 are the estimated values of longevity on milk EPD for each individual biome and illustrate the differences in regression coefficient by biome.

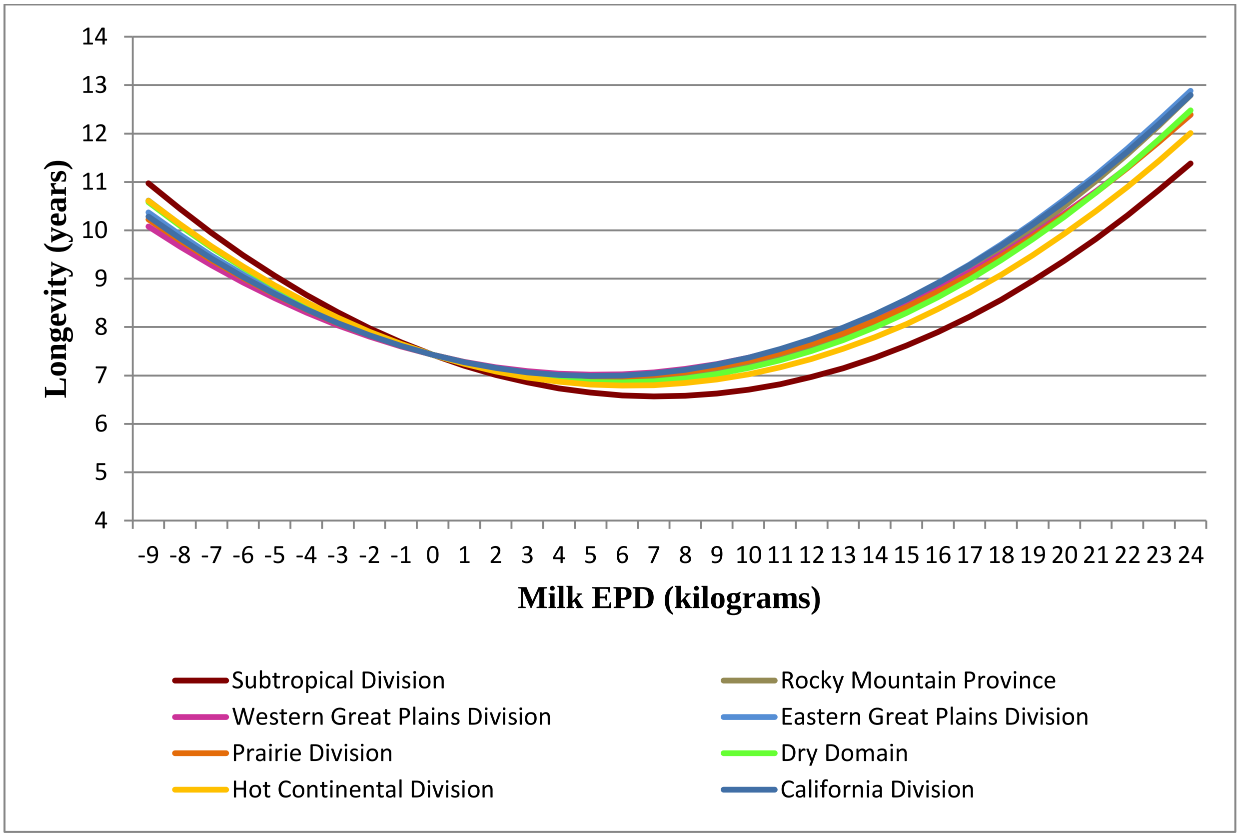


Figure 6. Graph of the regression of longevity on milk EPD for each biome.

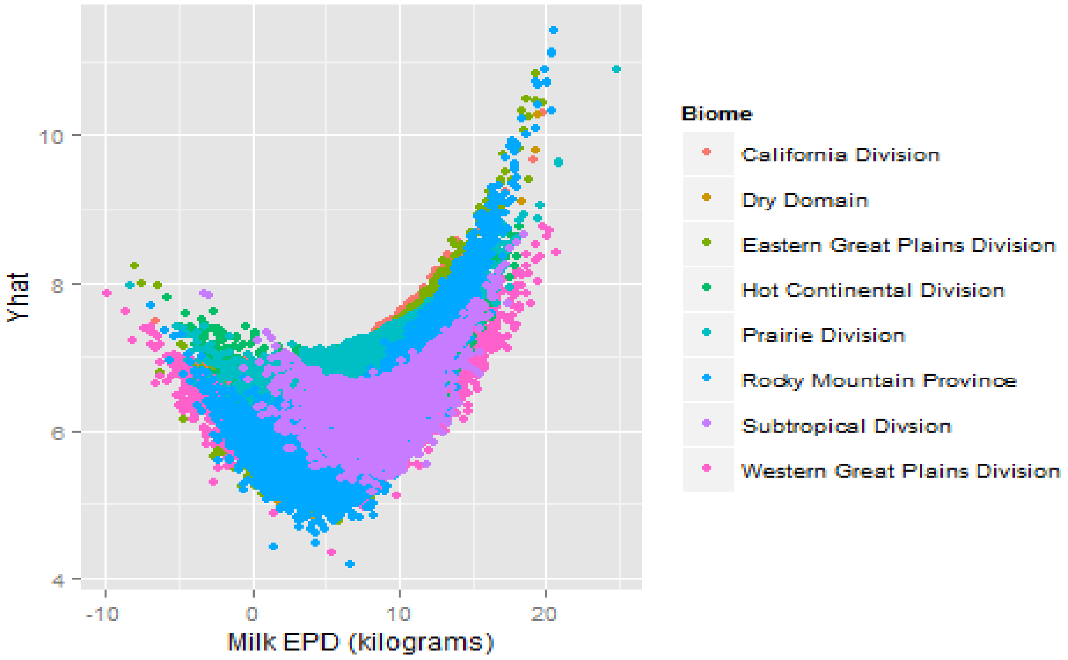


Figure 7. Illustration of the resulting estimates of the dependent variable longevity regressed on milk EPD for all biomes combined

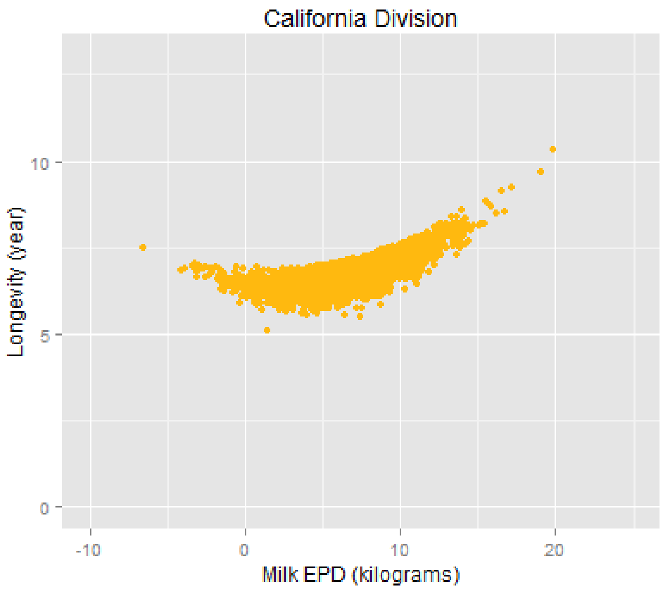


Figure 8. Illustration of estimates of the dependent variable longevity regressed on milk EPD (kilograms) for the cows within the California Division biome.

