DETERMINATION OF ENERGY EFFICIENCY OF BEEF COWS UNDER GRAZING CONDITIONS USING A MECHANISTIC MODEL AND THE EVALUATION OF A SLOW-RELEASE UREA PRODUCT FOR FINISHING BEEF CATTLE

A Dissertation

by

BRANDI MARIE BOURG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2011

Major Subject: Animal Science

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Approved by:

Chair of Committee,	Luis O. Tedeschi
Committee Members,	Tryon Wickersham
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Major Subject: Animal Science

ABSTRACT

Determination of Energy Efficiency of Beef Cows under Grazing Conditions Using a Mechanistic Model and the Evaluation of a Slow-Release Urea Product for Finishing Beef Cattle. (December 2011)

Brandi Marie Bourg, B.S., Louisiana State University;

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The cow/calf phase of production represents a large expense in the production of beef, and efficient beef cows use fewer resources to obtain the same outcome in a sustainable environment. The objective of study 1 was to utilize a mechanistic nutrition model to estimate metabolizable energy requirement (MER) of grazing cows based on changes in cow body weight (BW) and fatness measurements (body condition score, BCS) along with calf age and BW, as well as forage quality and quantity. In addition, an energy efficiency index (EEI), computed as MER of the cow and calf divided by calf weaning BW, was used to rank cows within a herd based on their efficiency of utilizing available forage to meet their maintenance requirements and support calf growth. Data were collected from one herd of approximately 140 Santa Gertrudis cows over a four-year period, and analyzed per calving cycle, conception to weaning. The model's estimation of EEI appears to be moderately heritable and repeatable across years, and efficient cows might have greater peak milk and be leaner.

In typical feedlot diets, the rates of ruminal fermentation of highly processed grains and the hydrolysis rate of urea may not match. Asynchronous utilization of carbohydrate and protein would result in some portion of the urea unknot being utilized by the ruminal microbes and ultimately the animal. The use of slow-release urea (SRU) products offers a unique opportunity to synchronize ruminal fermentation of carbohydrate with non-protein nitrogen (NPN) release rate. Two experiments were conducted to examine the impact of source, urea or SRU, and level of dietary NPN on 1) performance and carcass characteristics and 2) N balance of finishing cattle. Steers had lower initial F:G when SRU was used as the only source of feed N (treatment 3), suggesting that SRU may replace both NPN and true protein feeds in finishing cattle diets. High levels of either NPN source had greater N intake and urinary N excretion, as well as N absorption and no major differences were observed between SRU and urea, suggesting that SRU can replace urea at different levels of N intake.

DEDICATION

This dissertation is dedicated to my parents, Judy and Donald Bourg, your support made this possible, and to my wonderful family and friends who helped me through all these years, and of course, to my fiancé, Matt Karisch, I couldn't have done it without you.

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I would like to thank my committee chair, Dr. Luis Tedeschi, and my committee members, Dr. Tryon Wickersham, Dr. Gordon Carstens, and Dr. Andy Herring, for their guidance and support throughout the course of this research.

Thanks also go to my friends and fellow graduate students and the department faculty and staff for making my time at Texas A&M University a great experience. Especially, thanks go out to Robynne Gomez, Wimberley Kreuger, Flavio Ribeiro, Andre Aguiar, Joel Walter, Aimee Hafla, Trey Dittmar, Phillip Lancaster, Lisa Slay, Candice Moore and the many other graduate students, student workers, and staff who helped in collecting and running all of my samples.

Finally, thanks to my mother and father for their encouragement and support and to my fiancé for his patience and love.

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CHAPTER I

INTRODUCTION

With cost of livestock production increasing each year, producers are continually searching for a cheaper, more efficient way to produce their product. By increasing the efficiency of production, they can increase profitability. The cow/calf phase of production represents a large portion of the expense involved in beef production. Feed energy consumption during the cow/calf component of the production cycle represents as much as 65% of the metabolizable energy (**ME**) consumed from conception to harvest (Ferrell and Jenkins, 1982).

In their discussion of matching cow type and milking ability to available land and forage, Fox et al. (2004a) stated that the identification of the most efficient cow type for a particular farm requires finding the best match of ME requirements with feed energy available. It is very important to realize that a particular cow that is efficient under one production situation may not be the same under all conditions. There are many factors, such as milk production, temperament, maintenance requirements, or tissue accretion, which may affect why some cows are more efficient at converting available forage resources to pounds of calf weaned. Therefore, it is important to identify cows that are more efficient in converting available forage resources into more pounds of weaned calf,

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This dissertation follows the style of Journal of Animal Science.

while still maintaining adequate condition to ensure rebreeding. Efficient beef cows use fewer resources to produce the same outcome in a sustainable environment, according to Tedeschi et al. (2004). Therefore, new techniques for identifying these efficient beef cows need to be evaluated.

Approximately 11.5 million head of cattle were on feed in the U.S. on January 1, 2011 (USDA-NASS 2011). Typically, these cattle are fed diets that range from 12.5 to 14.4% CP with 0.5 to 1.5% urea (Galyean, 1996). The majority of feedlot nutritionists consulted by Vasconcelos and Galyean (2007) indicated that steam-flaked corn was the primary grain fed. In feedlot rations, grain processing is typically used to increase the availability of starch, and results in a faster rate of starch degradation. In typical feedlot diets, the rates of ruminal fermentation of these highly processed grains and hydrolysis rate of urea may not match. This asynchronous fermentation would result in some portion of the urea would not be utilized by the animal. Taylor-Edwards et al. (2009a) found that steers fed urea had increased ruminal ammonia concentration 58% over that observed when a slow-release urea (**SRU**) product was fed. Use of SRU products offers a unique opportunity to synchronize ruminal fermentation of carbohydrate with NPN release rate. Previously, SRU products, such as biuret (Hatfield et al., 1959; Oltjen et al., 1968; Fonnesbeck et al., 1975), starea (Thompson et al., 1972), urea phosphate (Oltjen et al., 1968), or coated urea (Owens, et al. 1980) were shown to be ineffective, either releasing NPN too slowly to be utilized efficiently, or too quickly so as not to provide a beneficial effect over feeding urea. Optigen® II is a blended urea product designed to release N at a slower rate. When compared to a true protein source such as soybean

meal, Optigen® II has a CP value of 256% compared to 53% for soybean meal (Tikofsky and Harrison 2007). Therefore, a thorough evaluation on what effects this SRU may have on feedlot performance and ultimately carcass characteristics, as well as the metabolic effects of SRU.

CHAPTER II

LITERATURE REVIEW

COW ENERGY EFFICIENCY

Much of the recent research in beef cattle production has been directed toward improving the efficiency of our systems. Advancements have been made due to increases in reproductive efficiency, nutritional concepts, and genetic selection. While much of this research has been directed toward improving the efficiency of finishing systems, the efficiency of the cow-calf enterprise is often neglected. However, beef cows are responsible for 60 to 70% of the total of energy expenditure used to produce beef (Johnson, 1984); at least 50% of this energy is expended to maintain the cow. Ferrell and Jenkins (1985) found that regardless of cow type approximately 73% of ME consumed by a mature cow is used for maintenance. McGrann (1999), according to standardized performance analysis (**SPA**) data (1991-1999), found that feed costs represented about 42% of total annual cow costs. Large portions, approximately 70%, of feed expenses are directed toward cow maintenance (Ferrell, 1988). Therefore, reducing cow maintenance requirement may be an effective way to improve cow-herd efficiency by allowing more of consumed energy to be directed toward other sources, such as lactation, or fat storage, and may also be an effective way to improve profitability. Jenkins and Ferrell (2002) revisited the idea of beef cow efficiency, and concluded that for an evaluation of biological efficiency, productivity must be expressed relative to some unit of input. The authors also concluded that an efficient cow for one producer in a certain environment is

likely to be inefficient under a different management program. This stresses the importance of considering beef cow energy efficiency relative to environment.

Jenkins and Ferrell (1994) described biological efficiency of a cow-calf herd as the ability of the cow to convert feed resources to calf weight at weaning. In their study, the productivity of nine diverse breeds was evaluated under various intake levels. Jenkins and Ferrell (1994) noted that in more nutritionally restrictive situations, or environments, breed crosses with a lower genetic potential for growth and lactation ranked higher for pregnancy rate, calf weaning weight, and calf weaning weight per cow exposed, than under less restrictive situations. Most of the rank changes noted concerned reproductive traits. Cow feed consumption was the primary factor that affected biological production efficiency through the weaning phase, primarily by influencing reproductive status and productivity. The authors noted that it is important for life-cycle production efficiency of a breed or cross should be evaluated under actual production conditions. Selection for reduced feed intake, and accordingly energy consumption, could a major manipulator tool in improving efficiency of cowherds, and it is important that these factors are analyzed under actual production conditions.

In their attempt to characterize efficient and inefficient beef cows, DiCostanzo et al. (1991), collected performance and individual intake data from Angus cows fed through 2 consecutive periods, at maintenance and ad libitum intake levels. Average daily gain (**ADG**) was used to sort cows into one of three efficiency categories, average, efficient or inefficient, based on the difference between actual ADG and ADG predicted based on BW and DMI. A negative correlation was noted between ADG and ME_m

during the maintenance period, such that those cows with lower ME_m (metabolizable energy requirements for maintenance) requirements gained more weight relative to predicted gain. This suggests that during periods where intake is limited, i.e. drought or winter, those more efficient individuals would be more able to maintain their weight, and/or condition perhaps due to lower ME_m. During the ad libitum period, although cows of all three efficiency types retained similar amounts of energy, inefficient cows had higher DM and ME intakes. Therefore, during periods where forage intake is not limiting, more efficient cows will be able to deposit more energy stores on the same amount of forage intake than those cows who are less efficient. DiCostanzo et al. (1991) also noted that inefficient cows exhibited a more complete digestion of feedstuffs than efficient cows, and suggested that inefficient cows may need to utilize their feed more efficiently to meet their higher energy costs associated with maintenance. Inefficient cows tended to have less fat and a higher rate of protein accretion than average or efficient cows in this particular study, which may partially explain their higher ME requirements for maintenance, as it is more energetically efficient to deposit fat than protein. In their discussion of energy efficiency of conversion to the various products, Johnson et al. (2003) indicated that lipid is the most energetically efficient tissue, followed by milk, protein, and fetal tissue. The results from this study, therefore, suggest that there are indeed between animal differences in the use of available energy, and which may provide opportunities to select for more efficient cows, or against inefficient cows.

In a review of work done on beef cattle energy efficiency, Johnson et al. (2003) noted that fattening steers retain only 16-18% of energy that they consume, with the largest lost associated with maintenance function, and that the maintenance component comprises approximately 73% of ME requirements. Therefore, an ability to select for a reduction in maintenance requirements would lead to more energy retained, and therefore may help to improve the efficiency of energy use. The authors state that the term efficiency requires a numerator and denominator along with units of each. These energy ratios should embody three components according to Johnson et al. (2003): diet energy cost of maintaining the animal per unit of time, diet energy cost per unit of product, and rate of product per unit of time. It is important that any term we use to define the efficiency of a cow/calf production system contain these components.

Johnson et al. (2003) noted that in spite of selection pressures, maintenance requirements of cattle appear to have remained relatively unchanged over the past hundred years. In support of this observation, Johnson et al. (2003) noted that for cattle fed grains and oil meals, Kellner's (1909) estimation of 116 kcal/kg$^{0.75}$ of BW is very similar to the NRC (1996) estimation of 112 kcal/kg$^{0.75}$ of BW. This suggests that there has been limited progress over the years in selecting for cattle with improved feed efficiency or lower maintenance requirements, even though we have only become more concerned with these selections in more recent years.

According to Randel (1990), the effects of inadequate prepartum nutrition on postpartum reproductive performance has long been recognized. Cows that are undernourished post-partum will experience a longer period from calving to first estrus

and subsequent re-breeding. Females that lose weight and body fat, or condition, at the time of calving will return to estrus later in the breeding season. This will decrease the number of females that conceive early in the breeding season, and overall conception rates. The number of cows bred at first service is also lowered with decreased nutrient intake. Although it is not known whether this is due to a decrease in ovulation or hormonal function, its effect remains the same, a decrease in the number of bred cows at the end of the breeding season.

Body condition scoring (**BCS**) is an indicator of the energy status of a cow. Although it is subjective in nature, and may be imprecise, it is a functional and widely used method of determining the energy status of a cow (Randel 1990). Body condition scoring offers a way to measure of the relative fatness of an animal, and if done consistently by the same person it is a good way to rank individuals within the herd and determine which females are most in need of additional energy. Adipose tissue is energy dense and not deposited by a cow until excess energy is available. Accordingly, measures, even imprecise measures, of adiposity are a good way assess the nutritional status of a cow herd. The percentage of open cows, calving interval, and calf vigor at birth are all closely related to the body condition at calving and during the breeding season (Randel 1990). Therefore, body condition scoring is a useful management tool in estimating energy retained by the cowherd, and may be useful in assessing difference in efficiency of energy retention.

A limitation to the use of models to predict nutrient requirements is the difficulty of accurately estimating milk production, which has a large effect on total ME requirements. Fox et al. (2004a) described a system where calf WW was used to predict milk production, and integrated into a model developed by Fox et al. (1988). The CNCPS model was utilized to determine expected calf weights at different levels of mature size and milk production. In a study conducted to evaluate these predictions, Fox et al. (2004a) noted that results were consistent with expectations that as milk level increased, calf WW increased. Figure 2.1., adapted from Fox et al. (2004a), illustrates the effect of month of lactation on ME requirements of beef cows. It is noted that total ME requirements are highest during the months of peak lactation. Therefore, it is important to account for milk production when attempting to quantify between animal variation in energy efficiency for beef cows.

