FACTORS INFLUENCING COW PERFORMANCE AND INTAKE

BY

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THESIS

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ABSTRACT

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Two studies were conducted to determine how weaning system, residual feed intake (RFI), and residual average daily gain (RADG) affect cow performance and intake. In Study 1, a two-year study was conducted using Angus and Simmental X Angus heifers (n=114) to evaluate how weaning system (early weaning (EW) vs. normal weaning (NW)) affects cow-calf performance and intake. All cows with male calves were early weaned at 130 d while cows with female calves were normal weaned at 200 d. These animals were then evaluated for individual intake at 60 d, 120 d, 180 d, and 240 d postpartum. Weigh-suckle-weigh (WSW) was used to determine milk production for the lactating periods. BW, Hip height, body condition score (BCS, 1-9 scale), and backfat via ultrasound were measured. No differences ($P > 0.05$) were noted in the 60 and 120 d postpartum cow measurements, but calf BW did differ ($P < 0.05$) with male calves being heaver. At 180 d postpartum cows with their offspring early-weaned had increased ($P < 0.05$) BW (18.7 kg), BCS (0.29) and decreased DMI (1.23 kg). At 240 d postpartum cows that had been early-weaned had an increased ($P < 0.05$) BW (30.5 kg), BCS (0.31), and BF (0.22 cm). There were no differences ($P > 0.05$) in DMI or overall pregnancy rate. Early weaning can improve cow condition and decrease intake, allowing for increased stocking rates. In Study 2, a two-year study was conducted using Angus and Simmental X Angus heifers (n=114) to determine their residual feed intake (RFI) and residual average daily gain (RADG) as yearlings using the GrowSafe® system. These animals were then evaluated for individual intake at 60 d postpartum (lactating period) and 240 d postpartum (dry period). The same measurements were taken as in Study 1. For the lactating period, correlations were: heifer DMI and cow DMI (0.35), heifer RFI and cow DMI (0.20), heifer RFI and cow BW (-0.08), heifer RFI and cow hip height (0.02), heifer RFI and milk production (-0.09), heifer RADG and cow DMI (-0.06), heifer RADG and cow BW (0.21), heifer RADG and cow hip height (0.25), and heifer RADG and milk production (0.03). For the dry period correlations were: heifer DMI and cow DMI (0.06), heifer RFI and cow DMI (0.29), heifer RFI and cow BW (0.00), heifer RFI and cow hip height (-0.09), heifer RADG and cow DMI (-0.10), heifer RADG and cow BW (0.23), and heifer RADG and cow hip height (0.31). Heifer RFI is correlated with cow intake and thus can be used to help predict intake and efficiency without effecting performance.

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Introduction

With input costs constantly on the rise, it is becoming ever more important for beef producers to be able to get the maximum amount of performance out of their cows with fewer inputs; therefore being more efficient. Feed costs represent the greatest operating cost for cow-calf producers; accounting for over 60% of the variation in total annual cow costs (Miller et al., 2001). If feed consumption can be decreased without affecting animal production then there can be an increase in profitability for the cow-calf producer.

There are several ways to describe feed efficiency. The most common method is using gross efficiency or a feed conversion ratio (FCR). This is defined as the ratio between production outputs and feed inputs (Archer et al., 1999). Brelin and Brannang (1982) showed strong correlations (-0.61 to -0.95) between an animal's growth rate and the feed conversion ratio. This selection for efficiency can be effective in a finishing setting, where maximum growth and large size are desirable; however, it is not applicable to cow-calf operations because it leads to increased mature cow weights. Increased mature cow size could lead to higher feed requirements which will cost the producer more money.

Partial efficiency of growth is another, yet less common, way to measure efficiency. It is defined as the ratio of weight gain to feed after the expected requirements for maintenance have been removed (Archer et al., 1999). These maintenance requirements can be determined from feeding tables such as the NRC (1996). However, estimation from a feeding table uses the assumption that there is no variation in the efficiency of feed use for maintenance. There is considerable research data that suggests this is a false assumption. As a result there can be highly variable results produced; therefore it is not commonly used.

Cow-calf producers often measure as cow/calf efficiency. Shuey et al. (1993) examined the overall efficiency of beef production by calculating cow-calf efficiency by measuring the feed intake of both the cow and her offspring over an entire production cycle. This is defined as the time from weaning of one calf to the weaning of the next calf. The measured feed intake is then compared to the weight of the weaned calf which allows for the expression in kg calf weaned per kg of feed intake (Shuey et al., 1993). This efficiency measure does not include any intake or efficiency for the finishing phase, so it only represents part of the production cycle.

One of the newer forms of measuring feed efficiency is residual average daily gain (RADG). RADG is defined as the difference between actual weight gain and the gain predicted based on DMI, body weight, and fat cover. A regression equation is used to determine the animals predicted ADG, which is then subtracted from the actual ADG resulting in the RADG (www.angus.org). The average animal has a RADG value of 0. Animals having a more positive or higher RADG value would be more desirable. These values can only be compared from animal to animal with the same weaning contemporary group or on the same feed test. RADG has similar issues for the cow-calf producer as gross efficiency because selection of RADG results in heavier cows with higher nutrient requirements.

The other way of measuring feed efficiency is residual feed intake (RFI). RFI is measured by subtracting an animal’s actual intake from the predicted intake that is determined by using a regression equation (Archer et al., 1999). Like RADG, the average animal is 0. Unlike RADG, animals are preferred to have a negative or lower value which means that the animal ate less feed than was predicted. The real advantage of RFI is that it is phenotypically independent (mature size, ADG, etc.) so that selection does not result in increased cow size or cow production. RFI just reduces intake which makes it a very useful tool.

The issue with implementing any efficiency test in the beef cattle industry is the high cost for equipment that many producers do not want to incur. This cost comes from the equipment needed to accurately measure individual animal intake and the technical support to keep it functioning. This is the reason that over the past fifty years the pork and poultry industries have made significantly more improvement in overall efficiency than the beef industry mostly because feed costs are easily quantified in these other industries, while it is particularly difficult and costly to measure intake with beef animals that are grazing (Arthur and Herd, 2008).

Factors Effecting Feed Efficiency

Byerly (1941) was one of the first to acknowledge that individuals of the same body weight have vastly different feed requirements for the same amount of production. Many biological factors have been shown to have an effect on the variation that exists in beef cattle feed efficiency. Richardson and Herd (2004) listed the different factors and the variation they represent and showed that intake was two percent, digestion was ten percent, body composition was five percent, animal metabolism and protein turnover was thirty-seven percent of the variation, activity was ten percent, thermoregulation was nine percent, and then a multitude of other factors was twenty-seven percent of the variation.

Intake

Intake has been shown in multiple studies (Webster et al., 1975; Standing Committee on Agriculture, 2000; Herd and Arthur, 2009) to have considerable variation and to be highly related with the maintenance requirements in ruminant animals. With increased intake there is then an increase in visceral organ size of the animal, which leads to increased energy expense and therefore decreased animal efficiency (Herd and Arthur, 2009). Another component of intake that has an effect on efficiency is the animals' rate of intake and also the duration of the meal. Adam et al. (1984) showed that these two factors are important in the cost of intake in cattle. Animals with a lower RFI have a decreased intake compared to what would be expected and therefore could have decreased maintenance requirements in relation to high RFI cattle. Richardson (2003) reported that high RFI cattle exhibited a trend to have an increased number of meals when compared to low RFI cattle when analyzing the feeding patterns of Angus steers. Robinson and Oddy (2004) also showed that high RFI cattle had increased meal number and duration and this proved to be moderately heritable over generations when analyzed in 1481 finishing cattle on a high grain diet.

Digestion

In direct correlation to intake, digestion also plays a role in animal efficiency because as the amount of intake increase the digestion of feed decreases (Standing Committee on Agriculture, 2000). Herd et al. (1993) showed that in two different lines of ewes that were selected for and against weaning weight, that there was a two percent difference in the organic matter digestibility. From those same selection lines, rams from the high weaning weight ewes had a four percent increase in digestibility compared to that of the low weaning weight rams which is related to the overall efficiency of the animals (Oddy, 1993). RFI has also been shown to be correlated with digestibility. Richardson and Herd (2004) showed that, after a generation of selecting for RFI, lower RFI cattle have been shown to have increased digestibility of a diet when compared to the less efficient, high RFI cattle. Therefore, it can be inferred that digestion efficiency of the animal can have a significant effect of the performance efficiency.

Composition

Fat and lean tissue depositions have different energy costs associated with them. It has been shown that there is a greater amount of variation in lean gain than that of fat gain, which is caused by protein turnover having more variation between organs than fat turnover. These differences in variations can influence the animals' efficiency of nutrient utilization (Herd and Arthur, 2009). However, it has been found that the variation in composition is relatively small in relation to its effect on efficiency in young beef calves (Richardson and Herd, 2004). Richardson et al. (2001) showed that chemical composition was correlated with variation in RFI. Steers with low-RFI parents had less whole-body fat and more whole-body protein than those steers who were offspring of high-RFI animals. A possible explanation for this is the leptin concentration. It is a hormone that is synthesized by adipose tissue and is associated with increased fat deposition in cattle, it has been found to be correlated with RFI in beef cattle (Richardson et al., 2004). Additionally, Arthur et al. (2001) found that 12th rib fat depth and rump fat were positively correlated to RFI (0.17 and 0.06) in bulls and heifers. In feedlot steers the correlation was stronger (0.35 and 0.32) on live ultrasound measurements (Nkrumah et al., 2007) and stronger yet in older feedlot cattle at 0.48 and 0.72 (Robinson and Oddy, 2004). Therefore the indication is that body composition and variation in beef cattle efficiency is highly influenced by the age and maturity of the animal. Younger animals are growing and utilizing protein synthesis instead of fat deposition which is more efficient.