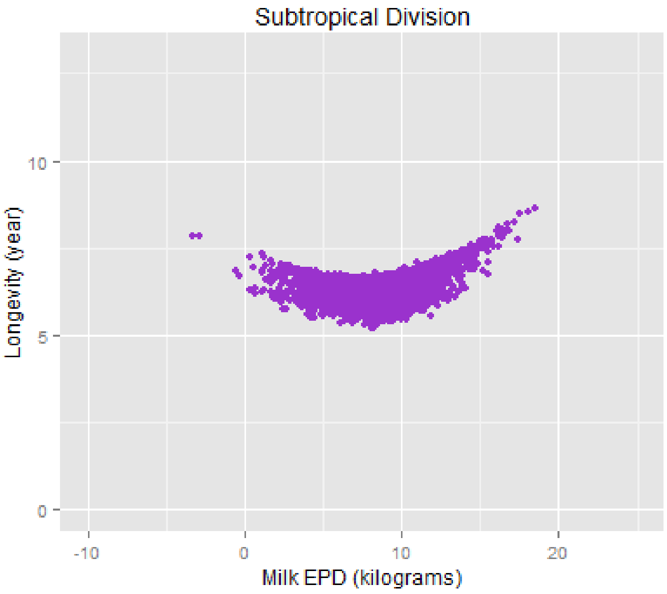


Figure 9. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Subtropical Division biome.

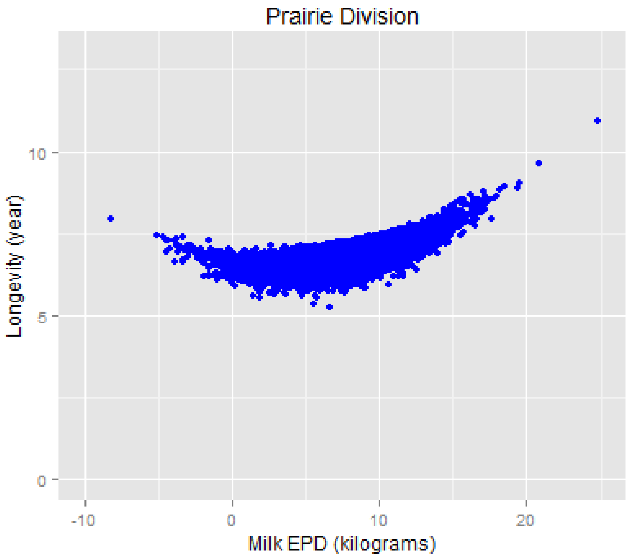


Figure 10. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Prairie Division biome.

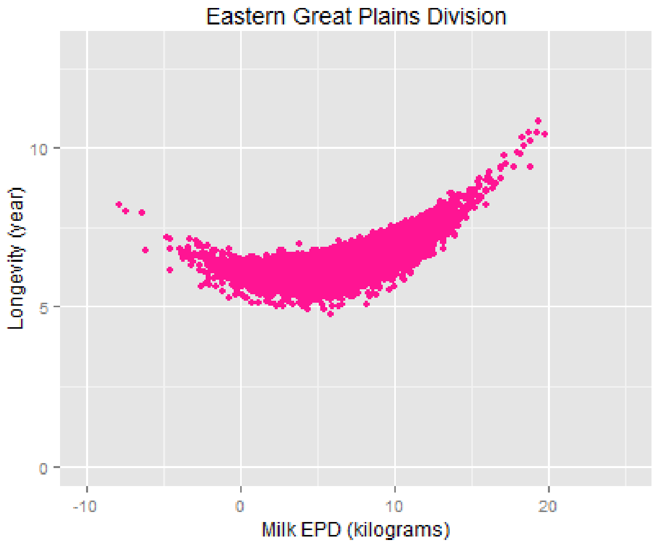


Figure 11. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Eastern Great Plains Division biome.

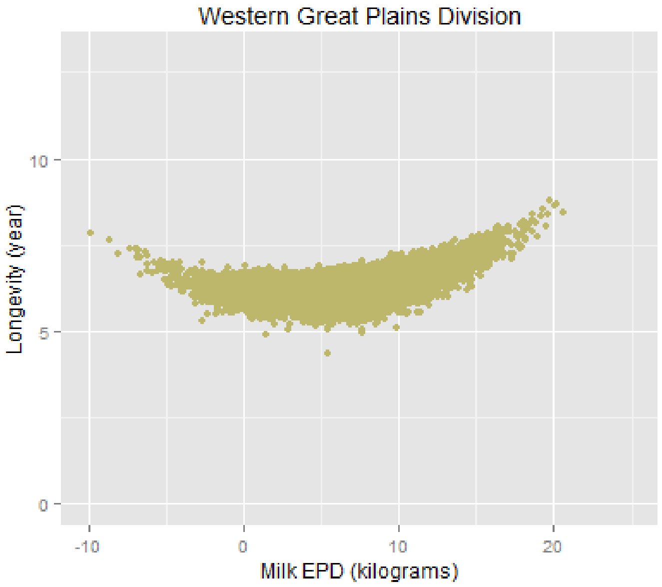


Figure 12. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Western Great Plains Division biome.

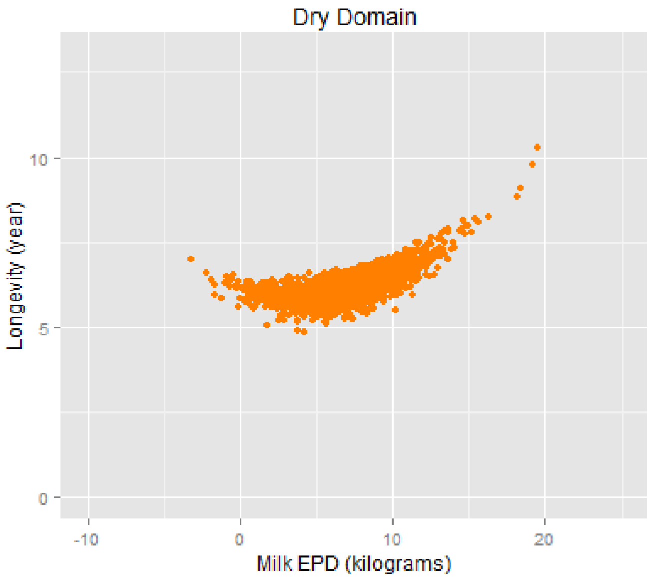


Figure13. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Dry Domain b
iome.