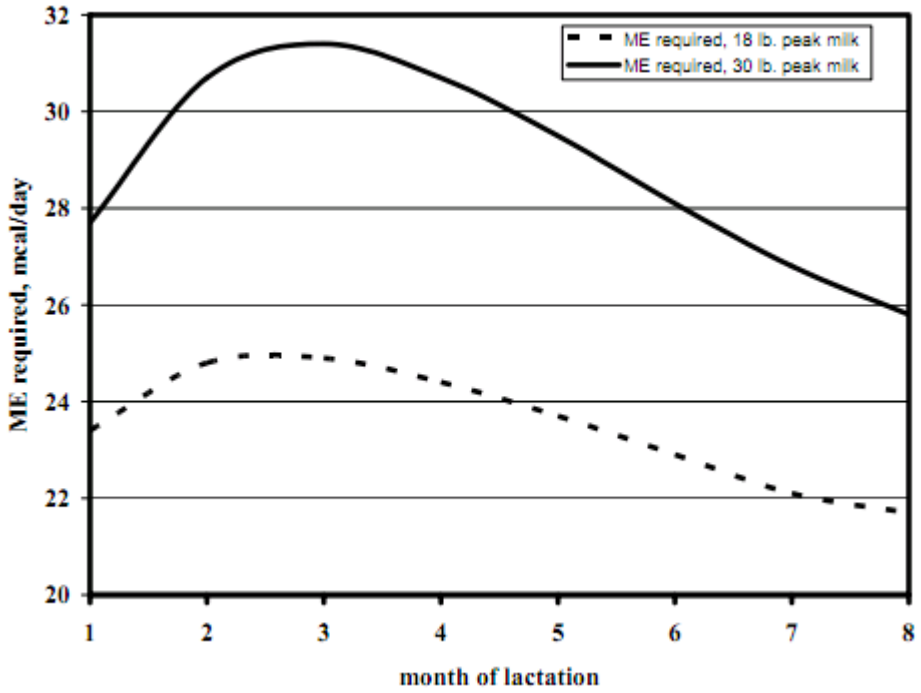

Figure 2.1. Effect of month of lactation on the ME requirements of beef cows, adapted from Fox et al. (2004a)

Tedeschi and Fox (2009) described a theoretical model to predict forage intake of nursing calves based on cow peak milk level. Varying levels of reconstituted milk were provided to Holstein steer calves from birth to weaning to mimic a typical lactation curve, and chopped alfalfa hay was fed to determine maximum voluntary forage intake. The authors found that forage DMI of the calf was impacted by both calf body weight (**BW**) and forage quality, and during the first 60 d milk intake was prioritized over forage intake. A sensitivity analysis using a Monte Carlo simulation indicated that calf forage DMI is likely less than 4.26 kg/d 95% of the time. An evaluation of the model indicated that it was able to predict growth of calves when forage intake was unknown,

which suggests that this model may be a useful tool in accounting for forage intake of calves to predict efficiency of the cow-calf system.

Fox et al. (1988) described a model to adjust maintenance requirements of beef cattle for varying combinations of temperature, wind, hide, hair coat, activity, and previous plane of nutrition. The authors describe a model that expands upon the National Research Council (**NRC**) requirements for beef cows to take into account six rather than two lactation curves. This model also calculates lactation requirements for nine mature cow sizes. In addition, the model attempted to more accurately allocate forage to cow-calf units to determine more accurate metabolizable energy (**ME**) requirements the cow-calf units. The authors found a wide range for ME requirements of cow-calf units that ranged from equal to the NRC during early lactation to 70% higher towards the end of lactation. As most of the variation in weaning weight (**WW**) can be attributed to milk production, frame size, and forage intake, the model offers an opportunity to more accurately predict WW and cow ME requirements, both of which are essential to predicting cow energy efficiency.

Reynoso-Campos et al. (2004) described a dynamic application of the Cornell Net Carbohydrate and Protein System (**CNCPS**) designed to predict the balance of animal nutrient requirements and performance with forage available on a daily basis. The model accounts for interactions between mobilization and repletion of tissue reserves and feed values. The CNCPS was modified to compute BW and body reserves changes based on a predicted peak milk, feed intake, and energy balance. The model was evaluated based on a typical grazing scenario for the Gulf Coast of Mexico for mature

Holstein × Brahman cows. Evaluation of the model indicated that its prediction of milk production, DMI, and changes in body weight and tissue reserves were consistent with previous findings and field observations. Findings indicated that during early lactation tissue reserves supplement intake to support milk production. This model appears to be a useful tool for farm or region-specific monitoring of changes in energy and protein balances over a calving interval, and may be a useful tool for predicting cow energy efficiency.

Tedeschi et al. (2004) described the development of a beef cow model for use in the Cattle Value Discovery System (**CVDSbc**). The model uses readily available inputs from production situations to make an estimation of an energy efficiency index (**EEI**) for each cow in a herd. This index is the ratio of cow metabolizable energy to calf weaning weight (Mcal/kg).

Tedeschi et al. (2006) described more extensively the development and evaluation of the above mentioned model. This model is based on the models described by Fox et al. (1988) and Reynoso-Campos et al. (2004), with some modifications. The structure of the model is described in Figure 2.2. The model was designed to estimate daily energy requirements of the cow with interactions between lactation and calf WW. Briefly, maintenance requirements are adjusted for conceptus weight, environment, physical activity, and physiological status, as recommended by the NRC (2000). Pregnancy and lactation requirements are also predicted using NRC (2000) recommendations. Milk production is computed through iteration, by changing peak milk until predicted WW matches the observed calf WW. Equations to estimate forage

and milk intake of the calf was based on data from Abdelsamei (1989). The effects of changing body condition score (**BCS**) was used to represent tissue mobilization and repletion. This effect was used to estimate energy availability from body reserves, similar to that described by Reynoso-Campos et al. (2004).

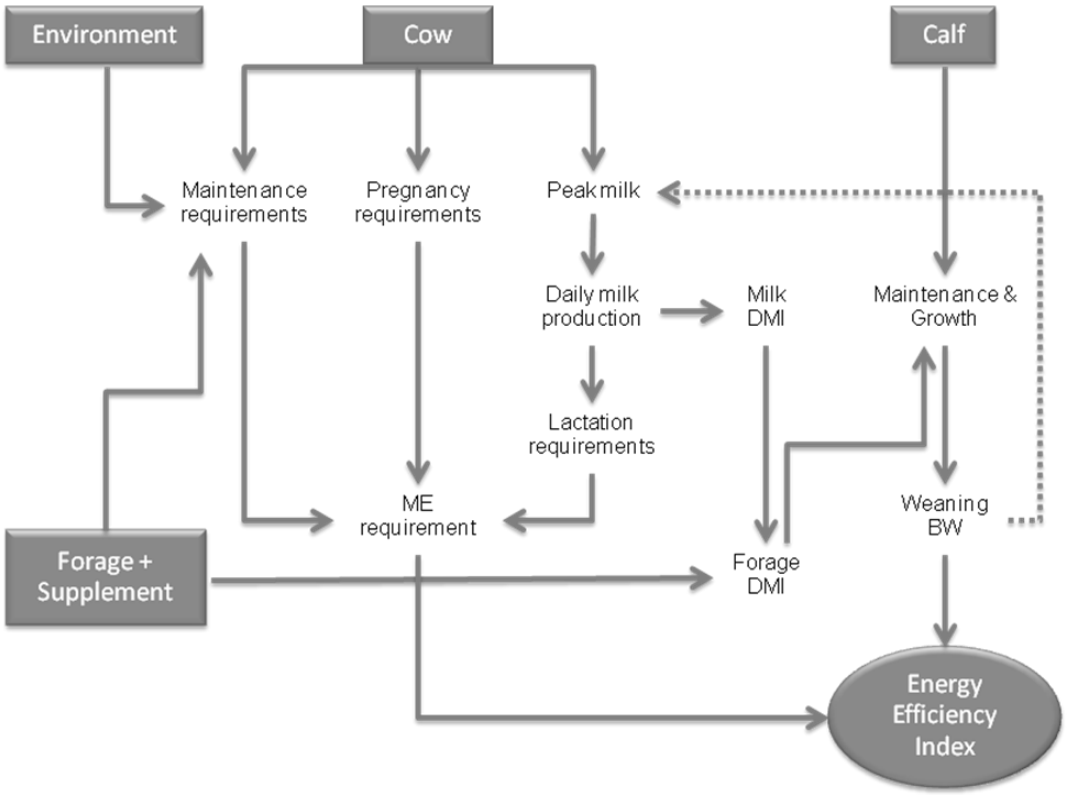

Figure 2.2. Flowchart of the mathematical model to predict energy efficiency index (EEI), adapted from Tedeschi et al. (2004)

In a preliminary analysis of the model's practical applications (Tedeschi et al. 2006), a database was collected from Bell Ranch, NM (N = 182). This database was used to evaluate the model's ability to rank cows from most to least efficient based on EEI. Results indicated that the model ranking of cows was able to identify those females that had been culled, and those which had been judged efficient based on observations from the ranch's management team. This evaluation shows that the model appears to be accurate in ranking cows within a herd based on their ME requirements in ratio to calf WW.

Individual cow temperament may also play a factor in affecting differences in cow productivity and efficiency. Voissinet (1997) found that steers with more excitable temperaments had decreased ADG in comparison with cattle with more docile temperaments based on subjective evaluations of the cattle. More objective measures of temperament have been proposed. Burrow et al. (1988) developed a technique known as exit velocity (**EV**) that measures the amount of time required for an animal to travel a fixed distance while exiting a confined area. Burrow (2001) reported that EV was moderately heritable. A combination of subjective and objective temperament measures may prove useful in identifying differences in energy efficiency among cow-calf units.

Johnson et al. (2003) stated that past research involving energy efficiency has focused on comparisons of groups or genotypes, and those factors that determine their dietary energy requirements. They suggest that future research focus on methods to assess between animal variation in energy efficiency, and variations among the maintenance requirements of mature beef cows. The model described by Tedeschi et al.

(2004) offers an alternative solution to predicting energy efficiency of beef cows as a ratio of inputs to outputs, with minimal input data requirements. However, it is important to evaluate the accuracy of the model's prediction with varying breed types, environments, and forage availability. It is also important to evaluate the relationships between selection of cows with improved EEI may have on other economically relevant traits, such as fatness, temperament, and calf performance, as well as its relationships with genetic information (EPD) of the cows and calves.

SLOW-RELEASE UREA IN BEEF CATTLE DIETS

Ruminant animals are unique among livestock species due to the extensive development of the forestomach, and a capacity for extensive fermentation of feedstuffs. This extensive fermentation alters the quantity and quality of proteins that reach the small intestine and are utilized by the animal, such that when animals are fed diets low in protein quality, the microbial population of the rumen is able to convert this diet to a high quality source of microbial protein (**MCP**) made available for absorption by the animal in the small intestine. Microbes hydrolyze dietary non-protein nitrogen (**NPN**) sources via urease to produce ammonia, which can serve as a source of that can be assimilated into MCP. To perform this task, the microbial population of the rumen requires both a source of energy and of N to produce high quality MCP that can be made available to the animal. Therefore, the amount and degradability of dietary carbohydrate, that provides the main source of energy for the animal, can have a major impact on ammonia absorption. In addition, in situations where dietary protein supply is limited,

the recycling of ammonia back to the gastrointestinal tract serves to provide a buffering effect to supply N for assimilation of MCP (Reynolds and Kristensen, 2008**)**.

As of January 2011, approximately 11.5 million head of cattle are on feed in the U. S. (USDA-NASS, 2011). Typically, these cattle are fed diets that range from 12.5 to 14.4% CP with 0.5 to 1.5% urea (Galyean, 1996). The majority of feedlot nutritionists consulted by Vasconcelos and Galyean (2007) indicated that steam-flaked corn was the primary grain fed. In feedlot rations, grain processing is typically used to increase the availability of starch, and results in starch being available for more rapid ruminal degradation. Taylor-Edwards et al. (2009a) found that feeding urea increased ruminal ammonia concentration 58% over that found when a slow-release urea product was fed on a N equivalent basis. Therefore, in typical feedlot diets, the rates of ruminal fermentation of these highly processed grains and hydrolysis rate of urea do not match. This asynchronous fermentation would mean that some of the urea fed would be unavailable for use by the animal. Slow-release urea products offer a unique opportunity to synchronize ruminal fermentation of carbohydrate with NPN release rate.

Factors Affecting Nitrogen Metabolism in the Rumen

Ammonia is produced in the rumen from the degradation of natural protein in the diet and from the degradation of NPN sources such as urea, which are typically fed in ruminant diets. Of this ammonia, a portion is used for the synthesis of MCP, while the rest is absorbed into the portal vein and transported to the liver. From this point, the liver will convert this ammonia into urea or use it to synthesize Gln from Glu (Reynolds and Kristensen 2008). Depending on diet type, MCP synthesis can provide 50 to 80% of the

protein absorbed in the small intestine of ruminants (Bach et al, 2005), which indicates the importance of MCP in meeting the protein requirements of the ruminant animal. Thus, it is important to consider the balance of dietary amino acids that escape ruminal fermentation, and how these complement the amino acids provided by the microbial protein (Clark et al, 1992).

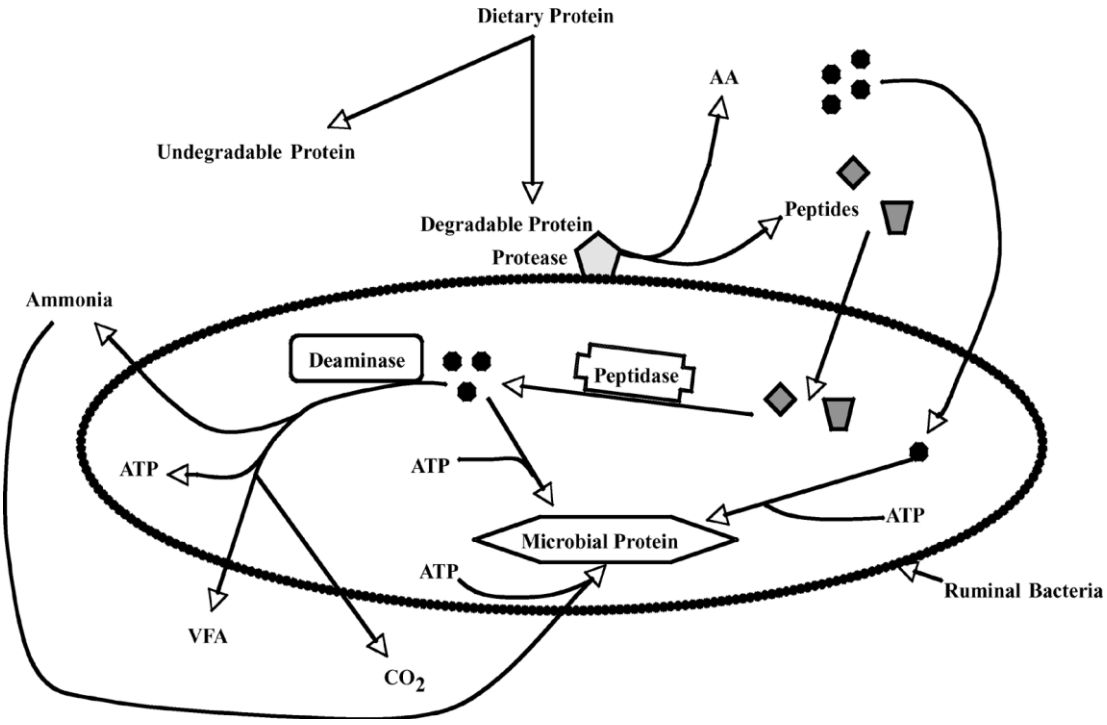

Figure 2.3. Schematic representation of protein degradation and fate of end products in the rumen, adapted from Bach et al. (2005)

Figure 2.3 illustrates a schematic representation of protein degradation in the rumen and the fate of end products, as adapted from Bach et al. (2005). Initially, protein

degradation in the rumen begins with the attachment of ruminal bacteria to undigested feed particles. Of the microbes present in the rumen, approximately 70 to 80% will attach to the feed particles and of those approximately 30 to 50% have some proteolytic activity (Bach et al, 2005). As a single protein contains many different bonds, the bacteria act symbiotically to degrade the protein to peptide and amino acids through the action of many different proteases. These peptides are then taken up by the microbial cells, where they can be further degraded into amino acids, which are either incorporated into MCP or deaminated to produce volatile fatty acids (**VFA**), CO_2, and NH_3. This process is dependent upon the energy available in the rumen, and when energy is limiting, the carbon skeleton of these amino acids will be fermented to VFA to provide a source of energy to the animal.