Metabolism

Variation in metabolism results in thirty-seven percent of the variation in efficiency (Richardson and Herd, 2004). This variation affects efficiency through its impact on maintenance energy in the animal. It has been shown that maintenance energy requirement per unit of metabolic body weight is highly correlated with variation in RFI (Herd and Bishop, 2000). Protein turnover is an energetically expensive process as its costs account for fifteen to twenty percent of the basal metabolic rate (Waterlow, 1988). The variation that exists in protein turnover alone can have an impact on genetic selection for traits such as growth (Oddy, 1999). This variation can be explained by the differences that exist in the rates of protein degradation and synthesis in the muscle of the animal (Oddy et al., 1998). Calpastatin, an inhibitor of the calcium activated protease calpain system, and therefore protein degradation were shown to differ in cattle that were selected for feed efficiency (McDonagh et al., 2001). Cattle selected from a low RFI line had significantly more calpastatin than those from the high RFI line (5.2 vs. 4.6 units/g tissue). Richardson and Herd (2004) reported a greater concentration of plasma protein and blood concentration of urea in cattle with a high RFI compared to steers with a low RFI. This is due to greater protein turnover in the high RFI cattle. In addition to protein turnover, stress plays an integral role in how metabolism affects efficiency. Richardson et al. (2004) showed that in beef steers there are genetic relationships between RFI and plasma cortisol and immune system variables. Their results suggest that high RFI cattle are more susceptible to stress. Since the physiological response to stressors result in an increase in the animals metabolic rate and energy use along with an increase in catabolic processes, lipolysis and protein degradation, stress can play a substantial role in the overall efficiency of the animal (Knott et al., 2008).

The concentration of insulin-like growth factor-I (IGF-I) has been shown to be genetically correlated with growth, carcass traits, and also feed efficiency in cattle (Moore et al., 2005). IGF-I concentration was measured in 6520 Angus cattle to estimate the heritability of IGF-I and its phenotypic and genetic correlation with RFI. In this study, a moderate heritability (0.35) was shown for IGF-I and that IGF-I and RFI had a correlation of 0.41. This study suggests that genes responsible for increased concentrations of IGF-I in the animals' blood are also associated with increased RFI (Moore et al., 2005).

Activity

Differences in activity among animals change their amount of energy use. As a result the energy that is then available for maintenance and also for growth is increased which improves overall feed efficiency. Activity has been shown to contribute up to eighty percent of the variation of efficiency in poultry lines that were selected for high and low residual food consumption (Luiting et al., 1991). Mousel et al. (2001) conducted a study in mice selected for heat loss. Those with high heat loss, which represent poor efficiency, were twice as active as the more efficient mice. In cattle, the same trend has also been shown. Richardson et al. (1999) showed a significant correlation of activity with efficiency by using a pedometer counter on beef bulls that were selected for either high or low net feed efficiency. Ten percent of the variation in efficiency was explained by the animals' activity which includes the energy expended in eating, ruminating, and also movement (Richardson et al., 1999).

Thermoregulation

Thermoregulation accounts for a relatively small percent of the variation that is present in feed efficiency at nine percent (Richardson and Herd, 2004). Very little research has been done to show a relationship between efficiency and respiration rate, the means of a ruminant expelling the heat generated by the digestion process. One way an animal will cope with an increase in heat stress is by decreasing its intake. This will result in less heat produced from rumen fermentation than normal and thus less heat to expel through respiration. Nkrumah et al. (2006) showed that steers selected for increased efficiency had lower daily heat production. The more efficient steers produced twenty-one percent less heat than the steers that had the poorest overall efficiency.

Residual Feed Intake

Koch et al. (1963) first proposed the idea of RFI in beef cattle by suggesting that the feed intake could be adjusted for weight gain and body weight by separating feed intake into two sections; the feed intake expected for the given level of production and a residual portion. The residual portion is then used to find animals that differ from their expected intake. The more efficient animals in terms of RFI have lower values than those that prove to be less efficient. The animals' intake can be predicted by either using feeding standards (NRC, 1996) or by calculating a regression equation using the actual data for a group of animals from a feeding period (Arthur et al., 2001). Unlike other forms of measuring feed efficiency, RFI allows for measurement without being correlated to any phenotypic trait that is used in its estimations (Basarab et al., 2003).

Testing for RFI

The testing phase for RFI requires measuring DMI and growth over a period of time. One of the most important things of this testing phase is to control as many factors as possible such as; age, sex, diet composition, and testing procedures (Arthur and Herd, 2008). Because of the fact that individual intake and performance must be measured to calculate RFI, it is a very expensive test and is one of the limitations keeping RFI from being used in every segment of the beef cattle industry.

Cow Intake and RFI

The testing that is done for RFI is mostly done in feedlot animals and which are harvested when they reach a certain desired endpoint. While there are tests done on heifers, there is very limited data on the difference in intake of these animals once they are put into production. Meyer et al. (2008) conducted a study using two replicated (n = 7/replicate) of both low and high RFI classified cows in an 84 d grazing study. Intake was measured in grazing exclosures, weekly rising plate meter readings, and forage harvests every twenty-one days. There was no difference in BW change or BCS change between the two groups, however the low RFI cows had a twenty-one percent decrease in DMI compared to high RFI cows (Meyer et al., 2008).

Genetics of RFI

Research has shown that RFI as well as feed conversion ratio (FCR) to be moderately heritable across a multitude of breeds of beef cattle (Herd and Bishop, 2000; Arthur et al., 2001; Robinson and Oddy, 2004; Nkrumah et al., 2007). In these studies it was also shown that RFI is correlated to the animals FCR (0.45 – 0.85). As a result selection for RFI will also seem to result in improvement in the FCR. Unlike the FCR, RFI has been selected for without having an effect on animal growth. Correlations have been shown close to zero in these studies when comparing RFI to ADG and also metabolic weight. RFI is correlated with DMI (0.43 – 0.73) with low RFI cattle consuming less feed. While there is a large amount of information available for grain fed animals, there are relatively small amounts of data when animals are fed a forage diet. In a study conducted by Herd et al. (2002), steers (n = 51) out of either low or high RFI parents were fed on dry summer pasture and had a restricted ADG (0.46 kg/d). The low RFI steers outgained high RFI steers (0.50 kg/d vs. 0.42 kg/d), consumed less forage (3.04 kg/d vs. 3.23 kg/d), and had an improved FCR (6.4:1 vs. 8.5:1) (Herd et al., 2002).

Similarly to forage based steer diets, little research has been done with the effects of RFI on cow production. Arthur et al. (2005) conducted a study to analyze the differences in selecting lines for either low or high RFI over multiple generations on cow productivity. After 5 years of study (2 generations), progeny from the low RFI line (n = 62) consumed less feed when compared to those from the high RFI line (n = 72). At the same time, similarly to what is seen in the feedlot, there were no differences in cow performance traits; weight pregnancy rate (90.5 vs. 90.2), calving rate (89.2 vs. 88.3), weaning rate (81.5 vs. 80.2), milk production (7.5 kg/d vs. 7.8 kg/d), or calf weight at weaning (191.3 kg vs. 198.4 kg) (Arthur et al., 2005). Archer and Herd (2002) conducted a similar study observing the effect of RFI on cow production and found that after 2 generations of selecting for either high or low RFI, there were no significant differences in maternal production of the cows (n = 184) over three reproductive cycles, but the low RFI cows had a decreased DMI.

In addition to studies on heritability of RFI, there is now more work being done on genomics associated with RFI. Barendse et al. (2007) conducted a whole-genome association study assessing single nucleotide polymorphisms (SNP). In the study of 1,472 animals, it was found that 161 SNP were associated with RFI. This study shows that many different types of DNA variants play a part in RFI variation and that nongenic DNA variants are going to be important to completely indentify the molecular basis of RFI (Barendse et al., 2007). Because of the fact that RFI is challenging and expensive to test for, identifying a marker assisted trait would be very important for RFI to become widely adopted.

Benefits of RFI

There are two important benefits to utilizing RFI in a cow herd. First of all there is the economic benefit. This comes from the fact that cattle have decreased DMI with the same overall performance and therefore have lower input costs and are more profitable. The second is from an environmental standpoint. The benefit that RFI selection can have on the environment is from a methane production standpoint. The agriculture field is a source of greenhouse emissions throughout the world. Steinfeld et al. (2006) reported that livestock are responsible for eighteen percent of the worldwide greenhouse gas emissions. Livestock produce methane as well as nitrous oxide which have 21 and 310 times greater global warming potential than does carbon dioxide (AGO, 2001). Methane is the major gas emitted by ruminants as a by-product of enteric fermentation. Methane, along with nitrous oxide, can be produced from manure given certain types of management schemes (AGO, 2001). Hegarty et al. (2007) used Angus steers (n = 76) from lines selected for either low or high RFI and studied their relationship with methane production. There was a significant relationship between methane production and RFI (P = 0.01) with the low RFI steers producing less methane (Hegarty et al., 2007). Nkrumah et al. (2006) conducted a similar study utilizing crossbred steers (n = 27) to evaluate their methane production. There was a significant correlation (P < 0.05) of 0.44 with RFI and methane production. The resulting differences in methane production from this study accounted for 16,100 L/yr less for the low RFI animals than the high RFI steers (Nkrumah et al., 2006). Therefore, RFI could be used as a tool to help lower the greenhouse gas emissions that ruminants emit.