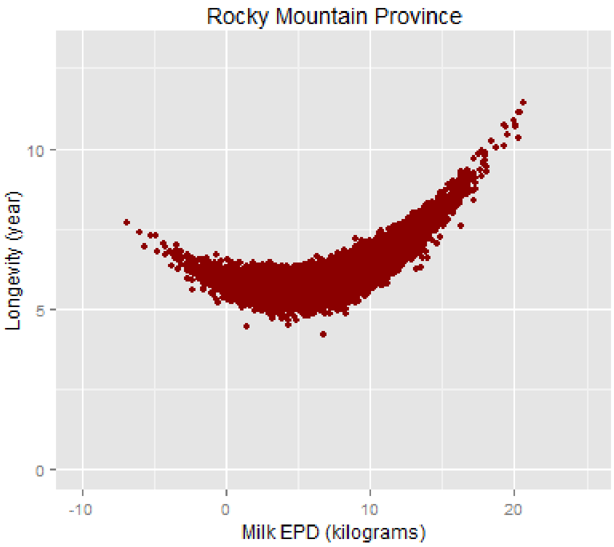


Figure 14. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Rocky Mountain Province biome.

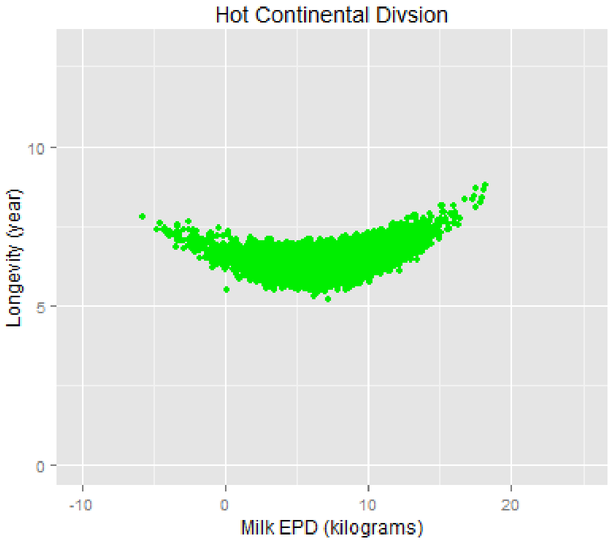


Figure 15. Illustration of estimates of the dependent variable longevity regressed on milk EPD for cows within the Hot Continental Division biome.

For model 2, both interactions (biome with milk EPD and biome with metabolic weight EPD) were found to be significant (*$P<0.001$*) and are listed in Table 5. The resulting parameter estimates and regression coefficients for the interaction of biome with milk EPD and biome with metabolic weight EPD are listed in Tables 8 and 9, respectively. As with model 1, all the regression coefficients for the interaction of biome with the quadratic of milk EPD indicated a positive relationship between longevity and milk EPD for higher levels when holding all other effects constant. However, the linear effect of milk EPD was negative resulting in lower levels of milk EPD having a negative effect on cow longevity until a point at which milk EPD increase longevity.

The resulting regression coefficients for the interaction of biome with metabolic weight EPD^2 indicated that for lower metabolic weight EPD, there was a negative effect on longevity but at higher levels longevity increased with the magnitude of that increase biome dependent. There were two biomes that were the exception (Subtropical Division and Hot Continental

Division), both in the southeastern United States. The subtropical province had a positive linear term and a negative quadratic term resulting in lower levels of metabolic weight EPD having a positive effect on longevity the local minimum of x was reached at which point, metabolic weight EPD had a negative effect on longevity. The Hot Continental Division had negative regression coefficients for both linear and quadratic terms of metabolic weight EPD; therefore metabolic weight EPD has a negative effect throughout the range in metabolic weight EPD.

Table 8. Parameter estimates for model 2 with cow longevity (years) regressed on the interaction of biome with milk EPD (pounds) and metabolic weight EPD (pounds).

[1]Biome	[2]Milk EPD Estimates	Standard Error	[3]Milk EPD^2 Estimates	Standard Error	[4]Metabolic Weight EPD	Standard Error	[5]Metabolic Weight EPD^2	Standard Error
Milk EPD	-0.2429	0.0937	0.0173	0.0053	-	-	-	-
Metabolic Weight EPD	-	-	-	-	0.4754	0.0988	-0.1204	0.0171
Subtropical Division	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rocky Mountain Division	0.0479	0.0011	0.0004	0.0011	-0.3197	0.0476	0.0287	0.0037
Western Great Plains Division	0.0836	0.0011	-0.0018	0.0011	-0.3755	0.0480	0.0310	0.0037
Eastern Great Plains Division	0.0567	0.0012	0.0001	0.0012	-0.5000	0.0505	0.0347	0.0038
Prairie Division	0.0625	0.0012	-0.0011	0.0012	-0.3878	0.0515	0.0294	0.0040
Dry Domain	0.0542	0.0016	-0.0003	0.0016	-0.4136	0.0731	0.0379	0.0052
Hot Continental	0.0369	0.0012	-0.0005	0.0012	-0.2794	0.0541	0.0235	0.0041
California Division	0.0686	0.0013	-0.0005	0.0013	-0.3936	0.0625	0.0335	0.0048

[1] Biome = the parameter of the interaction of biome by milk EPD

[2] Milk EPD Estimates = the parameter estimates for the regression of cow longevity (years) on milk EPD

[3] Milk EPD^2 Estimates = the parameter estimates for the regression of cow longevity (years) on milk EPD^2.

[4] Metabolic Weight EPD = the parameter estimates for the regression on cow longevity (years) on metabolic weight EPD.

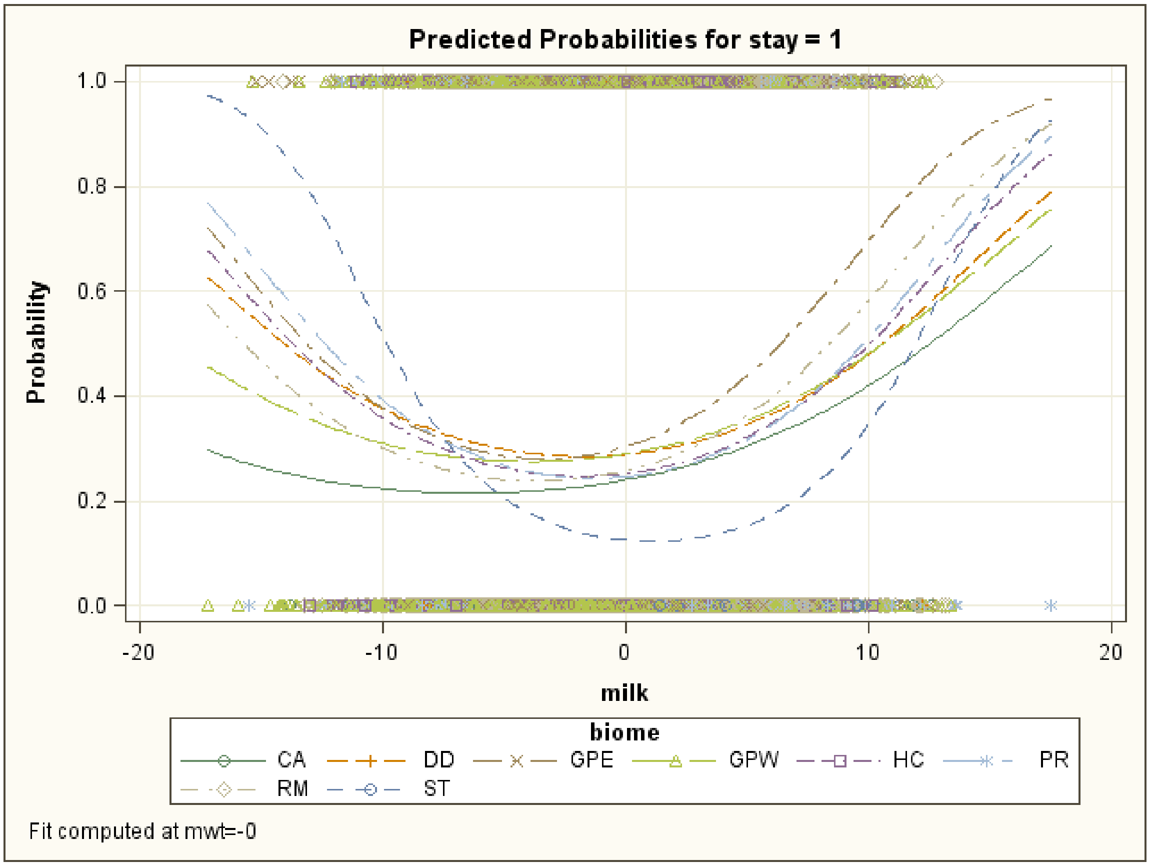
[5] Metabolic Weight EPD^2 = the parameter estimates for the regression of cow longevity (years) on metabolic weight EPD^2.