In understanding review of N metabolism in the rumen, Bach et al. (2005) discussed the major factors that affect protein degradation by microbes in the rumen. These factors include the type and solubility of protein in the ration, interactions with other nutrients, typically carbohydrate, and the microbial and the diversity of the population in the rumen, which is influenced by ration type, passage rate, and pH. Not only does the solubility of proteins increase protein degradability in the rumen, but structure also has a major impact as well. It has been indicated that while some proteins such as albumin may be soluble, they contain disulfide bonds or bonds within and between protein chains that slow their degradation rate in the rumen. When passage rate from the rumen is increased, protein degradation will in turn decrease, as rumen microbes have less time to degrade protein from feed particles in the rumen. An increase

in the proportion of concentrate in a ration will lead to a decrease in the pH of the rumen below the optimum range, which is between 5.5 and 7.0, for the proteolytic enzymes present in the rumen. However, the authors noted that even at the lower end of this range, protein degradation was reduced. However, it was also noted that regardless of pH, protein degradation was lower when high concentrate rations were the available substrate for microbial fermentation. Cattle fed a concentrate as compared to a forage ration had lower ammonia N concentrations irrelevant of pH level. As rations are changed from predominantly forage to predominantly concentrate ration, the microbial population of the rumen will be altered, such that different species predominate in the rumen based on substrate type. The authors hypothesize that the effects of pH, bacterial population, and substrate may interact to cause a decrease in protein degradation under certain conditions. Indeed, a decrease in pH could cause a reduction in cellulolytic bacteria, which would cause a reduction in fiber degradation, and a reduction in access of proteolytic bacteria to the protein in feed.

Reynolds and Kristensen (2008) reviewed N recycling in the ruminant, as well as the N economy of ruminants. The recycling of N back to the rumen is effected by many factors. Dietary factors affecting NH_3 absorption include not only the amount but also the degradability of N sources, with N sources coming from the diet as well as from endogenous sources. In addition, the authors indicate that the amount and degradability of carbohydrate in the diet can also affect NH_3 absorption, as the use of NH_3 for microbial protein synthesis is highly dependent on energy availability. Therefore, in situations where energy may be limiting, the ability of microbes to use recycled urea

may be diminished. However, in situations where dietary protein is limiting, the efficiency of utilization of recycled N by rumen microbes for protein synthesis is expected to be increased, and indeed would be an important source of N when dietary sources are below critical points.

In a review of N recycling in the ruminant, Lapierre and Lobley (2001) acknowledged that the N recycling system can account for more than double N intake by the ruminant animal, and thus can have a major impact on the N metabolism. The authors described the two main techniques that are commonly used to measure in vivo synthesis and urea cycling in the ruminant. Early work to estimate urea entry rate into the gut involved the infusion of [^{15}N] urea and subsequent measurement of urinary urea elimination, with the difference between these two rates being assumed entry into the digestive tract. When a joint infusion of [^{14}C] urea is included with the above technique, the amount of urea-N that entered the digestive tract, and was then recycled back to the liver urea cycle can also be calculated as the difference between the loss rates of [^{15}N] urea and [^{14}C] urea. The second method was adapted from a technique used to monitor urea-N kinetics in humans, and is illustrated in Figure 2.4. With this technique, [^{15}N^{15}N] urea is infused, and isotope analysis of the three species [^{15}N^{15}N] urea, [^{14}N^{15}N] urea, and [^{14}N^{14}N] urea that are formed in the body and eliminated in the urine can be quantified. The supplied dose of labeled urea, [^{15}N] urea in the feces, and the amount and isotope distribution of the labeled urea species in the urine are needed to calculate urea entry rate, gut entry rate, urea returned to the urea cycle, and urea used for anabolic

purposes. These techniques can provide important information of the recycling of urea in the ruminant across various diets.

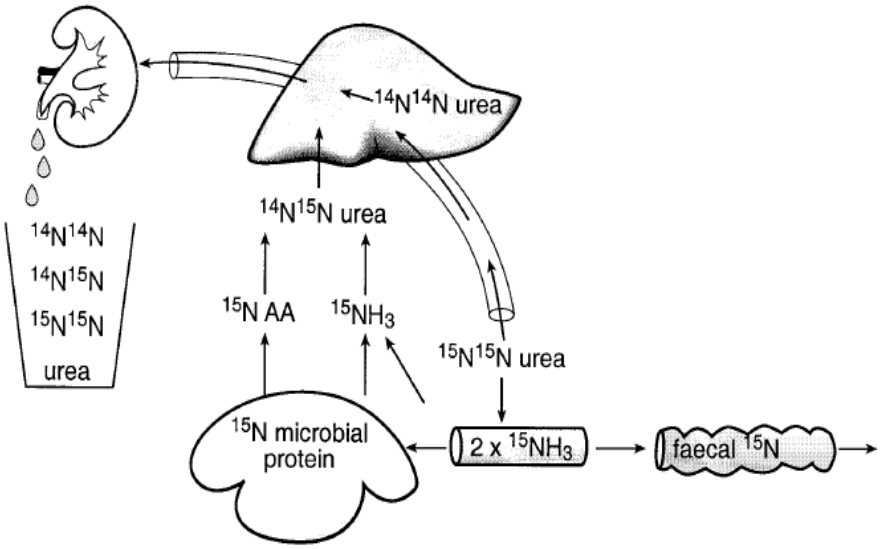

Figure 2.4. Use of [NN] urea and isotopomer analysis of urinary [NN], [NN] and [NN] urea to quantify fates of urea that enters the digestive tract, adapted from Lapirere and Lobley (2001)

Waterlow (1999) reviewed current knowledge and knowledge gaps involved with N balance in animals. Since the major variable affecting N output in the feces is urea, the author concluded that the regulation of urea production was key to understanding N balance. The main function of the urea cycle in the whole animal serves to preserve N homeostasis, and that changes in dietary protein will result in increased amounts of all of the urea cycle enzymes. The importance of this point is illustrated when considering the recycling of urea back to the gut in the ruminant. Excess NH_3 from NPN breakdown in

the rumen may be lost before it can be incorporated into MCP, and this increase in urea cycle enzymes with increased protein intake may allow for increased recycling of urea back to the rumen.

Use of Slow-Release Urea Sources in Ruminant Diets

Hatfield et al (1959) proposed that the ideal NPN compound for ruminants would not only be non-toxic, but would also release N at a gradual rate that would support rumen microbial activity at a continuous rate, even with feed levels and N intake may vary. Oltjen (1968) evaluated the effects on performance when NPN provided the only or primary source of N to ruminants. When NPN was the only N source, gains were reported to be decreased as compared to diets containing isolated soy protein as the N source. Interestingly, it was reported that when NPN was provided in a purified diet as the only N source, ruminants had decreased amounts of branched chain VFA, and plasma concentrations of essential amino acids were decreased. Therefore, it became evident by some of this early work that a source of true protein must also be provided to the animal, and a consideration of the release rate of NH3 was important.

Biuret was a slow-release urea compound that is synthesized either de novo though the combination of ammonium carbamate under high temperature and pressure, or through the controlled urea pyrolysis (Fonnesbeck, et al, 1975). Early work examining the use of biuret as possible NPN compound first examined the impact on toxicity and N utilization when biuret was fed to sheep and cattle (Oltjen, 1968). The results indicated that it was not cumulatively or acutely toxic, and did not have a

negative impact on growth. The decreased solubility of biuret may cause it to release N at a slower rate than urea, and alleviate some of the problems associated with the rapid release of NH_3 from urea in the rumen. The authors emphasize the importance of maintaining a readily available source of energy in diets containing NPN sources, to encourage a more efficient MCP production.

In a comparison of urea, biuret, urea phosphate and uric acid as possible NPN sources for cattle, Oltjen et al. (1968) examined changes in ruminal NH_3 levels to assess degradation rates of each compound. As expected from previous research, both urea and urea phosphate were rapidly degraded in the rumen, indicated by the rapid rise of NH_3 in the rumen after feeding, with pre-feeding NH_3 levels returning approximately 6 h after the diets were placed into the rumen. Conversely, biuret and uric acid were slowly degraded to NH_3, and following a 2 h period NH_3 concentration increased for steers fed uric acid. This peak in NH_3 was never noted in the biuret fed steers. This indicates that both compounds have decreased solubility in the rumen as compared to urea, and biuret in this case was essentially undegraded by rumen microbes. These results may indicate that the solubility of biuret may be too low to provide an adequate NH_3 supply for rumen microbes to synthesize MCP.

Starea is produced from cooking a grain urea mixture at high temperatures, and was an attempt to reduce the solubility and increase the acceptance of urea in grain diets (Thompson et al, 1972). In a feeding trial comparing urea and starea as NPN supplements, starea-containing rations showed increased palatability, and greater feed consumption. Analysis of NH_3 levels in steers fed starea as compared to urea showed a

decrease in NH_3 release and a more rapid decline in rumen NH_3 levels as compared to steers fed urea. This decline in NH_3 production indicates that feeding of Starea may alleviate some of the symptoms of toxicity associated with steers fed rations high in urea due to a decrease in solubility.

Providing an adequate supply of dietary energy to support MCP formation from NPN is of particular importance in lactating dairy cow rations. Golombeski et al. (2006) evaluated interactions between a slow-release urea, calcium chloride bound urea, and the addition of highly fermentable sugars from a blend of liquid co-products. A 6 × 6 Latin square design utilizing 12 lactating Brown Swiss cows, with a 2 × 2 factorial arrangement of treatments that included no supplemental fermentable sugar, supplemental fermentable sugar at 8.64% of the ration, no slow-release urea, or 0.61% addition of slow-release urea. The authors did not observe an interaction between fermentable sugar and slow-release urea inclusion. It was noted, however, that when slow-release urea replaced soybean meal, DMI were decreased, which led to a subsequent increase in feed efficiency, determined as kg of energy corrected milk per kg of DMI. In examining the rate of NH_3, no difference was noted between diets containing slow-release urea and with no slow-release urea, which implies that this product did deliver desirable slow-release characteristics. These results indicated that this slow-release urea product could offer a viable way to decrease diet costs from substitution of NPN for true protein feedstuffs such as soybean meal without having a negative impact on milk production in lactating dairy cows.

There have been several recent studies examining the effect of inclusion of a slow-release urea product into diets of growing and finishing beef cattle. One study compared urea, with a slow-release urea product (Optigen® 1200) in finishing rations, with NPN supplementation designed to meet varying levels of a deficiency in ruminal N supply (Tedeschi et al, 2002). Steers were fed in two phases for each of two experiments, a growing phase with diets containing more fiber, and a finishing phase with diets containing more concentrate. In this study, the authors did not sample rumen fluid to determine NH_3 levels to determine if the polymer coated slow-release urea product did in fact supply a more stable release rate of NH_3 as compared to urea. Results of the two trials did not indicate an improvement in performance when the slow-release urea product was fed, and indicated that this observation may have been due to recycling of N to the rumen. It was proposed that N recycling may maintain a steady supply of N in the rumen in conditions were N was not deficient, which would alter the expected effect of slow-release urea on rumen N supply. However, the authors did not measure urea kinetics in this experiment, and the use of isotopic tracers to examine this effect may serve to substantiate these findings.

A corn silage based diet was used recently to evaluate the effects of a polymer coated slow-release urea product on the performance and ruminal digesta characteristics of growing beef steers (Taylor-Edwards et al, 2009a). The authors' intention was to provide a release rate of urea that would parallel carbohydrate digestion in the rumen. Ruminally cannulated steers were used to observe changes in ruminal digesta characteristics, while 180 steers were used to observe differences in animal performance

at varying levels of either urea or slow-release urea inclusion. Ruminal NH_3 concentrations were decreased when slow-release urea was fed as compared to urea, while ruminal urease activity was increased. These results suggested that the product was effective in providing a slower rate of release than urea, while ruminal VFA production was not affected. For the performance trial, the authors indicated that there may have been a protein deficiency at low levels of NPN inclusion, which could have caused a decline in DMI. It is possible that in the situation where N was deficient, N recycling to the rumen may have served to meet the N deficiency initially, but over time, caused a decrease in the pool of urea able to be recycled back to the rumen. This N deficiency also may have led to decreased gains over the feeding period. The ruminal digesta trial suggested that the microbial population of the rumen did not adapt to the slow-release product over time, which would indicate that when diets supplied adequate N, this product could maintain its slow release of urea. These results suggested that when N supply in the rumen was adequate to meet microbial needs this slow release product provided similar performance to urea in corn silage based diets.

Summary

The ruminant animal has the unique ability to utilize non-protein sources of nitrogen to meet its protein needs due to the capacity of ruminal microorganisms to convert these sources into high quality microbial protein. Indeed, these microbes also have the capacity to utilize urea produced by the hepatic urea cycle to assemble MCP when N consumption by the animal may be deficient. This recycling of urea back to the rumen via saliva or through passive diffusion through the rumen wall plays an important

role in meeting the N requirements of rumen microflora when dietary protein is deficient.