Residual Average Daily Gain

Residual average daily gain (RADG) is one of the new ways of measuring feed efficiency. The American Angus Association (AAA) has developed and implemented this into an expected progeny difference (EPD) for efficiency. This measure of efficiency can be measured, similarly to RFI, by doing a feed test. But, the AAA states that the quickest way to determine an animals' RADG is using a comprehensive genetic evaluation of a vast array genetic evaluation of several indicator traits. Some of these traits include weaning weight, postweaning gain, subcutaneous fat thickness, calf DMI, and DMI genomic values (American Angus Association, 2010). These genetic values coupled with animal ADG and fat allows for the prediction of an animal's RADG potential. RADG is presented in terms of pounds per day that an animal gains in comparison to another given the same amount of DMI in the postweaning period, and as stated by the AAA "it is not a cow efficiency tool" (American Angus Association, 2010). When analyzing the RADG data, it is important to realize that, similarly to other EPDs, a more positive or higher value is desired because of their greater gain that is achieved (Iowa Beef Center, 2010). The use of RADG can be effective because it has been shown to be moderately heritable (0.31 to 0.41) and can be effective for feedlot cattle, but for the cow calf producer, it can lead to increased cow size that has increased requirements (MacNeil, 2010).

Summary

In order for the beef cattle industry to continue to thrive in times where input costs are continuously on the rise, producers are going to have to do more to ensure that their cattle are performing at a high efficiency. It has been shown that there are many factors that influence feed efficiency and that there are many ways that a producer can measure feed efficiency, but in order to take increased cow size and weight out of this equation, RFI appears to be the most valuable tool for the cow/calf producer. RFI has been shown to be a moderately heritable tool that does not have an impact on an animals' growth or carcass characteristics. It also does not impact cow production either. While measuring RFI is currently an expensive and time consuming method of determining feed efficiency, recent advances in the genetics field should allow for better predictions without having to do the actual RFI test. Therefore, it should be easier in the future for the beef cattle industry to be able to make strides in efficiency to continue to be competitive with the other livestock species.

Section 2. The Effects of Early Weaning on the Beef Herd

Introduction

Limited pasture productivity coupled with slow calf gains during the summer months represent significant problems for beef producers in the Midwest. Studies have shown the importance that milk production of the dam plays on calf gain (Neville, 1962; Rutledge et al., 1971). These studies indicated approximately 60% of the variation in weaning weight in non-creep fed calves is due to the variation in milk yield of the dam. Part of the variation in calf gains can be attributed to reduced influence that milk plays on calf gains in the latter months of lactations. By the time a calf reaches 120 days of age, over half of its energy requirements come from other sources than its mother's milk (Maddox, 1965). In a spring calving herd, this period corresponds to the time that forage availability and quality are decreasing; therefore another method of raising these calves could prove to be more economical for the producer.

Many different methods have been tried to overcome this challenge; creep feeding grain (Martin et al., 1981; Shike et al., 2007), creep grazing (Vicini et al., 1982; Bagely et al., 1987), early weaning calves and providing a concentrate on pasture (Harvey et al., 1975), feeding in a drylot (Myers et al., 1999; Shike et al., 2007). With feed costs representing over 60% of the costs of production (Miller et al., 2001), removing the calf from the cow would prove to be economical in various situations; feed quality is poor, short growing season of grazing forages, poor milk production of the cow, or period of drought. Early weaning has been shown to be an effective tool in these situations in several studies (Richardson et al., 1978; Neville and McCormick, 1981; Myers et al., 1999)

Effects of Early Weaning on the Cow

Cow Performance

Myers et al. (1999) conducted a study using crossbred cows (n = 168) to study the effects of early weaning on both cow and calf performance. Cows that had their calves early weaned had improved weight and BCS compared to those that were normal weaned ($P < 0.05$) and also had a trend for improved pregnancy rate ($P = 0.15$) compared to calves that were normal weaned at 215 days of age.

Lusby et al. (1981) also reported that early weaning can improve cow performance. Hereford X Angus primiparous heifers (n = 63) had their calves either early-weaned or normal-weaned. Heifers with normal-weaned calves lost 7.3 kg from calving to breeding, while the heifers that had their calves early-weaned gained 15.4 kg. There was also a significant different in overall conception rate of the cows ($P < 0.05$) with normal weaned cows having a 59.4% pregnancy rate and early-weaned at 96.8%.

Laster et al. (1973) studied the effects of early weaning a week before the beginning of breeding has on postpartum reproduction. They reported that early weaning increased the percentage of cows that showed estrus from calving through breeding as well as increased percentage of cows detected in estrus in the first 21 days of breeding. Early weaning also improved overall conception by 25.9% in primiparous heifers, 15.6% in 3-year-olds, and 7.9% in cows 4-years-old and over.

Arthington and Kalmbacher (2003) weaned fall calving, primiparous heifers in either January (early wean) or August (normal wean). In accordance with previous research, they observed a 39 kg increase in weight and higher BCS (6.34 vs. 4.75) in the early-weaned heifers at the time of normal weaning. The early-weaned heifers also had a higher pregnancy rate in year 1 (89.5% vs. 50%, P = 0.02) and a strong trend in year 2 (96.1% vs. 79%, P = 0.07).

Reduction in Feed/Increased Stocking Rates

While the primary focus of early weaning research is to examine performance effects of both the calf and the cow, some studies have also shown the effect early weaning has on forage availability. Peterson et al. (1987) weaned calves from the cows either at 110 (early weaned) or 222 (normal weaned) days of age. In order to monitor intake, cows were fed in a drylot after early weaning until normal weaning. Early weaned pairs outgained normal weaned pairs (29 kg vs. 20.7 kg) and cows that had their calves early weaned consumed 45.3% less TDN than did cows that still had their calves at side. Also, early-weaned cow-calf pairs consumed 20.4% less TDN than normal-weaned pairs and were 43.9% more efficient than the normal-weaned pairs (Peterson et al., 1987).

Harvey and Burns (1988) also did a study to evaluate the effect of weaning strategy on both stocking rates and cow performance. Pairs were placed onto one of three treatments; normal weaned at 2.3 cows/ha, early weaned at 2.55 cows/ha, and early weaned at 3.66 cows/ha. No differences were observed when comparing normal-weaned pairs and the early-weaned pairs with increased stocking rate, therefore early weaning can allow for increased stocking rate without having a negative impact on cow performance. When the normal-weaned was compared to the lower-stocked, early-weaned pairs (2.55 cows/ha), the early-weaned pairs gained 0.18 kg/d more than the normal-weaned pairs (Harvey and Burns, (1988).

Effects of Early Weaning on the Calf

In order for producers to utilize early weaning as a management system, it must be shown to be effective not only for the cow, but also for the calf. Many studies have been conducted in order to evaluate the effects of early weaning on calf performance and carcass characteristics.

Harvey et al. (1975) conducted an experiment using Angus calves (n = 216) to evaluate the effects of early weaning and feeding a concentrate diet. During the grazing period early-weaned calves gained 0.28kg/d more than the normal-weaned calves that were still nursing their dams. Yet, during the finishing phase the normal-weaned calves had a 0.09 kg greater ADG than the early-weaned calves. Yet, the early-weaned calves did tend to have a higher marbling score (16 vs. 14.1) and fat thickness (0.87 cm vs. 0.78 cm).

Myers et al. (1999) compared three different weaning ages (90, 152, and 215). Steers weaned at either 90 or 152 days had 0.85 kg higher ADG from 152 to 215 days when compared to the normal-weaned calves still alongside their dams. No differences in feedlot ADG were detected, but overall feed efficiency had a linear increase ($P < 0.01$) at 0.195, 0.178, and 0.160 respectively. No differences were detected in yield grade or marbling score ($P > 0.21$).

Fluharty et al. (2000) compared weaning cattle at 100 or 200 days. The early-weaned calves were 52.2 kg heavier at 200 days than the normal weaned calves. During the finishing phase, there was no difference in ADG, but the normal-weaned cattle were on feed for an additional 33 days. No differences were noted in carcass traits between the different weaning systems. Barker-Neef et al. (2001) also evaluated weaning at 100 and 200 days and observed that early-weaned steers gained 0.41kg/d more between the times of early and normal weaning. Additionally, no differences in carcass characteristics were seen.

Schoonmaker et al. (2002) compared weaning ages of 111 and 202 days. This study reported 0.53 kg higher ADG in early-weaned calves from early to normal weaning which is in agreement with other studies. A 14% decrease in DMI and 9% improvement in overall feed efficiency were also observed in early-weaned steers. No differences in yield grade, marbling score, or quality grade were seen.

Summary

Land is one of the limiting factors to overall cowherd numbers and in years of dry, hot weather, pasture growth is likely to be reduced in the summer months. Producers are then forced to either feed hay or grain to their herd or accept a reduction in weaning weights. If the winter feed supply is fed during the summer, a devastating economic loss can be incurred due to reduced calf weaning weights and the need to purchase additional winter feed for the herd. Early weaning has been shown not only to be beneficial to the cow in terms of increased weight, BCS, and reproductive efficiency, but also is advantageous for the calf resulting in increased weights if calves are sold at weaning. It has also been shown that early weaning can lead to advantages in marbling score which would be beneficial in a retained ownership situation. When deciding what type of weaning strategy is going to be implemented, a producer must weigh all of the costs and benefits associated and decide which option works best for their operation.