Table 9. Regression coefficient estimates for model 3, the regression of cow longevity (years) on milk EPD by biome class and metabolic weight EPD by biome class

[1]Biome	[2]Milk EPD Estimates	[3]Milk EPD^2 Estimates	[3]Metabolic Weight EPD Estimates	[3]Metabolic Weight EPD^2 Estimates
Subtropical Division	-0.2429	0.0173	0.4754	-0.1204
Rocky Mountain Division	-0.1372	0.0192	-0.2295	0.0189
Western Great Plains Division	-0.0587	0.0086	-0.3525	0.0301
Eastern Great Plains Division	-0.1179	0.0178	-0.6267	0.0480
Prairie Division	-0.1051	0.0122	-0.3796	0.0222
Dry Domain	-0.1235	0.0160	-0.4365	0.0639
Hot Continental	-0.1615	0.0148	-0.1407	-0.0064
California Division	-0.0917	0.0146	-0.3923	0.0426

[1]Biome = the parameter of the interaction of biome by milk EPD
[2]Milk EPD^2 Estimates = the regression coefficients for the regression of cow longevity (years) on the quadratic of milk EPD
[3]Metabolic Weight EPD^2 Estimates = the regression coefficients for the interaction of metabolic weight EPD and biome for the regression of a cow longevity on milk EPD squared and metabolic weight EPD squared

A logistic regression was conducted with stayability as the dependent variable with milk EPD, milk EPD^2, biome and metabolic weight EPD as the main effects (model 3). Also included in the model were the interactions of biome with milk EPD, and biome with milk EPD^2 which were significant *($P<.0001$ and $P=0.0001$,* respectively*)*. Due to collinearity between milk EPD and milk EPD^2, the data were centered setting the mean milk EPD to zero. The coefficient of determination (R^2) that resulted for model 3 was 0.01, indicating that only 1% of variability for stayability was explained by this model. Due to the quadratic term for milk EPD, the interpretation for the probability of a cow's successful stayability for a milk EPD of 7 kilograms would be different than at a milk level of 17 kilograms for a specific biome when compared to another biome. This was further illustrated in Figure 16. In this figure, the interaction between milk EPD and biome was clearly demonstrated. In addition, the rate of change in probability of a cow exhibiting successful stayability as milk EPD increases was illustrated in Figure 16.



Stay = stayability
Milk = milk EPD with the average milk EPD centered at zero.
Biome = geographical areas with similar climates and vegetation where Red Angus breeders are located. (CA = California Division, ST = Subtropical Division, PR= Prairie Division, GPE = Eastern Great Plains Division, GPW = Western Great Plains Division, DD = Dry Domain, and RM = Rocky Mountain Division)

Figure 16. Graph for the predicted probabilities for successful stayability illustrating milk EPD^2 within each biome. The data was centered with the average milk EPD equal to zero.

The odd ratios were calculated for three levels of milk EPD, 5.12, 7 and 8.98, which represented the lower quartile, mean and upper quartile from the data. The odds ratios for each biome when compared to the other 7 biomes within the three levels of milk EPD was presented in Table 10. An odds ratio of 1 indicated that the odds were unchanged when the value of the predictor variable (milk EPD) changes (Ott and Longnecker, 2010). When an odds ratio was less than one, a smaller proportion of cows exhibited successful stayability compared to cows who were unsuccessful. For example, the odds ratio for California Division compared to Dry Domain was 0.779 for milk EPD at 7 kilograms. This can be interpreted as the predicted odds for a cow in the California Division receiving a stayability score of 1 is 0.779 (approximately 3/4) times the odds for a cow in the Dry Domain. The largest odds ratios for all three levels of milk EPD were the comparison of Eastern Great Plains Division to the Subtropical Division. The odds for cows in the Eastern Great Plains Division receiving stayability scores of 1, when compared to cows in the Subtropical Division, was 3.041 times higher at a milk EPD of 7 (which is the average milk EPD).

For the lower quartile of milk EPD (5.12 kilograms), the comparisons of Dry Domain to Western Great Plains Division, Hot Continental Division to Prairie Division, and Hot Continental Division to Rocky Mountain Division were found not to be significant (odds ratios of 1) as their confidence intervals included 1. The odds ratios calculated at the average milk EPD for this data (7 kilograms) resulted in six biome comparisons with odds ratios of 1: California Division to Hot Continental, California Division to Prairie Division, Dry Domain to Eastern Great Plains, Dry Domain to Western Great Plains, Hot Continental to Prairie Division, and Hot Continental to Rocky Mountain Division. When the odds ratios for the upper quartile of milk EPD (8.98 kilograms) were calculated, California Division to Hot Continental, California Division to Prairie Division, Dry Domain to Western Great Plains Division, Dry Domain to Rocky Mountain Division, and Hot Continental to Prairie Division resulted in odds ratios of 1. The lowest odds ratio for all three levels of milk EPD examined was California Division versus Eastern Great Plains Division. It ranged from 0.683 (approximately 2/3) to 0.728 and would result in two-thirds as many cows receiving a stayability score of 1 for the California Division when compared to the Eastern Great Plains Division, holding all other variables within the model constant.

The resulting odds ratios illustrate the differences from biome to biome for the effects of milk EPD on stayability. When individual biomes were compared to another individual biome, differences for the effects of milk EPD on stayability were seen in addition to the variation from one comparison to another.