Numerous studies have demonstrated that urea can successfully provide supplemental N to provide adequate gains and efficiency at a reduced cost. However, urea rapidly releases NH_3 into the rumen fluid, and if consumed in large quantities can prove toxic (Bartley et al, 1976). Therefore, it has been proposed that a more ideal NPN supplement would release NH_3 at a slower rate to provide a more steady supply of N for rumen microbes to more adequately match the rate of energy supply in the rumen. There have been numerous attempts to develop and examine the effects of SRU products that released NH_3 at a slower rate than urea, as it was proposed that this might provide for a more efficient use of N by the animal. However, many of these studies have been unsuccessful. Some products released NH_3 too slowly, while others did not provide the difference in release rate from urea as was expected. It has been proposed by several researchers that when N supply may be limiting, the N recycling system of the ruminant may mitigate the response expected from the feeding of slow-release products as the supply of ruminal N is maintained through this recycling process. However, none of the studies that proposed this concept examined the rate or extent of urea recycling when these diets were fed. Therefore, there is potential for further manipulation of these products to more closely match carbohydrate fermentation and maximize the efficiency of N use through a coordination of these two processes.

CHAPTER III

USING A MECHANISTIC NUTRITION MODEL TO IDENTIFY EFFICIENT BEEF COWS UNDER GRAZING CONDITIONS

OBJECTIVES

The objectives of this study were to utilize a mechanistic nutrition model to estimate metabolizable energy requirement (**MER**) of grazing cows based on changes in cow body weight (**BW**) and fatness measurements (body condition score, **BCS**) along with calf age and BW, as well as forage quality and quantity. In addition, energy efficiency index (**EEI**), which is computed as MER of the cow and calf divided by calf weaning BW, was used to rank cows within a herd based on their efficiency of utilizing available forage to meet their maintenance requirements and support calf growth.

MATERIALS AND METHODS

Animals and Management

One herd of approximately 140 spring-calving purebred Santa Gertrudis cows, ranging in age from 3 to 15 years, was used for this study. All animals in this study were managed by the King Ranch (Kingsville, TX). Cow data was collected three times per year, at pre-calving (Jan or Dec), at branding (Jul), and at weaning (Sept or Oct). Calf data was collected twice per year, at branding and at weaning. At pre-calving, cow body weight (**BW**) and body condition score (**BCS**) were collected. At branding, cow BW, BCS, chute score (**CS**), and exit velocity (**EV**) were collected, along with calf BW, hip

height (**HH**) CS, and EV. At weaning, cow BW, BCS, CS, and EV were collected along with calf BW, HH, CS, and EV. At branding and weaning, ultrasound carcass measurements were obtained from each cow, and included 12^{th}-13^{th} rib backfat thickness (**uFT**), rump fat (**uRF**), and kidney fat depth (**uKFd**) depth. As described by Ribeiro et al. (2008), the kidney fat image was collected between the first lumbar vertebra and the 13th rib as shown in as a cross-sectional image. The ultrasound probe was placed on the flank region approximately 15 cm from the midline of the animal. Images were stored in the ultrasound console and interpreted chute side by the same technician. The uKFd measurement was taken between the ventral part of the abdominal muscles (*iliocostalis*, *obliquus abdominis interni*, and *obliquus abdominis externi*) and the end of the kidney fat. Internal fat (**IFAT**, kg) was calculated for each cow as IFAT = -11.41292 + 16.23754 × uFT + 1.83249 × uKFd, as devised by Ribeiro et al. (2008).

Exit velocity was calculated as the distance (1.83 m) traveled per second upon exiting the squeeze chute, as described by Burrow et al. (1988). The CS were recorded for all animals by the same observer, according to the 5-point system described by Grandin (1993): 1 = calm, no movement; 2 = restless, shifting; 3 = squirming, occasionally shaking of the chute; 4 = continuous vigorous movement and shaking of the chute; 5 = rearing, twisting of the body, or violent struggling.

Fecal samples were collected by rectal palpation of cows on 4 separate periods; July 2007, July 2009, September 2009, and September 2010. Fecal samples from each cow were dried and ground to pass through a 1 mm screen, and analyzed for digestible

organic matter (**DOM**) and crude protein (**CP**) content as described by Lyons and Stuth (1992).

In Vitro Anaerobic Fermentation and Gas Production

Forage samples were collected monthly from each pasture the animals grazed, and frozen for later analysis.

The analysis was performed at the Ruminant Nutrition Laboratory at Texas A&M University. The in vitro anaerobic fermentation chamber was similar to that described by Pell and Schofield (1993) and Schofield and Pell (1995). The chamber and procedures used in this analysis were described by Tedeschi et al. (2009). Briefly, the chamber included an incubator with multi plate stirrer, pressure sensors attached to 125-mL Wheaton bottles, which served as incubation flasks, an analog to digital converter device, and a PC-compatible computer provided with appropriate software (Pico Technology, Eaton Socon, Cambridgeshire, UK). Computer software automatically recorded pressure inside the flasks every 5 min over the 48 h incubation period. Approximately 200 mg of feed (whole TRT and individual feed ingredients) samples were added to a 125-mL Wheaton bottle, containing a Teflon-covered stir bar, and samples were then wetted with 2.0 mL of distilled water in order to prevent particle scattering. The phosphate-bicarbonate medium and reducing solution of Goering and Van Soest (1970) was used as in vitro medium, and continuously ventilated with CO2. Bottles were filled with 14 mL each of media, utilizing strict anaerobic technique in all transfers. Bottles were sealed with unused, lightly greased, butyl rubber stoppers, and crimp sealed. Rumen fluid inoculum was obtained from a non-lactating rumen-

cannulated Jersey cow, which had free access to mixed forages and mineral supplementation. The rumen fluid was filtered through 4 layers of cheesecloth followed with filtering through glass wool, and flushing continuously with CO_2. When it was observed that the fermentation chamber had reached 39ºC, 4 mL of rumen fluid were added to each bottle, the chamber door was closed and temperature allowed to rise back to 39ºC. At this point, each bottle was punctured with a needle for 5 s to zero pressure inside the bottle. Pressure recording was initiated when the chamber had once again reached 39ºC and continued for 48 h. The in vitro anaerobic fermentation data was used to compute metabolizable energy as shown by Aguiar et al. (2011).

Model Inputs and Statistical Analysis

Data were analyzed per calf production interval (conception to weaning), and divided into 4 years. Conception was assumed to be at the end of the breeding period, at branding data collection. Year 1contained data from July 2006 to October 2007, and year 2 contained data from December 2006 to September 2008, year 3 contained data from July 2008 to September 2009. Within herd EPD were obtained for milk, weaning weight (**WW**), average daily gain (**ADG**), hot carcass weight (**HCW**), ribeye area (**REA**), marbling (**MARB**), tenderness (**TEND**), and residual feed intake (**RFI**). Heritability ($\mathbf{h^2}$) estimates and EPD were calculated separately (John Genho, personal communication) and provided for this analysis.

The data collected were used as model inputs to compute metabolizable energy (**ME**) requirement for each cow as described by Tedeschi et al. (2004): (1) compute cow mature weight at BCS 5 adjusted for conceptus, (2) compute daily cow net energy

required for maintenance (adjusted for activity, environment), (3) compute cow pregnancy requirement, (4) predict cow peak milk from calf weaning BW and age, (5) compute cow lactation requirement, (6) compute calf forage ME intake, (7) compute total ME required, (8) compute ME efficiency (ME required/actual WW, ME required/adjusted WW, ME required/(adjusted WW + % of cull cow wt), (9) compute total herd ME, (10) compute cow fractional share of herd ME, and (11) compute cow cost (total costs × fractional share).

Briefly, as described by Tedeschi et al. (2004), maintenance requirements are adjusted for conceptus weight, environment, physical activity, and physiological status, as recommended by the NRC (2000). Pregnancy and lactation requirements are also predicted using NRC (2000) recommendations. Milk production is computed through iteration, by changing peak milk until predicted WW matches the observed calf WW. Equations to estimate forage and milk intake of the calf were based on data from Abdelsamei (1989). The effect of changing BCS was used to represent tissue mobilization and repletion. This effect was used to estimate energy availability from body reserves, similar to that described by Reynoso-Campos et al. (2004). This model is based on the models described by Fox et al. (1988) and Reynoso-Campos et al. (2004), with some modifications.

PROC CORR of SAS (SAS Inst. Inc., Cary, NC) was used to determine relationships between model-predicted peak milk and energy efficiency index (**EEI**) with cow and calf performance data and temperament data.

RESULTS AND DISCUSSION

Cow and Calf Performance

The summary data for years 1, 2, 3, and 4 are shown in Tables 3.1, 3.2, 3.3, and 3.4, respectively. Both BW and BCS increased from July 2006 to October 2007, from 487 kg to 528 kg, and from 4.62 to 5.59; respectively. In year 2, cow BW ranged from 602 kg in January 2008 to 519 kg in July 2008. Cows lost BCS from the fall of 2007 to the fall of 2008, from 5.59 to 5.34. This loss in BCS is likely due to a reduction in forage availability in 2008 as compared to 2007. In year 3, cows lost both BW and BCS from breeding (5.21, July 2008) to weaning (4.66, September 2009), and were lighter at weaning than the previous two years. Selk et al. (1988) observed that cows fed to lose 5% of their mid-gestation BW prior to calving also lost BCS during that same period, similar to the relationship noted between BW and BCS losses for year 3. This decline was likely due to a decrease in both forage quantity and quality due to drought in the summer of 2009. Ferrell and Jenkins (1984) found that cows lost weight and fat when fed at a low plane of nutrition. For year 1 cows, weighed 526 kg at weaning, and 534 kg at weaning in year 2, however, in year 3 cows only weighed an average of 451 kg at weaning. In year 4, cows gained BW from July of 2009 to September of 2010, with average weights of 492 ± 53.4 kg to 546 ± 64.4 kg. Cows were fatter at weaning in 2010 as compared to 2009 with BCS of 5.34 for 2010 and 4.66 for 2009.

Table 3.1. Cow and calf summary data year 1[1,2]

Items	Jul-06	Sep-06	Dec-06	Jul-07	Oct-07
N	138	140	101	136	132
Cow					
BW, kg	487 (47.6)	485 (49.2)	584 (57.5)	528 (60.9)	526 (68.0)
BCS	4.62 (0.61)	5.05 (0.53)	4.83 (0.78)	5.66 (3.89)	5.59 (0.89)
uKFd, cm	10.9 (1.09)	10.9 (1.45)		16.2 (1.52)	16.4 (1.45)
uBF, cm	0.35 (0.14)	0.46 (0.23)		0.51 (0.34)	0.58 (0.41)
uRF, cm	0.47 (0.38)	0.67 (0.58)		0.94 (0.84)	1.00 (0.88)
CS	3.05 (0.79)	2.92 (0.82)		2.29 (0.92)	2.29 (0.81)
Calf					
Birth wt, kg			35.0 (4.05)		
BW, kg				177 (34.1)	240 (37.7)
HH, cm				109 (4.65)	119 (4.46)
CS				2.09 (0.74)	2.20 (0.83)

[1]BW = body weight, BCS = body condition score, uKFd = ultrasound kidney fat depth, uBF = ultrasound back fat, uRF = ultrasound rump fat, CS = chute score, EV = exit velocity, HH = hip height
[2]Mean (standard deviation)

.

Table 3.2. Cow and calf summary data year 2[1,2]

Items	Jul-07	Oct-07	Jan-08	Jul-08	Sept-08
N	136	132	145	140	138
Cow					
BW, kg	528 (60.9)	526 (68.0)	602 (93.6)	519 (66.3)	534 (67.6)
BCS	5.66 (3.89)	5.59 (0.89)	5.02 (0.80)	5.21(0.58)	5.34 (0.65)
uKFd, cm	16.2 (1.52)	16.4 (1.45)			17.0 (1.26)
uBF, cm	0.51 (0.34)	0.58 (0.41)			0.58 (0.37)
uRF, cm	0.94 (0.84)	0.99 (0.91)			1.00 (0.88)
CS	2.29 (0.92)	2.29 (0.81)		1.69 (0.65)	2.17 (0.75)
Calf					
Birth wt, kg			35.9 (4.30)		
BW, kg				168 (27.1)	230 (32.1)
HH, cm					117 (4.51)
CS					2.14 (0.81)

[1]BW = body weight, BCS = body condition score, uKFd = ultrasound kidney fat depth, uBF = ultrasound back fat, uRF = ultrasound rump fat, CS = chute score, EV = exit velocity, HH = hip height
[2]Mean (standard deviation)

Table 3.3. Cow and calf summary data year 3[1,2]

Items	Jul-08	Sep-08	Jan-09[3]	Jul-09	Sep-09
N	140	138		160	156
Cow					
BW, kg	518 (66.2)	533 (67.6)		491(53.5)	451 (56.7)
BCS	5.21 (0.58)	5.35 (0.65)		5.00 (0.42)	4.66 (0.56)
uKFd, cm		17.0 (0.66)		16.3 (1.39)	
uBF, cm		0.58 (0.37)		0.33 (0.15)	0.32 (0.16)
uRF, cm		1.00 (0.88)		0.46 (0.43)	0.43 (0.45)
CS	1.69 (0.65)	2.17 (0.75)		1.84 (0.66v	1.71 (0.66)
Calf					
Birth wt, kg			35.5 (2.99)		
BW, kg				137.9 (23.0)	177.8 (23.7)
HH, cm				100.3(5.54)	114.1(4.47)
CS				1.88 (0.60)	2.01 (0.66)

[1]BW = body weight, BCS = body condition score, uKFd = ultrasound kidney fat depth, uBF = ultrasound back fat, uRF = ultrasound rump fat, CS = chute score, EV = exit velocity, HH = hip height
[2]Mean (standard deviation)
[3]Data not collected Jan-09

Table 3.4. Cow and calf summary data year 4[1,2]

Items	Jul-09	Sept-09	Dec-09	Jul-10	Sept-10
N	160	156	173	167	169
Cow					
BW, kg	491.5(53.4)	451.3 (56.5)	556.7 (73.7)	533.6 (59.5)	546.1 (64.4)
BCS	5.00 (0.42)	4.66 (0.56)	4.44 (0.56)	5.23 (0.52)	5.34 (0.55)
uKFd, cm	16.3 (1.39)				16.6 (1.60)
uBF, cm	0.33 (0.15)	0.32 (0.16)			0.79 (0.47)
uRF, cm	0.46 (0.43)	0.43 (0.45)			1.41 (0.87)
CS	1.84 (0.66)	1.71(0.66)		1.56 (0.64)	1.62 (0.63)
Calf					
Birth wt, kg			32.0 (3.07)		
BW, kg				152.5 (34.4)	227.7 (38.6)
HH, cm				103.1(6.44)	112.8 (12.6)
CS				1.78 (0.63)	1.62 (0.63)

[1]BW = body weight, BCS = body condition score, uKFd = ultrasound kidney fat depth, uBF = ultrasound back fat, uRF = ultrasound rump fat, CS = chute score, EV = exit velocity, HH = hip height
[2]Mean (standard deviation)

Calf birth weight was similar among all years, with the exception of year 4, where calves were numerically lighter. Cows also had the lowest pre-calving BCS at year 4. Spitzer et al. (1995) evaluated effects of BCS and weight change in cows prepartum, and observed that cows with increased BCS at parturition had heavier calves at birth, similar to the relationships observed in this study

Cows in year 3 weaned lighter calves (177 ± 23.7 kg), as compared to year 1 (240 ± 37.7 kg) and year 2 (230 ± 32.1 kg). Although heavier than the previous year, calves still weighed slightly less at weaning in year 4 (228 ± 38.6 kg) as compared to years 1 and 2. Spitzer et al. (1995) found that BCS of cows at parturition did not affect calf WW; however, BW at weaning may have had a greater effect than BCS at calving. A reduction in forage availability, and thus energy availability, in year 3 may have lead to reduced WW for year 3. Houghton et al. (1990) reported that cows fed more energy postpartum tended to wean heavier calves, and thus it is anticipated the the inverse is also true.. This suggests that energy availability may have greater impacts on calf WW, than cow BCS and BW, and may have lead to differences in WW observed across years.