Literature Cited

Adam, I., B. A. Young, A. M. Nicol, and A. A. Degan. 1984. Energy cost of eating in cattle given diets of different form. Anim. Prod. 38: 53-56.

American Angus Association. 2010. Angus feed efficiency selection tool: RADG. Accessed Mar 1, 2011. http://www.angus.org/Nce/Documents/ByTheNumbersRadg.pdf.

Australian Greenhouse Office – AGO. 2001. Greenhouse emissions from beef cattle. Canberra: Australian Greenhouse Office.

Archer, J. A., A. Reverter, R. M. Herd, D. J. Johnston, and P. F. Arthur. 2002. Genetic variation in feed intake and efficiency of mature beef cows and relationships with postweaning measurements. 7th World Congress on Genetics Applied to Livestock Production. Montpellier, France. 31: 221-224.

Archer, J. A., E. C. Richardson, R. M. Herd, and P. F. Arthur. 1999. Potential for selection to improve efficiency of feed use in beef cattle: A review. Aust. J. Agric. Res. 50: 147-161.

Arthington, J. D. and R. S. Kalmbacher. 2003. Effect of early weaning on the performance of three-year-old, first-calf beef heifers and calves reared in the subtropics. J. Anim. Sci. 81: 1136-1141.

Arthur, P. F. and R. M. Herd. 2008. Residual feed intake in beef cattle. Revista Brasileira de Zootencnia. 37: 269-279.

Arthur, P.F., J. A. Archer, D. J. Johnston, R. M. Herd, E. C. Richardson, and P. F. Parnell. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79: 2805-2811.

Arthur, P. F., R. M. Herd, J. F. Wilkins, and J. A. Archer. 2005. Maternal productivity of Angus cows divergently selected for post-weaning residual feed intake. Aust. J. Exp. Agric. 45: 985-993.

Bagely, C. P., J. C. Carpenter, Jr., J. I. Feazel, F. G. Hembry, D. C. Huffman, and K. L. Koonce. 1987. Effects of forage system on beef cow-calf productivity. J. Anim. Sci. 64: 678-686.

Barendse, W., A. Reverter, R. J. Bunch, B. E. Harrison, W. Barris, and M. B. Thomas. 2007. A validated whole-genome association study of efficient food conversion in cattle. Genetics. 176: 1893-1905.

Barker-Neef, J. M., D. D. Buskirk, J. R. Blackt, M. E. Doumit, and S. R. Rust. 2001. Biological and economic performance of early-weaned Angus steers. J. Anim. Sci. 79: 2762-2769.

Basarab, J. A., M. A. Price, J. L. Aalhus, E. K. Okine, W. M. Snelling, and K. L. Lyle. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83: 189-204.

Brelin, B. and E. Brannang. 1982. Phenotypic and genetic variation in feed efficiency of growing cattle and their relationship with growth rate, carcass traits, and metabolic efficiency. Swedish J. Agric. Res. 12: 29-34.

Byerly, T. C. 1941. Feed and other costs of producing market eggs. Bull. A1 (Technical). Univ. Maryland Agric. Exp. Stn., College Park, MD.

Fluharty, F. L., S. C. Loerch, T. B. Turner, S. J. Moeller, and G. D. Lowe. 2000. Effects of weaning age and diet on growth and carcass characteristics in steers. J. Anim. Sci. 78: 1759-1767.

Harvey, R. W. and J. C. Burns. 1988. Forage species, concentrate feeding level and cow management system in combination with early weaning. J. Anim. Sci. 66: 2722-2727

Harvey, R. W., J. C. Burns, T. N. Blumer, and A. C. Linnerud. 1975. Influence of early weaning on calf and pasture productivity. J. Anim. Sci. 41: 740-746.

Hegarty, R. S., J. P. Goopy, R. M. Herd, and B. McCorkell. 2007. Cattle selected for lower residual feed intake have reduced daily methane production. J. Anim. Sci. 85: 1479-1486.

Herd, R. M. and P. F. Arthur. 2009. Physiological basis for residual feed intake. J. Anim. Sci. 87: E64-E71.

Herd, R. M., and S. C. Bishop. 2000. Genetic variation in residual feed intake and its association with other production traits in British Hereford cattle. Livest. Prod. Sci. 63: 111-119.

Herd, R. M., R. S. Hegarty, R. W. Dicker. 2002. Selection for residual feed intake improves feed conversion ratio on pasture. Anim. Prod. Aust. 24: 85-88.

Herd, R. M., V. H. Oddy, and G. J. Lee. 1993. Effect of divergent selection for weaning weight on liveweight and wool growth responses to feed intake in merino ewes. Aust. J. Exp. Agric. 33: 699-705

Iowa Beef Center. 2010. Phenotypic feed efficiency: understanding data outputs. Accessed Mar 1, 2011. http://www.iowabeefcenter.org/Docs_cows/IBC41.pdf.

Knott, S. A., L. J. Cummins, F. R. Dunshea, and B. J. Leury. 2008. Rams with poor feed efficiency are highly responsive to an exogenous adrenocorticotropin hormone (ACTH) challenge. Domest. Anim. Endocrinol. 34: 261-268.

Koch, R. M., L. A. Swiger, D. Chambers, and K. E. Gregory. 1963. Efficiency of feed use in beef cattle. J. Anim. Sci. 22: 486-494.

Laster, D. B., H. A. Glimp, and K. E. Gregory. 1973. Effects of early weaning on postpartum reproduction of cows. J. Anim. Sci. 36: 734-740.

Luiting, P. J., W. Schrama, W. van Der Hel, E. M. Urff, P. G. J. J. van Boekholt, E. M. W. van Den Elsen, and M. W. A. Verstegen. 1991. Metabolic differences between white leghorns selected for high and low residual feed consumption. Pages 384-387 in Energy Metabolism of Farm Animals. C. Wenk and M. Boessinger, ed. Eur. Assoc. Anim. Prod. Publ. 58, Kartause, Switzerland.

Lusby, K. S., R. P. Wettemann, and E. J. Turman. 1981. Effects of early weaning calves from first-calf heifers on calf and heifer performance. J. Anim. Sci. 53: 1193-1197.

Maddox, L.A. 1965. Nutrient requirements of the cow and calf. Texas Agr. Exp. Sta. Bull. 1044.

MacNeil, M. 2010. Advances including DNA tests in genetic evaluations. Beef Improvement Federation 42nd Annual Research Symposium and Annual Meeting. Columbia, Missouri. June 30.

Martin, T. G., R. P. Lemenager, G. Srinivasas, and R. Alenda. 1981. Creep feed as a factor influencing performance of cows and calves. J. Anim. Sci. 53: 33-39.

McDonagh, M. D., R. M. Herd, E. C. Richardson, V. H. Oddy, J. A. Archer, and P. F. Arthur. 2001. Meat quality and the calpain system of feedlot steers following a single generation of divergent selection for residual feed intake. Aust. J. Exp. Agric. 41: 1013-1021.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D. F. Parrett, and L. L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17: 295–302.

Moore, K. L., D. J. Johnston, H-U. Graser, and R. M. Herd. 2005. Genetic and phenotypic relationships between insulin-like growth factor-I (IGF-I) and net feed intake, fat, and growth traits in Angus beef cattle. Aust. J. Anim. Res. 56: 211-218.

Mousel, M. R., W. W. Stroup, and M. K. Nielsen. 2001. Locomotor activity, core body temperature, and circadian rhythms in mice selected for high and low heat loss. J. Anim. Sci. 79: 861-868.

Myer, A. M., M. S. Kerley, and R. L. Kallenbach. 2008. The effect of residual feed intake classification on forage intake by grazing beef cows. J. Anim. Sci. 86: 2670-2679.

Myers, S. E., D. B. Faulkner, F. A. Ireland, and D. F. Parrett. 1999. Comparison of three weaning ages on cow-calf performance and steer carcass traits. J. Anim. Sci. 77: 323-329.

Neville, W. E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21: 315-320.

Neville, W. E., Jr. and W. C. McCormick. 1981. Performance of early- and normal-weaned beef calves and their dams. J. Anim. Sci. 52: 715-724.

Nkrumah, J. D., J. A. Basarab, Z. Wang, C. Li, M. A. Price, E. K. Okine, D. H Crews, and S. S. Moore. 2007. Genetic and phenotypic relationships of feed intake and measures of efficiency with growth and carcass merit of beef cattle. J. Anim. Sci. 85: 2711-2720.

Nkrumah, J. D., E. K. Okine, G. W. Mathison, K. Schmid, C. Li, J. A. Basarab, M. A. Price, Z. Wang, and S. S. Moore. 2006. Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle. J. Anim. Sci. 84: 145-153.

NRC. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press, Washington, DC.

Oddy, V. H. 1993. Increasing the efficiency of muscle growth. Final report Project DAN.33. Meat Res. Counc, Sydney, Australia.

Oddy, V. H. 1999. Genetic variation in protein metabolism and implications for variation in efficiency of growth. Rec. Adv. Anim. Nutr. Aust. 12: 23-29.

Oddy, V. H., R. M. Herd, M. B. McDonagh, R. Woodgate, C. A. Quinn, and K. Zirkler. 1998. Effect of divergent selection for yearling growth rate on protein metabolism in hind-limb muscle and whole body of Angus cattle. Livest. Prod. Sci. 56: 225-231.