Table 10. Odds ratios and confidence limits for the comparison of biomes at the lower quartile, mean and upper quartile for milk EPD

[1]Biome	Odds Ratio	95% Confidence Limits		Odds Ratio	95% Confidence Limits		Odds Ratio	95% Confidence Limits	
[2]Milk EPD	5.12 kg			7 kg			8.98 kg		
CA vs. DD	0.763	0.684	0.851	0.779	0.688	0.883	0.812	0.704	0.936
CA vs. GPE	0.689	0.637	0.745	0.728	0.665	0.797	0.683	0.617	0.755
CA vs. GPW	0.771	0.716	0.829	0.777	0.714	0.845	0.79	0.718	0.869
CA vs. HC	0.904	0.830	0.984	0.939	0.851	1.035	0.956	0.858	1.066
CA vs. PR	0.921	0.850	0.999	0.968	0.882	1.062	0.991	0.894	1.098
CA vs. RM	0.878	0.815	0.945	0.912	0.838	0.993	0.876	0.796	0.964
CA vs. ST	1.972	1.718	2.263	2.214	1.898	2.584	2.475	2.114	2.898
DD vs. GPE	0.903	0.824	0.989	0.934	0.841	1.037	0.841	0.748	0.947
DD vs. GPW	1.010	0.926	1.102	0.996	0.902	1.101	0.973	0.869	1.089
DD vs. HC	1.185	1.075	1.305	1.204	1.077	1.347	1.178	1.04	1.335
DD vs. PR	1.208	1.100	1.326	1.242	1.116	1.383	1.221	1.083	1.376
DD vs. RM	1.150	1.054	1.256	1.171	1.059	1.294	1.08	0.964	1.209
DD vs. ST	2.585	2.234	2.990	2.841	2.413	3.345	3.05	2.576	3.612
GPE vs. GPW	1.119	1.074	1.166	1.067	1.016	1.12	1.157	1.099	1.217
GPE vs. HC	1.313	1.237	1.393	1.289	1.202	1.383	1.401	1.302	1.507
GPE vs. PR	1.338	1.268	1.411	1.33	1.249	1.416	1.451	1.36	1.548
GPE vs. RM	1.275	1.222	1.330	1.253	1.192	1.317	1.283	1.219	1.351
GPE vs. ST	2.864	2.529	3.242	3.041	2.648	3.492	3.625	3.164	4.153
GPW vs. HC	1.173	1.113	1.237	1.209	1.135	1.286	1.211	1.135	1.292
GPW vs. PR	1.196	1.142	1.252	1.247	1.181	1.316	1.254	1.187	1.325
GPW vs. RM	1.139	1.103	1.176	1.175	1.131	1.22	1.109	1.067	1.153
GPW vs. ST	2.559	2.268	2.880	2.851	2.492	3.262	3.134	2.748	3.575
HC vs. PR	1.019	0.957	1.085	1.032	0.958	1.111	1.036	0.96	1.118
HC vs. RM	0.971	0.921	1.024	0.972	0.913	1.035	0.916	0.858	0.978
HC vs. ST	2.181	1.919	2.480	2.359	2.043	2.724	2.588	2.246	2.982
PR vs. RM	0.953	0.910	0.998	0.942	0.892	0.995	0.884	0.837	0.935
PR vs. ST	2.140	1.888	2.426	2.287	1.988	2.631	2.498	2.178	2.866
RM vs. ST	2.246	1.990	2.536	2.427	2.121	2.777	2.825	2.477	3.223

[1] Biome = the comparison of two of the eight biomes

[2] Milk EPD = level of milk EPD at which odds ratio was calculated

CA = California Division
ST = Subtropical Division
PR = Prairie Division
GPE = Eastern Great Plains Division
GPW = Western Great Plains Division
DD = Dry Domain
RM = Rocky Mountain Division

Beef Improvement Center Data

Data for BIC was analyzed in SAS 9.3 (SAS Institute Inc., Cary, NC) using the MIXED procedure. Two models were used for this analysis. The first model was a regression model with a quadratic term for milk EPD and the cow's longevity as the dependent variable. The second model was a logistic regression with stayability as the dependent variable.

The results for the first model (the regression of longevity on the cow's milk EPD^2 as a main effect with year) resulted in the effect of year not being significant (α=0.05). As a result, the effect of year was removed from the model and the resulting equation was:

$$y = 6.9384 - 0.2139x + 0.1002x^2 + \varepsilon$$

Therefore, the quadratic term of milk EPD^2 had a positive effect on longevity indicating that for the upper range of milk EPD there was a positive relationship between milk EPD and longevity (Figure 14).

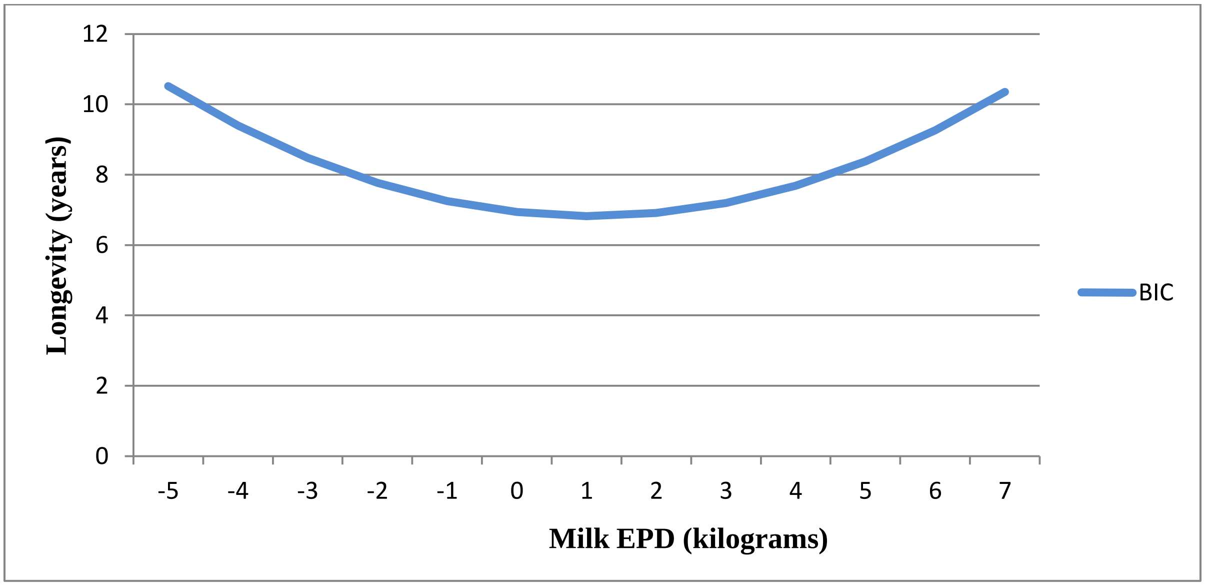


Figure 17. Graph of the regression of longevity on milk EPD for BIC.

Another approach was tested using the cow's sire's EPD for milk instead of the cow's milk EPD. However, when the sire's milk EPD was used the main effects milk EPD were not found to be significant (*P>0.05*). Since the sire's milk EPD doesn't have a regression coefficient significantly greater than zero, this indicated that there was no relationship between the cow's sire's milk EPD and her length of productive life within the herd. Analyzing the sire's milk EPD as reported by the American Angus Association for cow's who were sired by registered Angus bulls also resulted in regression coefficients that were not significantly different from 0.

Logistic regressions were conducted for stayability to 3 years and 6 years of age. For all models using the cow's sire's milk EPD, the regression coefficients had no significant effects on stayability. The results from the logistic regression using stayability of 3 and 6 years for the dam's milk EPD are reported in Table 10.