Chute score was consistent throughout year 1, ranging from 2.29 to 3.05. Chute score in year 2 ranged from 2.29 in July 2007 to 1.69 in July 2008. Chute score was consistent throughout the year 3, ranging from 1.69 ± 0.65 in July of 2008 to 2.17 ± 0.75 in September of 2008. Chute score was consistently lower in year 4 as compared to previous years, ranging from 1.56 ± 0.64 in July of 2010 to 1.84 ± 0.66 in September of 2009. This decrease in CS over the course of the study is expected as animals become accustomed to the working procedure. Curley et al. (2006) found that initial CS had the

little association with other CS measures taken on d 60 and 120, which is consistent with current findings.

Model-Predicted Values

Summary of model-predicted values for all 4 years are given in Table 3.5. Although complete data was collected on as many as 170 cows in a given year, due to either not weaning a calf, or missing data, model-predictions were only performed on cow-calf pairs with complete data (73 cow-calves in year 1, 62 cow-calves in year 2, 79 cow-calves in year 3, and 81 cow-calves in year 4).

Cows in year 1 had an average EEI of 34.7 ± 6.57 Mcal/kg, while cows in year 2 had an average EEI of 39.6 ± 4.25 Mcal/kg. For year 1, cows had an average predicted peak milk of 8.56 ± 1.22 kg/d. Cows in year 2 had an average predicted peak milk of

Table 3.5. Summary of model-predicted values[1]

Items	N	Mean (SD)	Min	Max
$EEI_{Year\ 1}$	73	34.7 (6.57)	26.5	77.4
$EEI_{Year\ 2}$	62	39.6 (4.25)	31.0	50.2
$EEI_{Year\ 3}$	79	51.4 (5.80)	41.7	70.9
$EEI_{Year\ 4}$	81	37.0 (6.20)	29.1	62.2
Peak $milk_{Year\ 1}$	73	8.56 (1.22)	3.09	10.9
Peak $milk_{Year\ 2}$	62	10.2 (1.29)	7.62	14.1
Peak $milk_{Year\ 3}$	79	9.10 (1.14)	6.60	13.4
Peak $milk_{Year\ 4}$	81	9.63 (1.44)	6.14	12.7

[1]EEI = energy efficiency index (mcal/kg), Peak milk, kg

10.2 ± 1.29 kg/d. In year 3, cows had an average EEI of 51.4 ± 5.80 Mcal/kg. This is higher than both the EEI for cows in year 1 and 2, and may be due to the drought experienced that year. Cows in year 4 had an average EEI of 37.0 ± 6.20 Mcal/kg, which is similar to year's 1 and 2. Peak milk for both year 3 and 4 (9.10 ± 1.14 kg/d and 9.63 ± 1.44 kg/d; respectively) was intermediate to years 1 and 2. These predicted peak milk values for all years were similar to average daily milk yield for Santa Gertrudis cows measured by Wistrand and Riggs (1966), which ranged from 4.2 to 11.5 kg/d. Wistrand and Riggs (1966) measured actual milk production from 13 Santa Gertrudis cows over 2 consecutive lactations concurrently using both the calf nursing, weigh-suckle-weigh technique, and machine milking to measure production. Daley et al. (1987) reported 24 hour milk yield from F1 *Bos indicus* cows with averages of 7.3 and 8.3 kg, which is lower than predicted peak milk in the current study Data reviewed by the NRC (1996) indicate that peak lactation occurs at approximately 8.5 weeks postpartum with a range of 4 to 14 kg/d, with the maximum reported for dual-purpose breeds. Predicted peak milk in this study were also within the range reported by the NRC (1996).

Table 3.6. Pearson correlation coefficients between model predicted values between years[1, 2]

Items	EEI Yr 2	EEI Yr 3	EEI Yr 4	Peak Milk Yr 1	Peak Milk Yr 2	Peak Milk Yr 3	Peak Milk Yr 4
EEI Yr 1	0.51**	0.47**	0.39**	-0.87**	-0.22	-0.37**	-0.25
EEI Yr 2		0.43**	0.52**	-0.39**	-0.58**	-0.07	-0.38**
EEI Yr 3			0.56**	-0.24*	-0.13	-0.58**	-0.43**
EEI Yr 4				-0.20	-0.37**	-0.20	-0.85**
Peak Milk Yr 1					0.36**	0.29*	0.26
Peak Milk Yr 2						0.03	0.42**
Peak Milk Yr 3							0.27*

[1] EEI= energy efficiency index, Yr = year

[2] *N* = 35 year 1 and 2, 43 year 1 and 3, 27 year 1 and 4, 43 year 2 and 3, 32 year 2 and 4, and 42 year 3 and 4

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Pearson correlation coefficients between model-predicted values across years are shown in Table 3.6. There were 35 cows with complete data in both years 1 and 2 and 43 cows with complete data in both year 1 and 3 and year 2 and 3. There were 27 cows with complete data in both years 1 and 4, 32 cows with complete data in both year 2 and 4, and 42 cows with complete data between year 3 and 4. Across years, EEI was moderately correlated, with r = 0.51 between year 1 and 2, r = 0.47 between year 1 and 3, r = 0.39 between year 1 and 4, r = 0.43 between year 2 and 3, r = 0.52 between year 2 and 4, and r = 0.56 between year 3 and 4. This suggests that the EEI may be repeatable for cows across years. Jenkins et al. (1991) examined differences in conversion of ME to calf weight gain among breed types with varying genetic potential for mature weight and milk yield, expressed as calf BW in grams per unit of ME consumed by the cow and calf (Mcal), which is the inverse of our ratio. Cows that produced the heaviest calves had greater ME requirements to maintain BW. This increase in output served to offset differences in energy requirements. It's possible that this same dilution is also noted in our EEI, as it is anticipated that those cows with greater potential for milk and growth likely have greater ME requirements.

Preliminary genetic assessment including 4 years of data of EEI and ME required (**MER**) for the observed performance as predicted by the model, indicated narrow sense h^2 (SE not provided) for EEI and MER of 0.58 and 0.05, respectively. The ratio of permanent environmental variance to phentotypic variance was 0.04 and 0.31, respectively. This indicates that significant genetic variation may exist to select for EEI.

Archer et al. (1999) reported heritability estimates from several studies examining feed conversion ratio (**FCR**) and residual feed intake (**RFI**) in growing cattle. Heritability estimates for FCR varied from 0.16 to 0.46 and 0.08 to 0.44 for RFI, lower than h^2 estimates for EEI in the current study. Pitchford (2004) reviewed h^2 estimates for RFI of lactating cattle and reported values from zero to 0.38. These results suggest that heritability estimates of RFI may be less in lactating cows compared to growing cattle.

Peak milk was positively correlated between years 1 and 2 (r = 0.36) and between years 2 and 4 (r = 0.42). Peak milk tended to be positively correlated for year 1 and 3 (r = 0.29) and for year 3 and 4 (r = 0.27), while peak milk was not correlated between year 2 and 3 or year 1 and 4. The weaker relationship of peak milk across year as compared to EEI may be due to greater effects of environment on milk production. The preliminary genetic assessment for peak milk indicated narrow sense h^2 of 0.12 (SE not provided), with a ratio of permanent environmental variance to phentotypic variance of 0.26. This indicated peak milk is lowly heritable. Meyer et al. (1994) reported h^2 for milk yield of Hereford cows of 0.12, which is in agreement with the value observed for model predicted peak milk in this study. Other previously published h^2 estimates have been higher, such as Dillard et al. (1978), who reported a h^2 of 0.44 in Hereford cows. This suggests that selection pressures for improved peak milk may require longer generations to see change in peak milk, and it may be better to select for improved EEI.

Within a year, EEI and peak milk were moderately to highly negatively correlated, with r = -0.87, -0.58, -0.58, -0.85 for year 1, 2, 3, and 4; respectively. This indicates that more efficient cows, with a lower EEI, had a higher predicted peak milk.

As calf WW is highly related to milk production, this negative relationship between peak milk and EEI is anticipated. Meyer et al. (1994) reported an estimate of direct-maternal genetic correlation between actual milk yield and weaning weight of 0.80, suggesting a very strong relationship between milk production and calf WW, a major component of EEI. Montano-Bermudez et al. (1990) reported a weak positive relationship between maintenance energy requirements of cows and 205-d milk production relative to metabolic weight (kg/MW), and observed that variation in milk production explained only 23% of the variation in energy requirements for maintenance. However, the authors also noted that although a large difference was observed in milk production (210 kg) between cows with medium and levels of milk production, no difference in maintenance requirements per MW was found. The authors did observe that cows with low milk production had lower maintenance requirements as compared to medium and high cows. These two studies indicated that the relationship between milk production and calf WW is much greater than the relationship between milk production and ME requirements. This suggests that as milk production increases per unit of metabolic weight, a greater increase in calf WW is expected when compared to ME requirements. AS Calf WW increases at a greater rate than MER, EEI is expected to decrease as milk production increases.

The current version of the CVDSbc does not account for differences in ME for maintenance (**ME_m**) due to variation in milk production. Montano-Bermudez et al. (1990) observed that as milk production increased by 1 kg/$kg^{0.75}$ BW, ME_m increased by 1.6 kcal/d, and that low milk production cows required 12% less energy per unit of MW

as compared to medium or high milk production cows. By adding this increased ME_m to total MER, it is possible that the relationship between EEI and peak milk may become less negative.

Relationships with Expected Progeny Differences

Pearson correlation coefficients between model-predicted values and EPDs are given in Table 3.7. There was no correlation with EEI and WW EPD. However, for years 2 and 3 there was a weak positive correlation with peak milk and WW EPD, such that cows with greater model-predicted peak milk had higher WW EPDs. For years 1 and 4, this same weak positive relationship between peak milk and WW EPD tended ($P < 0.10$) to exist. Energy efficiency index was negatively correlated to Milk EPD for all 4 years, such that more efficient cows had a higher genetic potential for milk. This is consistent with the relationship found between model-predicted peak milk and EEI. Peak milk was positively correlated to Milk EPD for all 4 years. Marston et al. (1992) reported relationships between total milk yield and milk EPD r = 0.32 for Angus cows, which is in agreement with the current findings of the relationship between model-predicted peak milk and milk EPD. For year 2, peak milk tended to be positively correlated with ADG EPD (r = 0.21). For year 1, peak milk tended ($P < 0.10$) to be positively correlated with HCW EPD (r = 0.21), and negatively correlated with Marb EPD (r = -0.23), such that cows with greater predicted peak milk had greater HCW EPD and lower marbling EPD. This suggests that progeny of these females would have larger carcasses with less intramuscular fat. For year 2, peak milk tended ($P < 0.10$) to be weakly positively correlated with ADG EPD. It is expected that cows with greater milk

production would produce calves with greater potential for ADG, but that was not the case in the current dataset, although a relatively small number of females was available for genetic analysis. Peak milk in year 3 tended ($P < 0.10$) to be weakly positively correlated with REA EPD. For year 3, EEI was weakly positively correlated with Marb EPD. There was no relationship between RFI EPD with EEI or peak milk for any year, and no other relationships between model-predicted values and EPDs were observed.

Table 3.7. Pearson correlation coefficients between model predicted values and within herd calculated EPD[1,2]

Items	WW EPD	Milk EPD	ADG EPD	HCW EPD	REA EPD	Marb EPD	TEND EPD	RFI EPD
EEI Yr 1	-0.11	-0.26**	-0.06	-0.13	-0.13	0.15	0.05	0.02
EEI Yr 2	0.08	-0.42**	0.17	0.17	-0.04	0.02	-0.08	-0.19
EEI Yr 3	-0.02	-0.46**	0.17	0.09	-0.14	0.26**	0.005	0.03
EEI Yr 4	-0.12	-0.45**	0.02	0.002	-0.11	0.09	0.02	-0.14
Peak Milk Yr 1	0.22*	0.31**	0.12	0.21*	0.17	-0.23*	-0.05	0.11
Peak Milk Yr 2	0.38**	0.46**	0.21*	0.20	0.15	-0.01	-0.08	0.13
Peak Milk Yr 3	0.23**	0.25**	-0.01	0.11	0.23*	-0.07	0.05	-0.09
Peak Milk Yr 4	0.19*	0.49**	-0.06	-0.0005	0.04	-0.15	0.08	0.15

[1] EEI= energy efficiency index, WW= weaning weight, ADG= average daily gain, HCW= hot carcass weight, REA= ribeye area, Marb= marbling, TEND = tenderness, RFI= residual feed intake
[2] N = 73 Year 1, N = 62 Year 2, N = 79 Year 3, and N = 81 Year 4
* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Table 3.8 has Pearson correlation coefficients for phenotypic traits and within herd calculated EPD. Weaning weight EPD was correlated with actual calf WW for each of the 4 years, although correlations were weak. Milk EPD was also weakly to moderately correlated with calf WW each year. This indicates that cows who weaned heavier calves had greater genetic potential for both WW and milk. Other relationships were not consistent across years. This is in agreement with the findings of Marston et al. (1992) who reported a relationship between adjusted 205-d weight and milk EPD of 0.32 for Angus cows. However, for years 2 and 3, cows with heavier BW at weaning had greater WW EPD ($r = 0.22$. For year 2, cows with a greater BCS at weaning had decreased genetic potential for milk ($r = -0.20$). For years 1 and 2, there was a weak negative relationship between RFI EPD and cow BCS at weaning, such that leaner cows would be expected to produce more efficient calves.