Peterson, G. A., T. B. Turner, K. M. Irvin, M. E. Davis, H. W. Newland, and W. R. Harvey. 1987. Cow and calf performance and economic considerations of early weaning of fall-born beef calves. J. Anim. Sci. 64: 15-22.

Richardson, A. T., T. G. Martin, and R. E. Hunsley. 1978. Weaning age of Angus heifer calves as a factor influencing calf and cow performance. J. Anim. Sci. 47: 6-14.

Richardson, E. C. 2003. Biological basis for variation in residual feed intake in beef cattle. PhD. Diss. Univ. New England, Armidale, Australia.

Richardson, E. C., R. J. Kilgour, J. A. Archer, and R. M. Herd. 1999. Pedometers measure differences in activity in bulls selected for high or low net feed efficiency. Proc. Aust. Soc. Study Anim. Behave. 26: 16 (Abstr.).

Richardson, E. C., R. M. Herd, J. A. Archer, and P. F. Arthur. 2004. Metabolic differences in Angus steers divergently selected for residual feed intake. Aust. J. Exp. Agric. 44: 441-452.

Richardson, E. C., R. M. Herd, V. H. Oddy, J. M. Thompson, J. A. Archer, and P. F. Arthur. 2001. Body composition and implications for heat production of Angus steer progeny of parents selected for and against residual feed intake. Aust. J. Exp. Agric. 41: 1065-1072.

Richardson, E. C. and R. M. Herd. 2004. Biological basis for variation in residual feed intake in beef cattle. 2. Synthesis of results following divergent selection. Aust. J. Exp. Agric. 44: 431-440.

Robinson, D. L. and V. H. Oddy. 2004. Genetic parameters for feed efficiency, fatness, muscle area, and feeding behaviour of feedlot finished beef cattle. Livest. Prod. Sci. 90: 255-270.

Rutledge, J. J., O. W. Robison, W. T. Ahlschwede, and J. E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33: 563-567.

Schoonmaker, J. P., S. C. Loerch, F. L. Fluharty, H. N. Zerby, and T. B. Turner. 2002. Effect of age at feedlot entry on performance and carcass characteristics of bulls and steers. J. Anim. Sci. 80: 2247-22454.

Shike, D. W., D. B. Faulkner, M. J. Cecava, D. F. Parrett, and F. A. Ireland. 2007. Effects of weaning age, creep feeding, and type of creep on steer performance, carcass traits, and economics. Prof. Anim. Sci. 23: 325-332.

Shuey, S. A., C. P. Birkelo, and D. M. Marshall. 1993. The relationship of the maintenance energy requirement to heifer production efficiency. J. Anim. Sci. 71: 2253-2259.

Standing Committee on Agriculture. 2000. Feeding standards for Australian livestock. Ruminants. CSIRO Publications, East Melbourne, Australia.

Steinfeld, H., P. Gerber, and T. Wassenaar. 2006. Livestock's long shadow – Environmental issues and options. Food and Agriculture Organization of the United Nations. Rome, Italy. pp 408.

Vicini, J. L., E. C. Prigge, W. B. Bryan, and G. A. Varga. 1982. Influence of forage species and creep grazing on a cow-calf system. II. Calf production. J. Anim. Sci. 55: 759-764.

Waterlow, J. C. 1988. The variability of energy metabolism in man. Comparative Nutr. pp 133-139.

Webster, A. J. F., P. O. Osuji, F. White, and J. F. Ingram. 1975. The influence of food intake on portal blood flow and heat production in the digestive tract of the sheep. Br. J. Nutr. 34: 125-139.

Chapter 2

Comparison of Weaning System on Cow-Calf Performance and Intake

Abstract

A two-year study was conducted using Angus and Simmental X Angus heifers (n=114) to evaluate how weaning system (early weaning vs. normal weaning) affects cow and calf performance and intake. All cows with male calves were early weaned at 130 d while cows with female calves were normal weaned at 200 d. These animals were then evaluated for individual intake at 60 d, 120 d, 180 d, and 240 d postpartum. Animals were fed a common forage diet during a 10 d evaluation period. Weigh-suckle-weigh was used to determine milk production for the lactating periods. In all periods, animals were weighed on consecutive days to determine weight. Hip height, body condition score (BCS, 1-9 scale), and backfat via ultrasound were measured. At 60 d postpartum, calf weight differed ($P = .01$) with male calves being 8.4 kg heavier, but no difference ($P = 0.44$) in intake was noted. Cows also exhibited no difference ($P > 0.35$) in performance traits based on calf sex, but there was a trend ($P = 0.13$) for cows with male calves to have a 1.26 kg/d higher DMI. As a pair, there was a trend for cows with male calves to have a seven percent increase in DMI. At 120 d postpartum, calf weight differed ($P = 0.02$) with male calves being 10.3 kg heavier, but no difference (0.22) in DMI. There were no differences ($P > 0.30$) in cow performance and intake or pair DMI. At 180 d postpartum, with male calves previously weaned, these cows had a 0.29 higher ($P < 0.01$) BCS, a 1.23 kg/d decrease in ($P = 0.03$) DMI, and trend ($P = 0.06$) for an 18.7 kg increase in BW. By leaving calves alongside their dam there was a 35% increase in DMI for the pair when compared to just the early-weaned cow. For the 70 d between early and normal weaning, there was a

saving of 400 kg of forage. At a cost of $0.10/kg, was calculated to be $40.00 for the 70 d period. At 240 d postpartum, when all calves are weaned, cows that had male calves had a 0.31 higher ($P < 0.01$) BCS, increased ($P < 0.01$) BF (0.90 vs. 0.68 cm), a 30.5 kg increase ($P < 0.01$) in BW, but no difference ($P = 0.43$) in DMI or overall pregnancy rate ($P = 0.75$) were seen. In this study, early weaning improved cow weight and condition and decreased intake at 180 d postpartum by removing the milk production strain from the dam.

Introduction

With rising inputs, increased economic pressure has been put on cow-calf producers to make better use of their resources and evaluate alternative systems of production. One problem for producers is maintaining pasture productivity and cow performance can be a problem for cattle producers. Research has shown that the cow has reduced milk production after the third month of lactation (Robison et al., 1978) and the calf is getting a majority of its nutrients that are required from another source. In a spring calving herd, this also can coincide with the time that pastures are having reduced productivity (Burns et al., 1983). Early weaning (Peterson et al., 1987; Myers et al., 1999a; Myers el al., 1999b) is a management practice that can increase both cow and calf performance. In a conventional cow-calf operation, there are little adverse effects to early weaning male progeny that are going to be sent to the feedlot and leaving replacement heifers alongside their dams. This could be an economical way to improve animal performance without incurring increased costs of developing replacement heifers.

Materials & Methods

Experimental Animals

One hundred fourteen Angus and Simmental X Angus primiparous cows from the University of Illinois Beef Field Research Laboratory in Urbana, IL were used to determine the effect of two different types of weaning strategies on both performance and intake of the cows and their calves. Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* (Consortium, 1988). All experimental procedures followed those approved by the University of Illinois Animal Care Advisory Committee.

Experimental Design

Two treatments were assigned to the cows based on sex of their calf. All cows with male calves were early-weaned at 120 days and all cows with female calves were normal weaned at 200 days. This was a two year study with 29 and 31 cows with female and male pairs respectively in year 1 and 29 and 25 female and male pairs in year 2. There was no interaction between year and treatment ($P > 0.10$) so results for the two years are combined. The resulting treatments groups were 58 cows with female calves and 56 cows with male calves. Individual animal was used as the experimental unit for this experiment.

Management and Diet

Cattle were placed in the barns at the Beef Field Research Laboratory for the 14 d evaluation phases (60, 120, 180, and 240 d postpartum) where they were fed a common forage based diet (60% TDN). At 60 d postpartum a 7 d adaptation phase was also implemented to adapt cows to the diet and eating out of Growsafe® bunks. Barns consist of 5 X 5 m pens with a single GrowSafe® bunk per pen. Eight of these pens were opened and cows were allowed access to 40 X 5 m pens with a 5 X 5 m creep pens so the calves would be able to eat without competition from the cows on each end of the cow pen. Eight GrowSafe® bunks allow for little competition between cows to ensure quality intake data results. While not on evaluation, cows were placed on pasture and rotated through mixed pastures of endophyte infected tall fescue (*Festuca arundinacea),* red clover *(Trifolium pretense),* and orchard grass (*Dactylis glomerata)*.

Data Collection

During the evaluation periods, measurements were taken to evaluate the performance of the animals. At the beginning of the period, the weigh-suckle-weigh procedure was done; calves were separated from the cows at 1200 on day 0 without access to feed or water, allowed to nurse at 1900 on day 0 to leave only residual milk in the mammary gland and then put back into pens separate from dams (dams were allowed access to feed and water between nursings), at 700 on day 1 calves were weighed (empty weight), allowed to nurse (pairing was done in a large pen and cross-nursing was prevented), and then reweighed and returned to its dam. The difference between the pre- and post-nursing weight was multiplied by two to provide an estimate of 24 h milk production. This was done for periods 60 and 120 d postpartum on all calves, 180 on females only (all males had already been weaned). The 240 d period was a dry period so no weigh-suckle-weigh was done.