Table 10. Regression coefficient estimates and odds ratio for the logistic regression of longevity on milk EPD of cow

	3 year stayability			6 year stayability		
	Odds Ratio	Regression Coefficient	[1]P-value	Odds Ratio	Regression Coefficient	[1]P-value
Intercept		-1.7423	<.0001		-0.3200	0.0007
milk	1.009	0.0194	0.7556	1.035	0.0347	0.4302
milk EPD^2	0.948	-0.0537	0.0078	0.965	-0.0354	0.0045

[1] p-value = p-values for regression coefficients

For a logistic regression, the regression coefficient measured the degree of association between the probability of the event occurring and the value of the independent variable (milk EPD). Additionally, if the regression coefficient was greater than zero (i.e. positive) the probability of the event occurring increased as the value of x increased. If the regression coefficient were positive, then as milk EPD increased, the probability of the cow receiving a stayability score of 1 would also increase. If the resulting regression coefficient was negative then as milk EPD increased the probability of a cow receiving a stayability score of 1 (success) decreased. The resulting regression coefficient for the quadratic term of milk EPD^2 was -0.0111 for 3 year stayability and -0.0073 for 6 year stayability which indicated that as the cow's milk EPD increased to high levels, the probability of her being culled from the herd (receiving a stayability score of 0) increased.

The odds ratio for the cow's milk EPD^2 was 0.989 and 0.993 for 3 year stayability and 6 year stayability, respectively. When an odds ratio was 1, the odds are unchanged when the value of the predictor variable (milk EPD) changes (Ott and Longnecker, 2010). For stayability to 3 years, the resulting odds ratio was 0.989. This would suggest that for every unit increase in milk EPD, there was a 1.1% increase in the odds of an animal being culled from the herd and therefore a stayability of 0. The odds ratio for stayability to 6 years was 0.993. This would result in a 0.7% increase in the odds of a cow receiving a stayability score of 0 for every unit change in milk EPD. It is worth noting that the regression coefficient when stayability was 6 years was smaller than for 3 years of age. The odds ratios for both 3 year and 6 year stayability are close to 1. These results show very little change in odds for receiving a stayability score of 1 as milk EPD increases.

Discussion

For both the Red Angus and BIC data, a statistically significant positive regression coefficient resulted when the continuous variable longevity was regressed on the quadratic term involving milk EPD. The linear effect of milk EPD on longevity was negative for both Red Angus and BIC. This suggests that for the upper range of milk EPD, the positive relationship between milk and longevity increases.

The results from this study are supported by other studies conducted with dairy cattle. De Lorenzo and Everett (1982) found positive regression coefficients for the regression of stayability to 48 months and 72 months on milk yield; however, the coefficients were small (.002 and .003, respectively). They also found that only a small portion of variability in stayability was explained by milk production. Since the largest reason to voluntarily cull in the dairy industry is based on milk production, it is reasonable to expect a positive relationship for stayability and milk (De Lorenzo and Everett, 1982). Everett et al. (1976), Short and Lawlor (1992), and Hudson and Van Vleck (1981) all reported positive genetic correlations for milk production and stayability to 36 months and 84 months ranging from 0.09 to 0.22. However, all of these studies were conducted with dairy cattle housed in more confined operations relative to grazing beef cattle which are typically managed in a more extensive approach. In addition, the dairy cattle were not maintained on rangeland and were fed diets in concentrated dairy systems.

De Lorenzo and Everett (1982) also included milk as a quadratic term (milk^2) in their predictions. A negative coefficient for the quadratic term was observed, suggesting that for upper levels of milk production there was a decrease in the positive relationship between milk and stayability as milk increased. This is in contrast to what was found in our study. This difference may be a result of the contrast in management of beef cattle compared to dairy cattle.

The results of the analysis with Red Angus demonstrated an interaction between milk EPD and environment (biome). Although the regression coefficients were all positive for each of the eight biomes, the amount of change per unit of milk EPD varied by biome. Genotype by environment interactions (GxE) for milk production have been reported in the dairy industry as was shown here. Hayes et al., (2003) examined Australian Holsteins across diverse environments and found a genetic correlation of -0.16 between milk production and environment (using the temperature humidity index to classify environment). Hailie-Mariam et al. (2008) found GxE for fertility traits, survival and milk yield in Holstein-Friesian cows with genetic correlations among the traits greater than 0.80.

Although the quadratic regression coefficients for the Red Angus data were all positive, the coefficients were not much higher than zero (<0.005). This would indicate that a considerable change in milk EPD would be required for a change in longevity. For these data, a 17.5 kilogram increase in milk EPD would be needed to increase longevity by 1 year. The addition of the interaction of the quadratic of metabolic weight EPD and biome (model 2) did not result in a directional change (i.e. from positive to negative) for the quadratic regression coefficients for milk EPD.

The results from the logistic regression further demonstrate the differences among biomes and the odds of a cow receiving a stayability score of 1 or 0. When comparing individual biomes effects on the cow's ability to remain in the herd relative to her milking ability differences were observed. However, in environments that we would expect to observe the largest difference, there was limited change in odds for a successful stayability score. For example, Dry Domain encompasses the deserts and more arid biomes of the United States. We expected to see drastic differences from Dry Domain compared to the Great Plains biomes or the eastern portion of the United States. However, our results show no change in odds (an odds ratio of 1.010) for cows in the Dry Domain versus Western Great Plains Division. When comparing the Dry Domain to the Subtropical Division the odds of a cow receiving a score of 1 is 2.585 times the odds of a cow in the Subtropical Division, a biome that receives a considerable amount of annual precipitation when compared to the Dry Domain.

Similar to the Red Angus data, the BIC data indicated positive quadratic regression coefficients for longevity regressed on milk EPD. However, the logistic regression for BIC resulted in a negative regression coefficient for both 3 and 6 year stayability. This suggested that as milk EPD increased the probability of the animal receiving a stayability score of 0 increased. However, the odds ratios are close to 1 (0.989 for 3 year stayability and 0.993 for 6 year stayability) indicating a large increase in milk EPD would be needed to cause a change in odds for changing a stayability score from 1 to 0.

The resulting small regression coefficients could be explained by the near zero genetic correlation between stayability and weaning weight (Martinez et al., 2005). Frazier et al., (1999) defined milk EPD as a combined predictor of genetic merit of milk production and maternal ability. However, milk EPD in beef cattle are based on pounds of calved weaned. Martinez et al., (2005) found near zero genetic correlations between stayability and weaning weight. This near zero genetic correlation may explain the small and near zero regression coefficients resulting from our study.

Based on our results from the Red Angus data set, we would fail to accept our hypothesis that in areas of forage restriction that cows with higher milk EPD have a higher probability of culling and therefore would not remain in the herd long enough to recoup their initial investment. Although the analysis of the Red Angus data does demonstrate differences between environments for the relationship of length of productive life and milk EPD, there is no indication that areas of forage restriction impact a cow being culled based on her milk EPD. According to the results from the BIC herd, we would reject our hypothesis that cows with high milk EPD would have an increased probability of being culled from the herd.

Data Limitations

The Red Angus data were comprised of registered seedstock cattle that may not be managed as a commercial herd. The use of irrigated pastures or farmland was not considered in this study but could add error to our evaluation as specific breeders may have access to these sources of forage. In addition, feeding management practices may have also influenced the results of this study and are not accounted for in this analysis. For example, Ochoa et al. (1981) found that creep feeding minimized environmental factors and could mask the milking ability of the dam.