Table 3.8. Pearson correlation coefficients between phenotypic traits and within herd calculated EPD[1,2]

Items	WW EPD	Milk EPD	ADG EPD	HCW EPD	REA EPD	MARB EPD	Tenderness EPD	RFI EPD
Year 1								
WW	0.24**	0.23**	0.14	0.21**	0.20**	-0.28**	0.02	0.16
Cow BW at weaning	0.12	-0.06	0.15	0.13	-0.01	0.02	-0.08	-0.14
Cow BCS at weaning	0.06	-0.14	0.12	0.13	0.002	0.03	-0.04	-0.23**
Year 2								
WW	0.32**	0.32**	0.11	0.16	0.16	0.03	-0.12	-0.08
Cow BW at weaning	0.22**	-0.11	0.19**	0.19**	0.07	0.18**	-0.01	-0.04
Cow BCS at weaning	0.14	-0.20**	0.19**	0.17*	0.07	0.21**	0.04	-0.16*
Year 3								
WW	0.22**	0.32**	-0.03	0.10	0.16	-0.10	0.17	-0.11
Cow BW at weaning	0.22**	-0.05	0.16*	0.18**	-0.12	-0.0.	0.16*	0.02
Cow BCS at weaning	0.03	-0.06	0.10	0.08	-0.01	-0.02	0.12	0.08
Year 4								
$WW_{Year\ 4}$	0.19*	0.48**	-0.01	0.03	0.02	-0.16	0.07	0.17
Cow BW at weaning	0.14	0.02	0.01	0.02	0.03	0.10	-0.01	0.04
Cow BCS at weaning	0.06	0.01	0.02	0.01	0.13	0.22**	-0.09	0.12

[1] WW = weaning weight, BW = body weight, BCS = body condition score, EPD = expected progeny difference, ADG = average daily gain, HCW = hot carcass weight, REA = ribeye area, Marb = marbling, RFI = residual feed intake

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Forage Quality

Table 3.9 has summary statistics for forage ME values for each year of the study. Mean forage ME values were similar for all years, with the exception of 2008. Forage ME was lowest from January to June of 2008 (data not shown) compared to other years, with the lowest ME value of the study observed in May 2008. Therefore, although average ME values are similar among years, the pattern of energy availability varied from year to year.

Table 3.9. Summary statistics of average forage ME values collected monthly and averaged for year for pasture grazed by Santa Gertrudis cows[1]

Items	Mean (Std Dev	Min	Max
2006	1.93 (0.18)	1.70	2.25
2007	1.85 (0.09)	1.69	2.04
2008	1.71 (0.15)	1.47	2.00
2009	1.92 (0.12)	1.79	2.11
2010	1.90 (0.15)	1.66	2.08

[1]ME = metabolizable energy, Mcal

Table 3.10 has the summary statistics for DOM and CP estimated from fecal samples collected from cows in July 2007, July 2009, September 2009, and September 2010. Both DOM and CP content were highest in September of 2009 as compared to the other 3 sample periods; however, DOM also had the greatest variability during this sample period. Samples from September of 2010 had the least DOM and CP of any of the sample periods. Both CP and DOM were greater in this evaluation than reported by

Lyons et al. (1993), using similar prediction equations for DOM and CP. The authors observed CP ranged from 5.4 to 6.9 and DOM from 57.6 to 59.2, differing by day and supplementation status. These differences are likely due to differences in forage type, quality, supplements, and sample times. The authors evaluated effects of either a 20% range cube supplement or no supplement for *Bos indicus* cows grazing native range.

Table 3.10. Summary statistics of NIRS predicted DOM and CP[1]

Items	N	Mean (Std Dev	Min	Max
July 2007 DOM	85	64.4 (1.16)	61.8	67.4
July 2007 CP	85	12.7 (1.48)	9.32	16.9
July 2009 DOM	132	59.7 (1.23)	56.9	64.7
July 2009 CP	132	7.66 (0.98)	5.43	12.3
Sept 2009 DOM	119	66.2 (1.84)	62.9	70.0
Sept 2009 CP	119	13.2 (1.10)	9.48	16.17
Sept 2010 DOM	148	58.2 (1.40)	54.6	61.1
Sept 2010 CP	148	7.00 (1.37)	3.49	11.1

[1] EEI= energy efficiency index, DOM= digestible organic matter, CP= crude protein

Pearson correlation coefficients between model-predicted values and NIRS predicted DOM and CP are given in Table 3.11. Within years when fecal samples were collected, the only significant relationship detected was for year 3. Peak milk in year 3 was negatively correlated with DOM sampled at weaning, such that cow with greater model-predicted peak milk had lower DOM. Relationships between NIRS predicted DOM and CP with model-predicted values were inconsistent across years. For year 3, EEI was negatively correlated with September 2010 DOM, while for year 4 EEI was

Table 3.11. Pearson correlation coefficients between model predicted values and NIRS predicted DOM and CP[1]

Items	July 2007 DOM	July 2007 CP	July 2009 DOM	July 2009 CP	Sept 2009 DOM	Sept 2009 CP	Sept 2010 DOM	Sept 2010 CP
$EEI_{Year\ 1}$	0.05	-0.12	0.01	0.13	-0.04	0.16	-0.28**	-0.12
$EEI_{Year\ 2}$	-0.17	-0.23	-0.39**	-0.28*	0.07	0.07	-0.07	-0.15
$EEI_{Year\ 3}$	-0.11	-0.09	0.01	0.04	0.13	0.15	-0.30**	-0.15
$EEI_{Year\ 4}$	-0.04	-0.09	-0.25**	0.10	0.27**	0.30**	0.09	0.14
Peak $Milk_{Year\ 1}$	-0.16	-0.01	-0.04	0.05	-0.11	-0.18	0.33**	0.24
Peak $Milk_{Year\ 2}$	0.17	0.16	0.31**	0.22	-0.04	-0.18	0.10	0.17
Peak $Milk_{Year\ 3}$	0.19	0.14	-0.10	0.001	-0.24*	-0.11	0.06	-0.06
Peak $Milk_{Year\ 4}$	-0.05	-0.21	0.20	-0.11	-0.12	-0.17	-0.08	-0.11

[1] EEI= energy efficiency index, DOM= Digestible organic matter, CP= Crude protein

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

positively correlated with September 2009 DOM and CP. Further investigation of these relationships is warranted.

Pearson correlation coefficients among phenotypic traits and NIRS predicted DOM and CP are given in Table 3.12. For year 1, cows were sampled at branding time (July 2007), and weak negative correlations were found with DOM and calf WW, cow BW at weaning, and cow BCS at weaning. This suggests that cows with lower DOM weaned lighter calves, and were lighter and thinner at weaning. In addition weak negative relationships were also observed among CP and cow BW and BCS at weaning. For year 3, cows were sampled at both branding (July 2009) and at weaning (September 2009). At branding, DOM was weakly negatively correlated with both cow BW and BCS at weaning, similar to the relationship found in year 1. However, for fecal samples collected at weaning, DOM was weakly positively correlated with cow BW, but not BCS at weaning. This indicates that heavier cows had greater DOM. No relationships were found with samples collected in year 4. These inconsistencies may be due to sample size or time or it is possible that the equations to calculate DOM and CP from fecal samples may need adjustment to better account for the variation of these Santa Gertrudis cows on south Texas range. Further investigation of this relationship is warranted.

Table 3.12. Pearson correlation coefficients between phenotypic traits of cows and calves by years and NIRS predicted DOM and CP[1]

Items	July 2007 DOM	July 2007 CP	July 2009 DOM	July 2009 CP	Sept 2009 DOM	Sept 2009 CP	Sept 2010 DOM	Sept 2010 CP
Year 1								
WW	-0.21*	-0.19	-0.05	0.04	-0.01	-0.11	0.13	0.05
Cow BW at weaning	-0.29**	-0.34**	-0.14	-0.01	-0.02	-0.07	-0.14	-0.11
Cow BCS at weaning	-0.21*	-0.27**	-0.23**	-0.28**	-0.06	-0.21*	-0.08	-0.13
Year 2								
WW	0.06	0.09	0.10	0.02	0.01	-0.05*	-0.11	-0.09
Cow BW at weaning	-0.12	-0.12	-0.08	-0.03	0.11	-0.02	-0.10	-0.06
Cow BCS at weaning	-0.06	-0.13	-0.04	0.01	-0.03	-0.11	-0.01	-0.09
Year 3								
WW	0.21	0.24	-0.15	-0.13	-0.10	-0.13	0.01	0.14
Cow BW at weaning	0.01	-0.10	-0.23**	-0.10	0.23**	0.15	-0.02	-0.09
Cow BCS at weaning	0.01	-0.03	-0.16*	-0.07	0.04	-0.05	-0.01	-0.10
Year 4								
WW	0.04	-0.17	0.21*	-0.05	-0.10	-0.13	-0.11	-0.12
Cow BW at weaning	0.16	0.03	0.09	0.12	0.13	0.11	-0.08	-0.04
Cow BCS at weaning	0.11	0.09	0.10	0.12	0.06	0.02	-0.03	-0.03

[1]NIRS = near infrared spectroscopy, DOM = digestible organic matter, WW = calf weaning weight, BW = body weight, BCS = body condition score

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Table 3.13. Summary statistics of cow and calf temperament values[1]

Items	N	Mean (SD)	Min	Max
Cow CS Yr 1	91	2.66 (0.66)	1.50	4.75
Cow CS Yr 2	108	2.05 (0.55)	1.00	3.75
Cow CS Yr 3	112	1.85 (0.49)	1.00	3.25
Cow CS Yr 4	148	1.68 (0.43)	1.00	3.25
Cow EV Yr 1	84	2.16 (0.77)	0.80	4.34
Cow EV Yr 2	101	2.45 (0.81)	0.85	4.71
Cow EV Yr 3	104	2.42 (0.68)	0.91	4.12
Cow EV Yr 4	106	2.45 (0.66)	1.05	4.10
Calf CS Yr 1	103	2.15 (0.64)	1.00	4.50
Calf CS Yr 2	109	2.14 (0.81)	1.00	5.00
Calf CS Yr 3	99	1.93 (0.49)	1.00	3.50
Calf CS Yr 4	90	1.80 (0.43)	1.00	2.50
Calf EV Yr 1	94	2.46 (0.52)	1.34	3.70
Calf EV Yr 2	105	2.70 (1.01)	0.77	7.97
Calf EV Yr 3	83	2.66 (0.45)	1.55	4.17
Calf EV Yr 4	77	2.73 (0.45)	1.94	4.56

[1]CS = Chute Score, EV = exit velocity, Yr = Year

Relationships of Model-Predicted Values and Temperament Measures

Descriptive statistics are presented in Table 3.13 for cow and calf temperament, by year. For cows, CS was numerically highest in year 1 and lowest in year 4, which indicates that cows may have grown accustomed to handling through the chute as the study progressed, as was also observed by Curley et al. (2006). However, cow EV showed the opposite trend, increasing from year 1 to 4. Calf CS followed the same trend in relation to year as cow chute score, with the lowest CS observed in year 4 and the highest in year 1. Once again, calf EV followed a similar trend to cow EV, with the highest EV in year 4 and the lowest in year 1. Curley et al. (2006) observed that EV measures taken at 0, 60, and 120 d were positively related; however, these authors noted

a decrease in EV over time, which differs from the results of the current study. However, mean EV is consistent with previously reported values (Nkrumah et al. 2007 and Curley et al. 2006).

Relationships between average CS and EV of cows for each year with EEI and peak milk are presented in Table 3.14. For year 2, peak milk tended ($P < 0.10$) to be weakly correlated in a negative manner with average CS from year 2. This indicates that cows with greater estimated peak milk tended to be less excitable, as indicated by a lower chute score. In agreement with these findings, Breuer et al. (2000) observed that dairy cows with more excitable temperaments had decreased milk production. Within year, no other relationships were found between either CS or EV with EEI or peak milk. This is in agreement with the results of Nkrumah et al. (2007), who examined relationships with feed efficiency and temperament in growing cattle. The authors examined relationships with flight speed, which is the equivalent of EV, with both FCR and RFI and found no phenotypic relationships.

Table 3.14. Pearson correlation coefficients between model predicted values and temperament values[1]

Items	EEI Yr 1	EEI Yr 2	EEI Yr 3	EEI Yr 4	Peak Milk Yr 1	Peak Milk Yr 2	Peak Milk Yr 3	Peak Milk Yr 4
CS Yr 1	-0.17	0.19	-0.20	-0.11	-0.06	-0.31**	0.23*	0.09
CS Yr 2	-0.19	0.10	-0.16	-0.09	-0.07	-0.23*	0.17	0.04
CS Yr 3	0.14	-0.10	-0.09	-0.01	-0.21	-0.08	0.02	-0.01
CS Yr 4	-0.12	0.02	-0.17	-0.05	-0.09	-0.21	0.05	0.07
EV Yr 1	-0.03	-0.05	-0.19	-0.29**	0.02	-0.05	0.33**	0.26*
EV Yr 2	-0.02	0.02	-0.17	-0.26**	-0.06	-0.13	0.07	0.16
EV Yr 3	0.14	0.10	-0.09	-0.01	-0.21	-0.08	0.02	-0.04
EV Yr 4	0.15	0.17	-0.15	-0.05	-0.24*	-0.12	0.05	-0.04

[1] EEI= energy efficiency index, Yr = Year, CS= chute score, EV= exit velocity

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Table 3.15 has the correlation coefficients for cow and calf temperament values with phenotypic traits for years 1 and 2. For year 1, cow BW at weaning was negatively correlated with both CS and EV, such that heavier cows had less excitable temperaments. Calf WW tended ($P < 0.10$) to be weakly negatively correlated with cow EV. For year 2, cow BW at weaning was weakly negatively correlated with EV, but not CS, while calf WW was weakly negatively correlated with CS. Calf temperament values were not correlated to any phenotypic traits for either year. This differs from the results of Hoppe et al. (2010) who observed that CS and EV of calves were negatively correlated with BW gain of several breeds of cattle. Table 3.16 has the correlation coefficients for cow and calf temperament values with phenotypic traits for years 3 and 4. For year 3 and 4, cow BW at weaning was negatively correlated with EV, but not CS, showing a similar relationship as observed in years 1 and 2. No other relationships with phenotypic traits and cow temperament values were observed. These results are in agreement with previous studies indicating that more excitable cattle exhibit lower BW gain (Burrow, 1997; Voisinet et al., 1997).