Individual intake was measured during each evaluation period by using the GrowSafe® automated feeding system (Model 4000E, GrowSafe Systems Ltd., 86 Airdrie, Alberta, Canada). Intakes were audited daily by trained personnel (10 d of acceptable data needed for each period). Feed intake data was considered acceptable if at least 85% of feed supplied to the bunk and 90% of corresponding feed assigned to an individual ID was accounted for. Data was also considered acceptable if 95% of the data sent from the weight panel was received at the computer to all data points sent for a 24 h period. Also, 95% of the data from an individual electronic identification tag needed to be received at the computer to all possible data sent from the electronic identification panel. A log was kept for repair or replacement of the component parts and data was subsequently discarded that day. The GrowSafe® system has been validated and is a viable method for obtaining individual feed intake (Basarab et al., 2003; Nkrumah et al., 2004; Lancaster et al., 2009).

At the conclusion of each evaluation period, weights were taken on two consecutive days, hip height recorded, BCS taken (1-9 scale), and cows were ultrasounded for 12^{th} rib fat thickness. These ultrasound measurements were taken by a trained technician with an Aloka 500SV (Wallingford, CT) B-110 mode instrument equipped with a 3.5-MHz general purpose transducer array. Backfat was taken in transverse orientation between the 12^{th} and 13^{th} ribs approximately 10 cm distal from the midline.

Statistical Analysis

Data was analyzed using the MIXED procedure of SAS (SAS Inst, Inc. Cary, NC) using a single degree of freedom orthogonal contrast. Individual animal served as the experimental unit. The independent variable in the model was treatment. Correlations between DMI for the respective periods were analyzed using the CORR procedure of SAS.

Results and Discussion

Correlations in cow DMI between periods are listed in Table 2-1. DMI between 60 d and 120 d postpartum were correlated (0.40, $P < 0.01$), as well as 180 d postpartum (0.25, $P < 0.01$)

and 240 d postpartum (0.41, P < 0.01). DMI was also correlated between 120 d postpartum and 180 d postpartum (0.67, P < 0.01) and 240 d postpartum (0.59, P < 0.01). Cow DMI between 180 d postpartum and 240 d postpartum were also correlated (0.67, P < 0.01). With all the periods being significantly correlated, they have merit standing on their own to represent individual cow DMI accurately for each stage of production.

Cow and calf performance and intake for the 60 d postpartum period are listed in Table 2-2. Calf BW was significantly different (P = 0.01) with male calves being 8.4 kg heavier than the female calves, however no difference in DMI (P = 0.44) was observed. There were no differences in cow traits measured; hip height (P = 0.73), BCS (P = 0.33), BF (P = 0.92), BW (0.90), or milk production (0.36). There was a trend (P = 0.13) for cows with male offspring to have a 1.26 kg/d increase in DMI. This difference would be expected if there was a difference in the cows' daily milk production, but no difference in milk production was detected using the weigh-suckle-weigh technique. Cow-calf pair DMI had a trend to be lower for the cows with female calves (18.44 vs. 19.83). This trend (P = 0.13) during this period is due to the difference in cow DMI for the period.

Cow and calf performance and intake for the 120 d postpartum period are listed in Table 2-3. Calf BW was significantly different (P = 0.02) with male calves being 10.3 kg heavier, but similarly to the 60 d postpartum period no difference was detected in calf DMI (0.22). Also, similar to the 60 d postpartum period, cow performance was similar with no differences in hip height (P = 0.73), BCS (P = 0.98), BF (P = 0.51), BW (P = 0.99), or milk production (P = 0.87). There was also no difference detected in intake (P = 0.50) or pair DMI (P = 0.33).

Cow and calf performance and intake for the 180 d postpartum period are listed in Table 2-4. Early weaning had an effect on cow performance and intake. While hip ht ($P = 0.47$) and BF ($P = 0.26$) were not significantly different, the cows with early weaned calves had an increased BCS ($P < 0.01$) and a strong trend to have increased BW ($P = 0.06$). Intake was also affected as cows with early weaned calves had 1.23 kg/d decreased DMI ($P = 0.03$). Pair DMI differed ($P < 0.01$) due to the fact that male calf was removed. By leaving calves alongside their dam there was a 35% increase in DMI for the pair when compared to just the cow that had been previously early weaned. Also, by early weaning calves, for the 70 d between early and normal weaning, there was a saving of 400 kg of forage. This substantial savings in forage, at a cost of $0.10/kg, was calculated to be $40.00 for the 70 d period. Therefore, early weaning can result in feed cost savings or allow producers to increase stocking rates.

Cow and calf performance and intake for the 240 d postpartum period are listed in Table 2-5. The previous differences in performance continued to hold true. Cows with early weaned progeny tended to have increased hip height ($P = 0.14$), had a higher BCS ($P < 0.01$), increased BF ($P < 0.01$), and also increased BW ($P < 0.01$). However there was no difference in DMI ($P = 0.43$). Overall pregnancy rates were similar among treatments (89.5 vs. 87.5). This is due to the limited animal numbers in this experiment and calves were weaned post-breeding and therefore had little impact on conception rates.

Myers et al. (1999a) also reported that cows with early weaned offspring have improved ADG (0.53 kg/d) and improved BCS change (0.23). Pregnancy rates were improved by 18% when early weaning was done a 90 d compared to 152d and 215d. Similar results were also observed by Myers et al. (1999b) with cows that had offspring early weaned having improved

ADG and BCS. Peterson et al. (1987) reported that cows with early-weaned offspring had a gain of 2.5 kg, whereas cows with normal weaned calves lost 18.2 kg between early and normal weaning. Cows with the normal-weaned calves lost both BW and condition due to the greater energy requirements for lactation that early-weaned cows did not have. Therefore, lactating cows did not consume enough feed in order to meet these extra energy requirements and instead had to utilize body stores. Cows with early-weaned calves consumed enough feed to meet energy requirements for maintenance and also weight gain. Story et al. (2000) observed that cows that had offspring early weaned had improved weight and BCS not only at the time of early weaning, but also four months after normal weaning indicating that the normal-weaned cows were not able to reach the same condition even after their calves had been weaned for an extended period of time. Story et al. also noted that total cow costs were numerically reduced ($410.16 vs. $421.21) for early-weaned cows compared to normal-weaned cows which were due to a decrease in DMI.

Implications

Early weaning not only offers increased benefits in terms of calf feedlot performance and carcass quality, but it can also have significant advantages for the cow. Cow gain and body condition score were improved through early weaning and with the energy requirement for lactation removed, DMI was decreased with this increase in performance. When forage supply is limited, early weaning can therefore be a viable option in order to maintain or increase cow performance in order for producers to maximize profit.

Literature Cited

Basarab, J. A., M. A. Price, J. L. Aalhus, E. K. Okine, W. M. Snelling, and K. L. Lyle. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83: 189-204.

Burns, J.C., R. W. Harvey, F. G. Giesbrecht, W. A. Cope, and A. C. Linnerud. 1983. Central Appalachian hill land pasture evaluation using cows and calves. III. Treatment comparisons of per animal and hectare responses. Agron. J. 75:878-885.

Consortium. 1988. Guide for the care and use of agriculture animals in agriculture research and teaching. Consortium for developing a guide for the care and use of agriculture animals in agriculture research and teaching, Association Headquarters, Savoy, Il.

Lancaster, P. A., G. E. Carstens, F. R. B. Ribeiro, L. O. Tedeschi, and D. H. Crews Jr. 2009. Characterization of feed efficiency traits and relationships with feeding behavior and ultrasound carcass traits in growing bulls. J. Anim. Sci. 87: 1528-1539.

Myers, S. E., D. B. Faulkner, F. A. Ireland, and D. F. Parrett. 1999a. Comparison of three weaning ages on cow-calf performance and steer carcass traits. J. Anim. Sci. 77: 323-329.

Myers, S. E., D. B. Faulkner, F. A. Ireland, L. L. Berger, and D. F. Parrett. 1999b. Production systems comparing early weaning to normal weaning with or without creep feeding for beef steers. J. Anim. Sci. 77: 300-310.

Nkrumah, J. D., J. A. Basarab, M. A. Price, E. K. Okine, A. Ammoura, S. Guercio, C. Hansen, C. Li, B. Benkel, and S. S. Moore. 2004. Different measures of energetic efficiency and their relationships with growth, feed intake, ultrasound, and carcass measurements in hybrid cattle. J. Anim. Sci. 82: 2451-2459.

Peterson, G. A., T. B. Turner, K. M. Irvin, M. E. Davis, H. W. Newland, and W. R. Harvey. 1987. Cow and calf performance and economic considerations of early weaning of fall-born beef calves. J. Anim. Sci. 64: 15-22.

Robison, O. W., M. K. M. Yusuff, and E. U. Dillard. 1978. Milk production in Hereford cow I. Means and correlations. J. Anim. Sci. 47: 131-136.

Story, C. E., R. J. Rasby, R. T. Clark, and C. T. Milton. 2000. Age of calf at weaning of spring calving beef cows and the effect on cow and calf performance and production economics. J. Anim. Sci. 78: 1403-1413.