Data provided by BIC represented one herd in one environment. The BIC herd was grazed on rangeland for 180 days and was maintained on pastures consisting of timothy and brome grasses with hay supplementation the remainder of the year. This may not be representative of commercial herds who are grazed on rangeland throughout the year.

CHAPTER 5

SUMMARY AND IMPLICATIONS

Summary

Two analyses were conducted to study the effect of milk EPD on a cow's longevity and stayability. The first data set was provided by RAAA representing cattle in various environments throughout the United States. The second data set was provided by BIC representing a herd within a single environment that is managed similar to most commercial herds in the Rocky Mountain region. Both studies involved examined the milk EPD as a genetic measure of milk production and how milk production was related to the cow's ability to remain in the herd for either a fixed number of years (stayability) or for overall length of life.

The first analysis performed on RAAA data showed a significant interaction between milk EPD and biome. While in all represented biomes, the trend was for increasing longevity as genetic potential for milk production increased. However, a threshold may be reached where the inverse relationship was evidenced by the significant nonlinear (quadratic) effects. A potential bias in this data may be the result of the seedstock nature of this data where the nutritional environment may be different than that in commercial herds in these regions.

The interaction of biome with milk EPD was further illustrated by the odds ratios resulting from the logistic regression using 6 year stayability. Pairwise comparisons between all 8 biomes resulted in odds ratios ranging from 0.689 to 2.864. This range in odds ratios demonstrated the differences between biomes for the effect of milk EPD on stayability. However, the results for biome comparisons for Dry Domain, which represents the desert areas of the United States, were unexpected. With the exception of Eastern Great Plains Division and

Western Great Plains Division, for a one kilogram increase in milk EPD, Dry Domain had better odds for cows to remain in the herd to the age of six than other biomes. Since Dry Domain could be considered the most arid biome, the opposite was expected. The largest odds ratios were seen when biomes were compared to Subtropical Division indicating that the odds of a cow receiving stayability score of 1 would be the lowest for this biome compared to the other 7 biomes. A potential explanation might be that lack of feed resources in an arid environment can be mitigated due to supplementation, but heat/humidity stress is not easily alleviated through managerial processes.

The results for the logistic regression of the Red Angus data demonstrated that the odds of a cow being culled from the herd prior to the age of 6 varied from environment to environment. Genotype by environment interactions on milk production and fertility have been observed by numerous studies conducted with dairy cattle. For example, Hailie-Mariam et al. (2008) found high genetic correlations for GxE of fertility, survival and milk yield in dairy cattle across environments. However, dairy cows have higher levels of milk production than beef cows in addition to being managed under more intensive and confined operations.

The second analysis was performed with data from BIC cattle. This herd was in our opinion more representative of a commercial herd and allowed us to examine a herd where environment was held constant. The dam’s milk EPD was used as well as the dam’s sire’s milk EPD in the analysis since the sire’s EPD would have a higher accuracy. However, using the sire’s milk EPD showed no statistical significance as a fixed effect when longevity or stayability was the dependent variable. The dam’s milk EPD was statistically important as a main effect in the model and showed a trend for upper levels of milk EPD and longevity to have a positive relationship.

The logistic regression model for BIC data with 3 year and 6 year stayability as the dependent variable yielded slightly different results than the previous model. For both 3 and 6 year stayability the odd ratios were close to one (0.989 and 0.993, respectively) with positive linear regression coefficient (0.0088 and 0.0157, respectively). This would suggested that for every unit increase of milk EPD, the probability of a stayability score of 1 would increase until reaching the local minimum of milk EPD. From that point on, there was a decrease in the probability of receiving a stayability score of 1. This was indicated by the regression coefficients for the quadratic term for milk EPD which were negative for both 3 and 6 year stayability. However, since the odds ratios were close to one, the increase in odds was less than 1% for each pound of increased milk EPD.

Implications

There is a direct economic gain for an increase in calf weaning weights in addition to economic importance for cattle reproductive efficiency for most cow/calf operations. A dam's milking ability has an effect on a calf's weaning weight. The relationship between a dam's milking ability and her reproductive efficiency has repeatedly been referred to as antagonistic in literature. Our study revealed a positive relationship between higher levels of milk EPD and longevity. Although more research would be needed, a threshold may exist where the levels of milk produced by a beef cow will make it difficult for cows to rebreed and remain in the herd. It is possible that these data do not reflect high enough milk EPD to illustrate this and that those thresholds have not been reached. Alternatively, selection for improved milk production may be offsetting environmental constraints on longevity.

Matching environment and genetic potential of a herd is a challenge for any cow/calf operation. Producers must find a balance when making decisions between profitability and the environmental limitations of their operation. Results from this study suggest a genotype by environment interaction between a beef cow’s milking ability and her environment. When making genetic selection decisions producers should consider level of environment as milk production levels increase.

REFERENCES

n.d. http://earth.google.com/ (Accessed 30 December 2013).

Adams, D.C., R.T. Clark, T.J. Klopfenstein, and J.D. Volesky. 1996. Matching the cow with forage resources. Rangelands. 18: 57-62.

Allison, P.D. 2012. Logistic Regression Using SAS: Theory and Application. SAS Institute Inc., Cary, NC. p. 1-108.

American Angus Association. Fall 2014. http://www.angus.org/nce/genetictrends.aspx (Accessed 19 August 2014).

Bastian, C.T., J.J. Jacobs, and M.A. Smith. 1995. How much sagebrush is too much: An economic threshold analysis. J. Range Manage. 48: 73-80.

Bischoff, K., V. Mercadate, and G.C. Lamb. 2012. Management of postpartum anestrus in beef cows. Gainsville: University of Florida.

Bourdon, R.M. 1997. Understanding Animal Breeding. 1st ed. Prentice-Hall, Inc., Upper Saddle River, NJ. p. 173-181.

Brink, T. and D. Kniffen. 1996. Calving intervals in young beef females. Beef Improvement Federation 38-47.

Burns, P.D and J.C. Spitzer. 1992. Influence of biostimulation of reproduction in postpartum beef cows. J. Anim. Sci. 1992: 70: 358-362.

Buzankas, M.E., D.A. Grossi, F. Baldi, D. Barrozo, L.O.C. Silva, R.A.A. Torres Junior, D.P. Munari and M.M Alencar. 2010. Genetic association between stayability and reproductive and growth traits in Canchim beef cattle. Livest. Sci. 132: 107-112.

Cammack, K.M, M.G. Thomas, R.M. Enns. 2009. Review: Reproductive Traits and Their Heritabilities in Beef Cattle. Prof. Anim. Sci. 517-528.

Clutter, A.C. and M.K. Nielsen. 1987. Effect of level of beef cow milk production on pre- and postweaning calf growth. J. Anim. Sci. 64: 1313-1322.

De Lorenzo, M.A. and R.W. Everett. 1982. Relationships Between Milk and Fat Porduction, Type, and Stayability in Holstein Sire Evaluation. J. Dairy Sci. 65: 1277-1285.

Dunn, T.G. and C.C. Kaltenbach. 1980. Nutrtition and the postpartum interval of the ewe, sow and cow. J. Anim. Sci. 51: 29-39.