Table 3.15. Pearson correlation coefficients of cow and calf temperament values with phenotypic traits, Yr 1 and 2[1]

Items	WW Yr 1	Cow BW Yr 1[2]	Cow BCS Yr 1[3]	WW Yr 2	Cow BW Yr 2[2]	Cow BCS Yr 2[3]
Cow CS Yr 1	-0.04	-0.26**	-0.07	-0.21	-0.16	0.08
Cow CS Yr 2	-0.17	-0.25**	-0.13	-0.22**	-0.19	-0.04
Cow EV Yr 1	-0.25*	-0.19*	-0.12	-0.12	-0.29**	0.05
Cow EV Yr 2	-0.15	-0.20**	-0.15	-0.15	-0.28**	-0.05
Calf CS Yr 1	-0.04	-0.01	0.04	-0.04	-0.13	-0.08
Calf CS Yr 2	0.08	0.03	-0.02	-0.03	0.06	0.07
Calf EV Yr 1	0.11	0.02	-0.06	-0.01	0.20*	-0.02
Calf EV Yr 2	0.01	-0.02	0.11	-0.15	-0.07	0.05

[1] Yr= Year, WW = calf weaning weight, BW = body weight, BCS = body condition score, CS = chute score, EV = exit velocity

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Table 3.16. Pearson correlation coefficients of cow and calf temperament values with phenotypic traits, Yr 3 and 4[1]

Items	WW Yr 3	Cow BW Yr 3[2]	Cow BCS Yr 3[3]	WW Yr 4	Cow BW Yr 4[2]	Cow BCS Yr 4[3]
Cow CS Yr 3	0.13	-0.09	0.09	-0.05	-0.14	-0.06
Cow CS Yr 4	0.10	-0.11	0.01	-0.09	-0.16	-0.11
Cow EV Yr 3	0.17	-0.28**	-0.08	0.09	-0.17*	0.07
Cow EV Yr 4	0.04	-0.24**	-0.06	0.04	-0.18*	0.10
Calf CS Yr 3	0.12	-0.05	0.05	0.14	-0.10	-0.13
Calf CS Yr 4	0.08	-0.03	0.14	0.25**	0.02	-0.03
Calf EV Yr 3	-0.16	-0.01	0.05	-0.07	0.06	0.06
Calf EV Yr 4	0.01	0.05	0.02	-0.11	-0.01	0.03

[1] Yr = Year, WW = calf weaning weight, BW = body weight, BCS = body condition score, CS = chute score,
EV = exit velocity

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Relationships between EEI and Fat Measurements

Descriptive statistics for cow fatness traits are given by year average in Table 3.17.Cows were fattest in year 2, as evidenced by all fatness measurements. Cows were leanest in years 3 and 4.

Table 3.17. Summary of cow fatness measurements[1,2,3]

Items	N	Mean (SD)	Min	Max
Year 1				
BCS	91	5.21 (1.09)	3.30	14.2
uBF, cm	85	0.75 (0.39)	0.26	1.67
uKFd, cm	30	13.8 (0.80)	12.7	15.5
IFAT[2], kg	29	26.0 (6.37)	18.8	44.2
Year 2				
BCS	75	5.36 (0.46)	4.10	6.50
uBF, cm	110	0.85 (0.52)	0.29	2.59
uKFd, cm	78	16.5 (1.13)	14.2	20.0
IFAT, kg	75	33.9 (10.5)	19.3	61.8
Year 3				
BCS	111	5.05 (0.40)	4.13	6.50
uBF, cm	111	0.39 (0.16)	0.22	1.02
uKFd, cm	82	16.5 (0.91)	14.8	19.3
IFAT, kg	78	25.2 (3.68)	19.8	40.4
Year 4				
BCS	148	4.94 (0.36)	4.20	6.20
uBF, cm	148	0.48 (0.19)	0.22	1.06
uKFd, cm	128	16.4 (1.08)	13.4	18.8
IFAT, kg	120	26.4 (4.30)	16.6	39.5

[1]BCS = body condition score, uBF = ultrasound fat thickness, uKFd = ultrasound kidney fat depth, IFAT = internal fat

[2] IFAT = -11.41292 + 16.23754 *uFT + 1.83249 * uKFd

[3]Values are average fatness measures for the year.

Relationships between internal fat estimates of cows and model-predicted values and observed BCS are given in Table 3.18. A strong positive relationship between internal fat estimates and EEI for year 1, indicating that more efficient cows had less internal fat. Although weaker, this same relationship was found for years 2 and 3, but no relationship was found between IFAT and EEI for year 4. In agreement with these results, Arthur et al. (2005) observed that cows selected for low RFI were leaner at the start of the breeding season, when all cows exhibited the greatest rib fat depth. This differs from the results of Basarab et al. (2007), who found no relationship between cow RFI and cow fatness measures at the start and end of test. This difference is likely due to the fact that EEI and RFI measure efficiency differently. EEI accounts for cow energy efficiency as a ratio of MER to calf weaning BW; however RFI accounts for differences in intake beyond that expected based on BW and gain of the cow. Basarab et al. (2007) did examine relationships with calf RFI, and found that cows that produced more efficient calves were fatter. For year 1, peak milk was moderately negatively correlated with IFAT, such that cows with higher peak milk were leaner. This relationship was not found for years 2, 3, and 4. Observed BCS was strongly positively correlated with IFAT estimates for all years.

DiCostanzo et al. (1991) characterized cow types as efficient, average, or inefficient based on actual ADG in relation to predicted gain over two consecutive 70 to 80 d periods, and found that those cows classified as inefficient had less fat and deposited more protein. The inconsistency with current findings is likely due to calculations of efficiency, as in this study efficiency was calculated relative to calf

output, while the study by DiCostanzo et al. (1991) only accounted for cow ADG. An evaluation of within herd variation for energy utilization by DiCostanzo et al. (1990), indicated that for cows with similar fat masses, cows with larger protein masses had higher maintenance energy requirements.

Table 3.18. Pearson correlation coefficients between internal fat measures and model predicted traits, and BCS[1,2]

Items	$IFAT_{Y1}$	$IFAT_{Y2}$	$IFAT_{Y3}$	$IFAT_{Y4}$
EEI_{Y1}	0.79**	0.55**	0.23*	0.23
EEI_{Y2}	0.30	0.27*	0.24*	0.11
EEI_{Y3}	0.69*	0.38**	0.33**	0.29**
EEI_{Y4}	0.44	0.36**	-0.03	0.19
Peak $Milk_{Y1}$	-0.51**	-0.32**	-0.07	-0.18
Peak $Milk_{Y2}$	-0.01	0.21	-0.07	-0.08
Peak $Milk_{Y3}$	-0.63**	-0.16	-0.17	-0.30**
Peak $Milk_{Y4}$	-0.36	-0.39**	0.05	-0.13
BCS_{Y1}	0.60**	0.53**	0.42**	-0.02
BCS_{Y2}	0.46**	0.64**	0.48**	-0.02
BCS_{Y3}	0.36*	0.43**	0.74**	-0.04
BCS_{Y4}	0.03	0.08	0.24**	0.79**

[1] EEI= energy efficiency index, BCS= body condition score, IFAT= internal fat, uBF = ultrasound fat thickness, uKFd = ultrasound kidney fat depth
[2]IFAT= -11.41292 + 16.23754 × uBF + 1.83249 × uKFd
* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

Table 3.19 gives Pearson correlation coefficients among internal fat and phenotypic traits for each year. Calf WW was negatively correlated with IFAT in year 1, such that cows that weaned heavier calves were leaner. This relationship was not found in years 2, 3, or 4. Previous literature has shown conflicting results dependent upon

when BCS was measured. Some reported no relationship between cow BCS at pre-calving and calf WW (Spitzer et al., 1995). While others showed that as cow BCS increased so did calf ADG (Kunkle et al. 1994). Both cow BW and BCS at weaning were moderately to strongly positively correlated with IFAT for all 4 years. These results were as expected based on previous work examining relationships of cow fatness measures to BW. Selk et al. (1988) observed fluctuations in BCS as cow BW increased

Table 3.19. Pearson correlation coefficients between internal fat measures and phenotypic traits[1]

Items	$IFAT_{Yr1}$[2]	$IFAT_{Yr2}$	$IFAT_{Yr3}$	$IFAT_{Yr4}$
Year 1				
WW	-0.51**	-0.38**	-0.18	0.30**
Cow BW at weaning	0.75**	0.73**	0.17	-0.16
Cow BCS at weaning	0.39**	0.70**	0.26**	0.02
Year 2				
WW	-0.48**	0.01	-0.28**	-0.11
Cow BW at weaning	0.70**	0.56**	0.54	0.06
Cow BCS at weaning	0.60**	0.58**	0.57	0.07
Year 3				
WW	-0.40	0.03	0.09	-0.39
Cow BW at weaning	0.35	0.26**	0.55**	0.15
Cow BCS at weaning	-0.05	0.08	0.46**	0.24**
Year 4				
WW	-0.38	-0.31	-0.18	-0.14
Cow BW at weaning	0.34	-0.08	0.22*	0.52**
Cow BCS at weaning	0.06	-0.04	0.28**	0.55**

[1] EEI = energy efficiency index, BCS = body condition score, IFAT = internal fat, Yr = Year

[2] IFAT = -11.41292 + 16.23754 × uBF + 1.83249 × uKFd

* and ** indicate that correlation coefficients differ from zero at $P < 0.10$ and $P < 0.05$, respectively

or decreased. Spitzer et al. (1995) observed a similar relationship between BW and BCS at calving. Bullock et al. (1991) reported a strong positive correlation between an ultrasound measure to predict fat stores of beef cows and BCS.

In summary, evaluations of 4 years of data collection indicate that the model's estimations of EEI and peak milk appear to be heritable and repeatable across years, as indicated by strong correlations of EEI and peak milk across years. Cows with a lower EEI, and therefore more efficient cows as indicated by the model, have a greater model-predicted peak milk and greater milk EPDs. This indicates a potential to wean heavier calves. This is further supported by the positive relationship between peak milk and WW EPD. For most years, the positive relationship between EEI and IFAT indicate that more efficient cows have less internal fat and are leaner. These results indicate that EEI may be a useful tool in selecting and ranking cows that are more efficient at converting available forage to more lbs of weaned calf.

CHAPTER IV

EFFECTS OF A SLOW-RELEASE UREA PRODUCT ON PERFORMANCE AND CARCASS CHARACTERISTICS OF BEEF STEERS FED STEAM-FLAKED CORN

OBJECTIVES

The objectives were to examine the impact of source (urea or slow-release urea; **SRU;** Optigen® II) and level of NPN on (1.) performance of growing cattle fed steam-flaked corn and (2.) the carcass characteristics of these cattle.

MATERIALS AND METHODS

All animal procedures were approved by the Texas A&M University Institutional Animal Care and Use Committee (IACUC # 2007-172).

Animals and Management

Sixty steers were obtained from at the Texas A&M University Agriculture Research Station at McGregor, TX. Steers were sired by Angus bulls and out of 5/8 Angus 3/8 Nellore dams. One week after weaning, BW, hip height (**HH**), exit velocity (**EV**), and chute score (**CS**) were obtained. Exit velocity was calculated as the distance (1.83 m) traveled per second upon exiting the squeeze chute, as described by Burrow et al. (1988). The CS for all steers was recorded by the same observer, according to the 5-point system described by Grandin (1993): 1 = calm, no movement; 2 = restless, shifting; 3 = squirming, occasionally shaking of the chute; 4 = continuous vigorous

movement and shaking of the chute; 5 = rearing, twisting of the body, or violent struggling. Steers were blocked by post-weaning BW, and randomly assigned to treatment (**TRT**) and pen within block, with 5 pens/TRT and 4 steers/pen. Following 2 weeks of adaptation to bunks, steers were sorted to pens and adapted over 69 d to 1 of 3 steam-flaked corn based diets. Steers were fed 6 step-up diets containing increasing amounts of steam-flaked corn and NPN source during this adaptation period. Without restriction of feed and water, BW were collected prior to feeding, every 14 d throughout the measurement period. At both the start and end of the trial, BW, HH, EV, CS, and ultrasound carcass measures (intramuscular fat **IMF;** LM area **LMA**, fat thickness **FT**) were obtained. Individual intakes were measured using Calan gate feeders (American Calan, Northwood, NH) for 105 d. Feed was delivered twice daily, with feed refusals measured weekly.

Residual Feed Intake

Residual feed intake (**RFI**) was measured during the first 70 d of test. Average daily gain and initial BW (**IBW**) were determined from the linear regression of the first 70 days on test. The RFI was calculated within treatment as the difference between actual DMI and the DMI predicted from the multiple linear regression of DMI on mid-test metabolic BW and ADG using Eq. [1]. The RFI is the ε term in Eq. [1].

$$DMI = \beta_0 + \beta_1 \times BW^{0.75} + \beta_2 \times ADG + \varepsilon \quad [1]$$

where β_0 is the intercept, β_1 is the slope of mid-test metabolic BW, β_2 is the slope of ADG, and ε is the normally, independently, identically distributed error term (i.e. RFI).

Diets

Table 4.1 provides the composition of the TRT diets used in the study. TRT 1 (1.2% NPN) contained urea as the NPN source, TRT 2 (1.3% NPN) contained SRU as the NPN source, while TRT 3 (3.1% NPN) contained SRU as the NPN source with no cottonseed meal. TRT 1 and TRT 2 contained cottonseed meal and NPN as CP sources, while TRT 3 contained only NPN. TRT 1 and TRT 2 were isonitrogenous (CP = 13.2%) and isoenergetic (ME = 2.58 Mcal/kg DM), while TRT 3 was isoenergetic with more CP (14.8%).

Individual feed ingredients were sampled weekly, and composited for analysis. Chemical analysis was conducted by an independent laboratory (Cumberland Valley Analytical Services Inc., Hagerstown, MD). Chemical analysis of the feed ingredients was used with the Large Ruminant Nutrition System (**LRNS**; http://nutritionmodels.tamu.edu) to balance the diets for ME and metabolizable protein (**MP**), and ruminal N balance. The LRNS is based on the Cornell Net Carbohydrate and Protein System (**CNCPS**) version 5, as described by Fox et al. (2004b).