Tables

Table 2-1. Correlations between cow DMI[a]

	Cow DMI		
Item	120 d postpartum	180 d postpartum	240 d postpartum
Cow DMI			
60 d postpartum	0.40	0.25	0.41
120 d postpartum		0.67	0.59
180 d postpartum			0.67

[a]All correlations P < 0.01

Table 2-2. 60 d postpartum				
	Treatments[a]			P value
Item	Female (1)	Male (2)	SEM[b]	1 vs. 2
Cow				
Hip Ht., cm	134.7	134.5	0.465	0.73
BCS[c]	5.58	5.46	0.081	0.33
BF, cm	0.60	0.60	0.028	0.92
Milk, kg/d	7.45	7.89	0.334	0.36
BW, kg	561.4	559.5	8.435	0.90
DMI, kg/d	17.89	19.15	0.590	0.13
Calf				
BW, kg	83.2	91.6	2.326	0.01
DMI, kg/d	0.55	0.68	0.058	0.44
Pair				
DMI, kg/d	18.44	19.83	0.615	0.13

[a]Female = cow with female calf, Male = cow with male calf
[b]Pooled standard error of the mean
[c]Body Condition Score (1 = emaciated, 9 = extremely fat)

Table 2-3. 120 d postpartum

	Treatments[a]			P value
Item	Female Calves (1)	Male Calves (2)	SEM[b]	1 vs. 2
Cow				
Hip Ht., cm	134.7	134.5	0.450	0.73
BCS[c]	5.58	5.58	0.066	0.98
BF, cm	0.56	0.53	0.024	0.51
Milk, kg/d	8.40	8.47	0.302	0.87
BW, kg	568.6	568.6	7.578	0.99
DMI, kg/d	17.28	17.63	0.371	0.50
Calf				
BW, kg	127.3	137.6	3.019	0.02
DMI, kg/d	1.94	2.17	0.130	0.22
Pair				
DMI, kg/d	19.22	19.80	0.417	0.33

[a]Female = cow with female calf, Male = cow with male calf
[b]Pooled standard error of the mean
[c]Body Condition Score (1 = emaciated, 9 = extremely fat)

Table 2-4. 180 d postpartum				
	Treatments[a]			P value
Item	Female Calves (1)	Male Calves (2)	SEM[b]	1 vs. 2
Cow				
Hip Ht., cm	135.0	135.5	0.874	0.47
BCS[c]	5.66	5.95	0.069	<0.01
BF, cm	0.56	0.60	0.25	0.26
Milk, kg/d	6.22	NA	0.268	
BW, kg	577.7	596.4	6.886	0.06
DMI, kg/d	17.53	16.30	0.390	0.03
Calf				
BW, kg	193.2	NA	3.591	
DMI, kg/d	4.52	NA	0.166	
Pair				
DMI, kg/d[d]	22.05	16.30	0.422	<0.01

[a]Female = cow with female calf, Male = cow with male calf
[b]Pooled standard error of the mean
[c]Body Condition Score (1 = emaciated, 9 = extremely fat)
[d]Only cow DMI included as male calves weaned

Table 2-5. 240 d postpartum				
	Treatments			P Value
Item	Female Calves (1)	Male Calves (2)	SEM	1 vs. 2
Cow				
Hip Ht., cm	135.5	136.4	0.356	0.14
BCS[c]	5.75	6.06	0.051	<0.01
BF, cm	0.68	0.90	0.026	<0.01
BW, kg	614.5	645.0	6.994	<0.01
DMI, kg/d	18.96	19.56	0.535	0.43
Pregnancy, %[d]	89.5	87.5	0.043	0.75

[a]Female = cow with female calf, Male = cow with male calf
[b]Pooled standard error of the mean
[c]Body Condition Score (1 = emaciated, 9 = extremely fat)
[d]Overall Pregnancy Rate

Chapter 3

Utilizing Heifer RFI and RADG to Predict Cow Intake and Efficiency

Abstract

A two-year study was conducted using Angus and Simmental X Angus heifers (n=114) to determine their residual feed intake (RFI) and residual average daily gain (RADG) as yearlings using the GrowSafe® system. These animals were then evaluated for individual intake at 60 d postpartum (lactating period) and 240 d postpartum (dry period). Animals were fed a common forage diet during a 10 d evaluation period. Weigh-suckle-weigh was used to determine milk production for the lactating period. In both periods, animals were weighed on consecutive days to determine weight. Hip height, body condition score (BCS, 1-9 scale), and backfat via ultrasound were measured. The individual animal DMI was determined for each period. Yearling female correlations were: heifer RFI and heifer DMI (0.57), heifer RFI and heifer ADG (0.00), heifer RADG and heifer DMI (0.01), heifer RADG and heifer ADG (0.89), heifer RFI and heifer RADG (-0.18). For the lactating period, correlations were: heifer DMI and cow DMI (0.35), heifer RFI and cow DMI (0.20), heifer RFI and cow BW (-0.08), heifer RFI and cow hip height (0.02), heifer RFI and milk production (-0.09), heifer RADG and cow DMI (-0.06), heifer RADG and cow BW (0.21), heifer RADG and cow hip height (0.25), and heifer RADG and milk production (0.03). For the dry period correlations were: heifer DMI and cow DMI (0.06), heifer RFI and cow DMI (0.29), heifer RFI and cow BW (0.00), heifer RFI and cow hip height (-0.09), heifer RADG and cow DMI (-0.10), heifer RADG and cow BW (0.23), and heifer RADG and cow hip height (0.31). Heifer RFI is correlated with cow intake and thus can be used to help predict intake and efficiency.

Introduction

Providing feed to animals is a major cost of beef production. Miller et al. (2001) stated that feed costs represent over 60% of the total costs in a beef operation. Therefore, improving the feed efficiency is an important goal for producers to obtain. In many beef production systems, a large amount of the feed is consumed by the breeding herd. Any reduction that can be made in feed intake can have an important benefit in terms of profitability for cow-calf operations. Feed conversion ratio or gross efficiency have long been used to measure efficiency, but residual feed intake (RFI) may be a more accurate representation of the genetic and biological differences represented in feed efficiency (Archer et al., 1999). RFI is calculated as the difference between an animal's actual measured intake and its predicted intake based on its growth rate and BW. RFI is a moderately heritable trait and phenotypically independent of growth and body size, unlike gross efficiency (Arthur et al., 2001). Feed intake has been shown to be decreased when animals were determined to be low RFI (high efficiency) or selected from low RFI lines in feedlot cattle (Herd et al., 2003). However, little information is known on how differences in RFI relate in forage intake of the cow herd.

Residual average daily gain (RADG) is defined as the difference between actual weight gain and the gain predicted on the basis of dry matter intake, maintenance of body weight and fat cover. Like RFI, a regression equation is developed using the actual gains, feed intakes, average weights on test and fat cover of an animal's herd mates. This unique equation is then used to calculate the individual RADG.

Materials and Methods

Experimental Animals

One hundred fourteen Angus and Simmental X Angus primiparous cows from the University of Illinois Beef Field Research Laboratory in Urbana, IL were used to determine the efficacy of utilizing heifer RFI and RADG to predict cows' intake and efficiency. These animals were evaluated as heifers in order to determine RFI and RADG. Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* (Consortium, 1988). All experimental procedures followed those approved by the University of Illinois Animal Care Advisory Committee.

Experimental Design

Individual animal served as the experimental unit for this trial. This was a two year study with 60 pairs in year 1 and 54 pairs in year 2. During each of the respective years cows were blocked into two groups to lessen the effects of calving date on measured traits. Diet for year 1 was an alfalfa hay blend mixed with condensed corn solubles to aid in processing and year 2 was a mixture of alfalfa hay and oatlege. While the diets were different in ingredients both of these forage diets consisted of similar TDN (58%). There was no interaction ($P > 0.10$) between year and treatment thus results from the two years were combined.

Management and Diet

Cattle were placed in the barns at the Beef Field Research Laboratory for the 14 d evaluation phases (60 (lactating) and 240 d (dry) postpartum) where they were fed a common forage based diet (60% TDN). For the 60 d postpartum period, a 7 d adaptation period was used to adapt cows to the forage diet and eating from the Growsafe® bunks. Only a single period was used for the lactating period due to there being repeatability in DMI between 60 d, 120 d, and 180 d (Adcock, unpublished data). Barns consist of 5 X 5 m pens with a single GrowSafe® bunk per pen. Eight of these pens were opened and cows were allowed access to 40 X 5 m pens with two 5 X 5 m creep pens so the calves would be able to eat without competition from the cows on each end of the cow pen. Eight GrowSafe® bunks (≤ 3 cows/bunk) allow for little competition between cows to ensure quality intake data results. While not on evaluation, cows were placed on pasture and rotated through mixed pastures of endophyte infected tall fescue (*Festuca arundinacea),* red clover *(Trifolium pretense),* and orchard grass (*Dactylis glomerata)*.

Data Collection

During the evaluation periods, measurements were taken to evaluate the performance of the animals. At the beginning of the period, the weigh-suckle-weigh procedure was performed. Calves were separated from the cows at 1200 on day 0 without access to feed or water, allowed to nurse at 1900 on day 0 to leave only residual milk in the mammary gland and then put back into pens separate from dams (dams were allowed access to feed and water between nursings). At 700 on day 1 calves were weighed (empty weight), allowed to nurse (pairing was done in a large pen and cross-nursing was prevented), and then reweighed and returned to its dam. The difference between the pre- and post-nursing weight was multiplied by two to provide an estimate of 24 h milk production. This was done for the 60 d postpartum period. The 240 d period was a dry period so no weigh-suckle-weigh was done.