Ferrell, C.L. and T.G. Jenkins. 1985. Cow type and nutritional environment: Nutritional aspects. J. Anim. Sci. 61: 725-741.

Fox, D.G., C.J. Sniffen and J.D. O'Connor. Adjusting nutrient requirements of beef cattle for animal and environmental variations. J. Anim. Sci. 66: 1475-1495.

Frazier, E.L., L.R. Sprott, J.O. Sanders, P.F. Dahm, J.R. Crouch and J.W. Turner. 1999. Sire marbling score expected progeny difference and weaning weight maternal expected progeny difference associations with age at first calving and calving interval in Angus beef cattle. J. Anim. Sci. 77: 1322-1328.

Freking, B.A. and D.M. Marshall. 1992. Interrelationships of heifer milk porduction and other biological traits with prodcution efficiency to weaning. J. Anim. Sci. 70: 646-655.

Gilmour, A. R., Gogel, B. J., Cullis, B. R., et al. (2009). ASReml User Guide Release 3.0. VSN Int., Hemel Hempstead, UK.

Hawkins, D.E., M.K. Petersen, M.G. Thomas, J.E. Sawyer, and R.C. Waterman. 2000. Can beef heifers and young postpartum cows be physiologically and nutritionally manipulated to optimize reproductive efficiency? J. Anim. Sci. 77: 1-10.

Hayes, B.J., M. Carrick, P. Bowman and M.E. Goddard. 2003. Genotype x Environment interaction for milk production of daughters of Australian dairy sires from test-day records. J. Dairy Sci. 86: 3736-3744.

Hudson, G.F.S. and L.D. VanVleck. 1981. Relationship between production and stayability in holstein catte. J.Dairy Sci. 2246-2250.

Jenkins, T.G. and C.L. Ferrell. 1992. Lactation characteristics of nine breeds of cattle fed various quantities of dietary energy. J. Anim. Sci. 70: 1652-1660.

Lee, C. and E.J. Pollak. 2002. Genetic antagonism between body weight and milk production in beef cattle. J. Anim. Sci. 80: 316-321.

Lewis, J.M., T.J. Klopfenstein, R.A. Stock and M.K. Nielsen. 1990. Evaluation of intesive vs extensive systems of beef production and the effect of level of beef cow milk prodcution on postweaning performance. J. Anim. Sci. 68: 2517-2524.

Lucy, M. C. 2001. Reproductive loss in high-producing dairy cattle: Where will it end? J. Dairy Sci. 84: 1277-1293.

Marietta College Main Biomes Page. 2013. n.d. http://www.marietta.edu/~biol/biomes/bioregion_map.htm. (Accessed 30 December 2013)

Marston, T.T., D.D. Simms, R.R. Schalles, K.O. Zoellner, L.C. Marin and G.M. Fink. 1992. Relationship of milk production, milk expected progeny difference, and calf weaning weight in angus and simmental cow-calf paris. J. Anim. Sci. 70: 3304-3310.

Martinez, G.E., R.M. Kock, L.V. Cundiff, K.E. Gregory, S.D. Kachman and L.D. Van Vleck. 2005. Genetic parameters for stayability, stayability at calving, an stayability at weaning to specified ages for Hereford cows. J. Anim. Sci. 83: 2033-2042.

Minick, J.A., D.S. Buchanan, and S.D. Rupert. 2001. Milk production of crossbred daughters of high- and low-milk EPD Angus and Hereford bulls. J. Anim. Sci. 79: 1386-1393.

Montano-Bermudez, M., M.K. Nielsen and G.H. Deutscher. 1990. Energy requirements for maintenance of crossbred beef cattle with different genetic potential for milk. J. Anim. Sci. 68: 2279-2288.

Monthly Weather Forecast. 2014. http://www.weather.com/weather/wxclimatology/monthly/USWY0052. (Accessed 20 January 2014).

Neville, W.E. Jr. and M.E. McCullough. 1969. Calculated energy requirements of lactating and non-lactating Hereford cows. J. Anim. Sci. 29: 823.

Neville, W.E. Jr. 1974. Comparison of energy requirements of non-lactating and lactating Hereford cows and estimates of energetic efficiency of milk production. J. Anim. Sci. 38: 681.

NRC. 2000. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.

Ochoa, P.G., W.L. Mangus, J.S. Brinks, and A.H. Denham. 1981. Effect of creep feeding bull calves on dam most probable producing ability values. J. Anim. Sci. 53: 567-574.

Ott, R.L. and M. Longnecker. 2010. An Introduction to Statistical Methods and Data Analysis (6th Ed.) Brooks/Cole Cengage Learning, Belmont, CA.

Patle, B.R. and V.D. Mudgal. 1977. Utilization of dietary energy requirements for maintenance, milk production and lipogenesis by lactating crossbred cows druing their midstage of lacation. J. Anim. Sci. 37:23.

Rogers, P.L., C.T. Gaskins, K.A. Johnson, and M.D. MacNeil. 2004. Evaluating longevity of composite beef females using survival analysis techniques. J. Anim. Sci. 82: 860-866.

Seger, P. L. 2012. Pathways to pregnancy and parturition. 3rd ed. Current Conceptions, Inc., Redmond, OR.

Short, R.E., R.A. Bellows, R.B. staigmiller, J.G. berardinelli and E.E. Custer. 1990. Pysiological mechanisms controling anestrus and infertility in postpartum beef cattle. J. Anim. Sci. 68: 799-816.

Short, T.H., R.W. Blake, R.L. Quaas and L.D. Van Vleck. 1990. Heterogeneous Within-Herd Variance. 1. Genetic Parameters for First and Second Lactation Milk Yeilds of Grade Holstein Cows. J. Dairy Sci. 73: 3312-3320.

Short, T.H.and T.J. Lawlor. 1992. Genetic parameters of conformation traits, milk yield, and herd life in Holsteins. J. Diary Sci. 75: 1987-1998.

Sieber. M, A.E. Freeman and D.H. Kelly. 1988. Relationshipes between body measurements, body weight and productivity in Holstein dairy cows. J. Dairy Sci. 71: 3437-3445.

Snelling, W.M., B.L. Golden, R.M. Bourdon. 1995. Within-herd genetic analyses of styability of beef females. J. Anim. Sci. 73: 993-1001.

Snelling, Warren Mark. 1994. Genetic Analyses of Binary Stayability Measures of Beef Females (Doctoral dissertation). Colorado State University Library (SF207 S543 1994).

Stevenson, J.S., E.L. Knoppel, J.E. Minton, B.E. Salfen and H.A. Garverick. 1994. Estrus, ovulation, luteinizing hormone, and suckling-induced hormones in mastectomized cows with and without unrestriced presence of the calf. J. Anim. Sci. 72: 690-699.

Wettemann, R.P., C.A. Lents, N.H. Ciccioli, F.J. White and I Rubio. 2003. Nitritional and suckling mediated anovulation in beef cows. J. Anim. Sci. 81:E48-E59.

Williams, G.L. 2005. Physiology and management of the postpartum suckled cow for controlled breeding programs. Applied Reproductive Strategies in Beef Cattle. Beeville: Texas A&M University.