Individual intake was measured during each evaluation period by using the GrowSafe® automated feeding system (Model 4000E, GrowSafe Systems Ltd., 86 Airdrie, Alberta, Canada). Intakes were audited daily by trained personnel (10 d of acceptable data needed for each period). Feed intake data was considered acceptable if at least 85% of feed supplied to the bunk and 90% of corresponding feed assigned to an individual ID was accounted for. Data was also considered acceptable if 95% of the data sent from the weigh panel was received at the computer for a 24 h period. Also, 95% of the data from an individual electronic identification tag needed to be received at the computer from the electronic identification panel. A log was kept for repair or replacement of the component parts and data was subsequently discarded that day. The GrowSafe® system has been validated and is a viable method for obtaining individual feed intake (Basarab et al., 2003, Nkrumah et al., 2004, Lancaster et al., 2009).

At the conclusion of each evaluation period, weights were taken on two consecutive days, hip height recorded, BCS taken (1-9 scale), and cows were ultrasounded for 12th rib fat thickness. These ultrasound measurements were taken by trained personnel with an Aloka 500SV (Wallingford, CT) B-110 mode instrument equipped with a 3.5-MHz general purpose transducer array. Backfat was taken in transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline.

Statistical Analysis

Data was analyzed using the CORR procedure of SAS (SAS Inst, Inc. Cary, NC). PROC REG procedure with stepwise selection was used to determine which factors had the biggest influence on intake. Individual animal served as the experimental unit.

Results and Discussion

All correlations are shown in Table 3-1. Data collected on these females as yearlings resulted in heifer RFI and DMI being correlated (P < 0.01, 0.57), but not correlated (P = 0.99) to ADG (0.00). RADG measured as heifers was not correlated (P = 0.88) to DMI (0.01), but was (P < 0.01) to ADG (0.89). RFI and RADG measured as heifers were correlated (P = 0.06, -0.18). For the lactating period, heifer RFI was correlated (P < 0.05) to cow DMI (0.20). At the same time, in the lactating period, heifer RFI was not correlated with any measured phenotypic trait as two-year olds (P > 0.30); BW and MW (-0.08), hip height (-0.02), BCS (-0.03), BF (-0.03) and milk production (-0.09). During the dry period, heifer RFI was correlated (P < 0.05) to cow DMI (0.29). Heifer RFI however was not correlated (P > 0.30) to BW and MW (0.00), hip height (-0.09), BCS (-0.09), and BF (-0.01). DMI for the lactating period had an average of 18.51 kg/d (SEM 4.48 kg) with a range of 9.45 kg/d to 31.72 kg/d. With this range in cow DMI, at a simple cost of $0.10/kg/d, this could result in feed cost differences of $812.86/cow/year. With a reduction in one standard deviation from the mean intake would result in a savings of $512.10/cow/year.

Archer et al. (2002) also showed significant correlations between heifer RFI and cow DMI (0.34). Heifer DMI and cow DMI were also correlated (0.51). They also reported significant correlations between heifer ADG and cow ADG (0.28), but not heifer RFI and cow ADG (0.06). This further shows that RFI measured postweaning can be selected for without having an effect on production traits, just reducing an animals' DMI. This is true not only for the animals as yearlings, but more importantly holds true when these animals are in production within a herd.

When correlating heifer residual average daily gain (RADG) during the lactating period, significant correlations (P > 0.05) between heifer ADG (0.89), cow BW and MW (0.21), hip height (0.25), and BCS (0.21) were observed, Yet not correlated (P > 0.30) to heifer DMI (0.01), cow BF (0.07), milk production (0.03), and DMI (-0.09). During the dry period heifer RADG was correlated (P < 0.05) to cow BW and MW (0.23 and 0.22) as well as hip height (0.31). Heifer RADG was not correlated (P > 0.28) to BCS (0.01), BF (0.03), and DMI (-.10).

DMI for the lactating period had an average of 18.51 kg/d (SEM 4.48 kg) with a range of 9.45 to 31.72 kg/d. This range in cow DMI with a cost of $0.10/kg DM, could result in feed cost differences of $2.22/cow/d. Reducing intake by one standard deviation from the mean would result in a savings of $0.70/cow/d. For the dry period, the average DMI was 19.25 kg/d (SEM 4.04 kg/d) with a range of 12.34 to 34.7 kg/d. At this range in DMI at the same feed costs as in previous period, there would be a savings of $2.24/cow/d. Reducing intake by one standard deviation would result in a savings of $0.76/cow/d.

The prediction equations based on animal measurements are shown in Table 3-2. Animal variables contributing (P < 0.05) to equations predicting cow DMI were heifer RFI, Cow MW, quadratic MW, and BF. Equations predicting DMI for each respective period had R^2 of 0.13. In addition to these prediction equations, the NRC (1996) was used to predict intake. Cow BW, BCS, and milk production (60 d only) was input in order to determine predicted DMI. On a group basis (4 groups), for the 60 d postpartum NRC PDMI and DMI was correlated (0.64) and at 240 d postpartum NRC PDMI and DMI (0.55). However, individual animal basis resulted in non significant correlations at 60 d (0.11) and 240 d postpartum (0.15). While the NRC proves to be effective in predicting group DMI, which is its use, it is not effective in predicting individual animal intake even when all physical factors are accounted for due to large variation that exists in cow intake.

Implications

Residual feed intake done on animals as yearlings is viable for predicting intake when put into production. Unlike RADG, RFI allows for section for increased efficiency without affecting production traits, specifically increasing cow size. While there are concerns with implementing RFI, particularly cost and time, its benefits in terms of savings on feed costs could make up for the added expense.

Literature Cited

Archer, J. A., A. Reverter, R. M. Herd, D. J. Johnston, and P. F. Arthur. 2002. Genetic variation in feed intake and efficiency of mature beef cows and relationships with postweaning measurements. 7th World Congress on Genetics Applied to Livestock Production. Montpellier, France. 31: 221-224.

Archer, J. A., E. C. Richardson, R. M. Herd, and P. F. Arthur. 1999. Potential for selection to improve efficiency of feed use in beef cattle: A review. Aust. J. Agric. Res. 50: 147-161.

Arthur, P.F., J. A. Archer, D. J. Johnston, R. M. Herd, E. C. Richardson, and P. F. Parnell. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency, and other postweaning traits in Angus cattle. J. Anim. Sci. 79: 2805-2811.

Basarab, J. A., M. A. Price, J. L. Aalhus, E. K. Okine, W. M. Snelling, and K. L. Lyle. 2003. Residual feed intake and body composition in young growing cattle. Can. J. Anim. Sci. 83: 189-204.

Consortium. 1988. Guide for the care and use of agriculture animals in agriculture research and teaching. Consortium for developing a guide for the care and use of agriculture animals in agriculture research and teaching, Association Headquarters, Savoy, Il.

Herd, R. M., J. A. Archer, and P. F. Arthur. 2003. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 81(E Suppl.): E9-E 17.

Lancaster, P. A., G. E. Carstens, F. R. B. Ribeiro, L. O. Tedeschi, and D. H. Crews Jr. 2009. Characterization of feed efficiency traits and relationships with feeding behavior and ultrasound carcass traits in growing bulls. J. Anim. Sci. 87: 1528-1539.

Nkrumah, J. D., J. A. Basarab, M. A. Price, E. K. Okine, A. Ammoura, S. Guercio, C. Hansen, C. Li, B. Benkel, and S. S. Moore. 2004. Different measures of energetic efficiency and their relationships with growth, feed intake, ultrasound, and carcass measurements in hybrid cattle. J. Anim. Sci. 82: 2451-2459.

Tables

Table 3-1. Correlations among measured traits (N = 114)[a]

Item	Heifer RADG	Heifer DMI	Heifer ADG	Cow BW 1	Cow MW 1	Hip Ht 1	BCS 1	BF 1	Milk Prod.	DMI 1	Cow BW 4	Cow MW 4	Hip Ht 4	BCS 4	BF 4	DMI 4
Heifer RFI	-.18	.57	.00	-.08	-.08	.02	-.02	-.03	-.09	.20	.00	.00	-.09	-.09	-.01	.29
Heifer RADG		.01	.89	.21	.21	.25	.21	.07	.03	-.09	.23	.22	.31	.01	.03	-.10
Heifer DMI			-.16	-.26	-.26	0.32	-.22	-.37	-.37	.35	-.24	-.24	-.09	.03	.18	.06
Heifer ADG				.39	.39	.18	.32	.30	.17	-.17	.42	.22	.31	.01	.03	-.10
Cow BW 1					.99	.31	.76	.71	.26	-.02	.84	.84	.57	.41	.09	.16
Cow MW 1						.31	.76	.71	.26	-.02	.84	.84	.57	.41	.09	.16
Hip Ht 1							.06	-.07	-.08	.13	.28	.28	.63	.01	-.02	.11
BCS 1								.67	.07	-.09	.64	.64	.27	.36	.12	.09
BF 1									.13	-.22	.55	.55	.23	.32	.20	.05
Milk Prod.										.02	.26	.26	.20	.02	-.19	.28
DMI 1											.01	.01	-.05	.16	.31	.41
Cow BW 4												.99	.59	.49	.24	.20
Cow MW 4													.59	.50	.24	.20
Hip Ht 4														.17	.01	.11
BCS 4															.56	.04
BF 4																.07

[a]For null hypothesis that IRI = 0, $P < 0.10$ if $r > 0.15$; $P < 0.05$ if $r > 0.18$; $P < 0.01$ if $r > 0.23$.

Table 3-2. Equations for predicting cow DMI.

Predicted Variable	Intercept	Heifer RFI	Cow MW	Quadratic MW	BF	R^2	RSD[a]
60 d, lactating	35.19	1.01		0.0004	-2.02	0.13	5.53
240 d, dry	15.79	1.28	0.12			0.13	12.06

[a]Residual standard deviation