In Vitro Anaerobic Fermentation and Gas Production

Analysis was performed at the Ruminant Nutrition Laboratory at Texas A&M University using whole samples of each TRT as well as individual feed ingredients, excluding NPN and molasses. The in vitro anaerobic fermentation chamber was similar to that described by Pell and Schofield (1993) and Schofield and Pell (1995). The

Table 4.1. Ingredient and nutrient composition of experimental diets[1]

Items	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$
Ingredient, % of DM			
Steam flaked corn[2]	66.8	66.7	72.2
Cottonseed hulls	16.7	16.7	16.7
Cottonseed meal	7.18	7.18	0
Molasses	5.71	5.71	5.7
Vitamin/Mineral Premix	2.35	2.35	2.35
Urea	1.2	0	0
SRU	0	1.31	3.06
Nutrient composition[3]			
DM, %	85	85	85
CP, % of DM	13.2	13.3	14.8
NDF, % of DM	25.1	25.1	23.7
NPN, % of DM	1.3	1.3	3.1
ME, Mcal/kg	2.6	2.6	2.6
Starch, % of NFC	89.7	89.7	90.3
Soluble CP[4], % of DM	41	24	28
DIP, % of DM	69	70	78
IVGP Fermentations[5]			
ME, Mcal/kg	2.63	2.63	2.67
TDN, %	72.8	72.8	73.8

[1] $U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% SRU, $O_{3.1}$= 3.1% SRU no cottonseed meal, IVGP= in vitro gas production, NFC = non-fiber carbohydrate, DIP = degraded intake protein
[2]Corn amount also contains corn used as carrier for treatments
[3]Nutrient composition values from composites of individual feed ingredients sampled weekly and predicted by the Large Ruminant Nutrition System.
[4]LRNS uses 35% soluble CP for Optigen; we assumed solubility equal to urea (100%).
[5]Assuming a fractional passage rate of 6%/h.

chamber and procedures used in this analysis were described by Tedeschi et al. (2009). Briefly, the chamber included an incubator with multi plate stirrer, pressure sensors

attached to 125-mL Wheaton bottles, which served as incubation flasks, an analog to digital converter device, and a PC-compatible computer provided with appropriate software (Pico Technology, Eaton Socon, Cambridgeshire, UK). Computer software automatically recorded pressure inside the flasks every 5 min over the 48 h incubation period. Approximately 200 mg of feed (whole TRT and individual feed ingredients) samples were added to a 125-mL Wheaton bottle, containing a Teflon-covered stir bar, and samples were then wetted with 2.0 mL of distilled water in order to prevent particle scattering. The phosphate-bicarbonate medium and reducing solution of Goering and Van Soest (1970) was used as in vitro medium, and continuously ventilated with CO_2. Bottles were filled with 14 mL each of media, utilizing strict anaerobic technique in all transfers. Bottles were sealed with unused, lightly greased, butyl rubber stoppers, and crimp sealed. Rumen fluid inoculum was obtained from a non-lactating rumen-cannulated Jersey cow, which had free access to mixed forages and mineral supplementation. The rumen fluid was filtered through 4 layers of cheesecloth followed with filtering through glass wool, and flushing continuously with CO_2. When it was observed that the fermentation chamber had reached 39ºC, 4 mL of rumen fluid were added to each bottle, the chamber door was closed and temperature allowed to rise back to 39ºC. At this point, each bottle was punctured with a needle for 5 s to zero pressure inside the bottle. Pressure recording was initiated when the chamber had once again reached 39ºC and continued for 48 h.

Carcass

The three most and least efficient steers from each TRT were selected based on RFI calculated within TRT, for 18 steers, 6 steers per TRT. Feed was withheld overnight with free access to water, and steers were slaughtered at the Rosenthal Meat Science and Technology Center, Texas A&M University, College Station. Live BW, HCW, and organ weights (spleen, heart, kidney, and liver) were recorded. The whole gastrointestinal tracts (**GIT**) were removed and dissected, after a 24 h chill, to obtain total physical separable internal fat weights. As described by Ribeiro et al. (2008), measurements of carcass kidney fat depth (**cKFd**) were taken from the hot carcass by using a tape measure. The measurement was taken from the midline (vertebrae) to the end of the kidney fat. The KPH depot was removed from the carcass before splitting. The 9 to 11th rib sections were removed according to Hankins and Howe (1946). Rib sections from each steer were dissected, and fat, lean, and bone were separated and weights recorded. Fat and lean tissues were analyzed to determine moisture, fat, and protein content according to Hankins and Howe (1946) procedure. Nitrogen was determined by total combustion (Rapid N Cube, Elementar Americas, Inc, Mt Laurel, NJ), moisture percentage was calculated using an oven-dry procedure, and fat content determined by Soxhlet apparatus using diethyl ether (AOAC, 1990). Tissue CP was calculated as N × 6.25.

Calculations and Statistical Analyses

Animal Performance and Carcass Measures. The experimental unit for the performance trial was the pen, as TRT were assigned to individual pens to prevent cross

feeding of animals fed different TRT. All data was analyzed using SAS version 9.2 using PROC MIXED (SAS Int. Inc., Cary, NC). Treatment effects were declared significant at $P < 0.05$ and trends were declared at $P < 0.10$. Cumulative animal performance was evaluated in 3 periods, with period 1 as d 0 to 35, period 2 as d 0 to 70, and period 3 as d 0 to 105, with period 3 representing the entire 105 d trial. The IBW was used as a covariate when either IBW or its interaction with TRT were deemed significant at $P < 0.10$. For those variables, with a significant interaction between IBW and TRT, results were examined at 325 and 375 kg IBW, which contained the lightest and heaviest initial steers based on an average BW of 353 kg with a range of 280 to 414 kg. Orthogonal contrasts were used to evaluate differences between TRT 1 and TRT 2, and TRT 1 plus TRT 2 with TRT 3.

Gas Production Data. Kinetic analysis of the 48-h cumulative gas production was evaluated using several nonlinear functions as described by Tedeschi et al. (2008a,b). The nonlinear function with the lowest sum of square errors was selected. Nonlinear fitting was performed using GasFit 3.6 (http://nutritionmodels.tamu.edu) as described by Williams et al. (2010). Gas production data was used to compute TDN and ME as described by Tedeschi et al. (2009) and Aguiar et al. (2011), and to compare them with the TDN and ME predicted by the LRNS model.

RESULTS AND DISCUSSION

Animal Performance

Steer performance over the 105 d trial is given in Table 4.2. There were no significant differences in IBW or final BW among the 3 TRT ($P = 0.74$ and $P = 0.12$; respectively). However, steers in TRT 3 were numerically 15 kg lighter at the start of the trial, likely due to differences in step up diets, than steers in TRT 2 and 13 kg lighter than steers in TRT 1. The orthogonal contrast analysis indicated that steers in TRT 1 were lighter at the end of the test than steers on TRT 2 ($P = 0.04$), with no difference in final BW between steers in TRT 1 and 2 combined as compared to TRT 3 ($P = 0.64$). There was a tendency for an interaction ($P = 0.09$) between IBW and TRT for final BW, such that for steers with lighter initial weights, TRT 2 had the heaviest final BW of 465 kg, and tended ($P = 0.09$) to be heavier than steers on TRT 1, which had final BW of 445 kg. Steers on TRT 3 were intermediate in their final BW at 455 kg. For steers with heavier IBW, TRT 3 (514 kg) had the heaviest final BW followed by TRT 1 (510 kg) and TRT 2 (506 kg), but were not statistically different ($P > 0.10$).

It was hypothesized the synchronization between carbohydrate ruminal degradation and NPN release into the rumen would improve the efficiency of utilization of available N, thereby improving animal performance. No statistical difference in animal performance for the complete 105-d feeding trial was observed. Taylor-Edwards et al. (2009a) supplemented urea and a SRU to steers fed a corn-silage based diet. As

Table 4.2. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on performance, intake, and efficiency of beef steers[1]

	Period 1 (0-35 d)				Period 2 (0-70 d)				Period 3 (0-105 d)			
Items	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM[2]	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM
IBW, kg									357	359	344	13.9
FBW, kg	388	390	390	1.56	425	430	431	2.97	482	489	489	6.22
ADG, kg/d	1.19	1.29	1.31	0.06	1.31	1.38	1.44	0.08	1.18	1.23	1.24	0.06
DMI, kg/d	7.85	7.75	7.49	0.23	8.13	8.17	7.94	0.23	8.24	8.18	7.95	0.17
F:G	$7.39^{a,x}$	$6.09^{a,b,y}$	5.76^{b}	0.47	6.57^{a}	$5.97^{a,b}$	5.58^{b}	0.29	7.14	6.90	6.51	0.30

[1] $U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% SRU, $O_{3.1}$= 3.1% SRU no cottonseed meal, IBW = initial BW, FBW = final BW

[2]Greatest SEM among treatment LS means

^{a,b,c} = Within a row means without a common superscript differ ($P < 0.05$)

^{x,y,z}= Within a row means without a common superscript tended to differ ($P < 0.10$)

was the case in this study, source of NPN did not affect initial or final BW, although their study only evaluated effects over a period of 56 d. Tedeschi et al. (2002), Pinos-Rodriguez et al. (2010), and Wahrmund and Hersom (2007) fed a similar SRU (Optigen® 1200) and found growth performance unaffected by NPN source. Optigen® 1200 was a prilled urea coated with a biodegradable polymer with a controlled release property (Akay et al. 2004).

For period 1, which included the first 35 d of the trial, ADG and DMI did not differ between TRT. Steers in TRT 3 (5.76) had lower ($P < 0.05$) F:G than TRT 1 (7.39), and steers on TRT 2 (6.09) tended ($P=0.07$) to have lower F:G than TRT 1. Both TRT 2 and 3 contained SRU as the NPN source, while TRT 1 contained urea as the sole NPN source. Taylor-Edwards et al. (2009a) observed no improvement in feed efficiency when SRU was fed over urea during the initial phase of the trial, as was observed in this study. However, the authors did observe a slight reduction in DMI for those steers fed SRU as compared to urea over the last half of their study. Although, not significant ($P = 0.53$) in this study, there was a numerical reduction in DMI when SRU was included as the NPN source, with TRT 1 having the greatest initial DMI (7.86 kg/d) and both TRT 2 (7.75 kg/d) and TRT 3 (7.49 kg/d) having slightly lower DMI. It is likely that although differences in ADG and DMI were not significant in this study, the combined difference in the variables resulted in observed differences in F:G during the 1st and 2nd periods of our study.

For period 2, there were no differences in ADG or DMI among the 3 TRT. Steers on TRT 3 (5.58) maintained lower ($P < 0.05$) F:G than TRT 1 (6.57). There was an

interaction between IBW and TRT (P=0.04) for F:G for this period. Initially, lighter steers had lower F:G for TRT 2 (5.48) and TRT 3 (5.66) as compared to steers on TRT 1 (6.91). Steers with a heavier initial weight had no difference in F:G, however, steers on TRT 2 (6.33) had the highest F:G, while TRT 1 (6.31) and TRT 3 (5.52) had lower numerical F:G.

For period 3, the cumulative 105 d trial, there were no differences in ADG, DMI, or F:G. However there was an interaction (P = 0.06) between IBW and TRT such that for steers with a heavier IBW, TRT 1 steers had greater (P = 0.04) DMI (8.7 kg/d) as compared to steers on TRT 3 (8.1 kg/d). For lighter IBW steers, TRT 1 had the least DMI (7.6 kg/d), with TRT 2 (7.9 kg/d) having the greatest DMI, however, there were no differences (P = 0.24) in DMI of lighter steers or average steers for this period. Tedeschi et al. (2002) did not observe differences in DMI during the finishing phase of a trial where steers were fed Optigen® 1200 or urea to prevent ruminal N deficiency as predicted by the CNCPS model. Although steers fed Optigen® 1200 to meet 50% of the ruminal N requirement had lower numerical DMI (8.94 kg/d) as compared to steer fed urea to meet the same requirement (9.44 kg/d). Similarly, Pinos-Rodriguez et al. (2010) fed a diet containing 1.1% Optigen® 1200 and found no difference in DMI as compared to a diet containing no SRU. Duff et al. (2000) noted a tendency for daily DMI to be 3% less in steers fed another SRU (i.e. Ruma Pro) as compared to control steers fed a steam-flaked corn and urea-based diet.

Ultrasound carcass measures from the start and end of the trial, along with the change in composition, are given in Table 4.3. There were no differences in initial

ultrasound carcass measures among the three TRT or in final LMA. Change in ultrasound carcass composition did not differ among the 3 TRT. However, there was an interaction ($P = 0.02$) between IBW and TRT for final FT, such that for steers that began the test at lighter BW, TRT 2 (1.07 cm) had the greatest ($P = 0.04$) final ultrasound FT, as compared to TRT 1 (0.83 cm), while TRT 3 (0.97 cm) was not different ($P = 0.21$). For steers that began the trial at heavier BW, there were no differences in final ultrasound FT ($P = 0.27$), although TRT 2 was the leanest (0.99 cm) while TRT 1 steers were the fattest (1.09 cm. There was also a tendency for an interaction ($P = 0.07$) between IBW and TRT for final IMF. Lighter IBW steers from TRT 3 had the greatest

Table 4.3. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on ultrasound carcass composition of beef steers[1, 2]

	Treatments				Contrast *P*-value	
Items	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM	$U_{1.2}$ vs. $O_{1.3}$	$U_{1.2} + O_{1.3}$ vs. $O_{3.1}$
Initial[3] uLMA, cm^2	47.7	45.6	44.3	2.32	0.51	0.41
Initial uFT, cm	0.56	0.59	0.60	0.04	0.57	0.59
Initial uIMF, %	4.13	3.68	3.96	0.23	0.18	0.85
Final uLMA, cm^2	79.9	76.1	72.9	4.18	0.52	0.33
Final uFT, cm	0.98	1.02	1.03	0.06	0.01	0.82
Final uIMF, %	4.17[a]	3.74[b]	3.93[a,b]	0.14	0.21	0.10
Change in uLMA, cm^2	32.1	29.8	29.5	4.50	0.55	0.94
Change in uFT, cm	0.42	0.43	0.48	0.05	0.02	0.70
Change in uIMF, %	0.05	0.19	0.20	0.20	0.57	0.84

[1] $N = 60$ steers

[2] $U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% SRU, $O_{3.1}$= 3.1% SRU no cottonseed meal, uLMA = ultrasound LM area, uFT = ultrasound fat thickness, uIMF = ultrasound intramuscular fat

[3]Initial ultrasound measures at d -14 and final ultrasound measures at d 105

[a,b,c]Within a row means without a common superscript differ ($P < 0.05$)

IMF (4.12%), with TRT 1 (3.97%) intermediate, and TRT 2 steers having the least IMF (3.79%). For heavier IBW steers, TRT 1 (4.32%) had more IMF ($P < 0.05$) than both TRT 3 (3.79%) and TRT 2 (3.71%). MacNeil et al. (2010) examined a large database of Angus cattle for indicators of carcass marbling using both ultrasound and genomic indicators and found an average IMF from 6,594 animals of 3.91%, which is similar to the steers in this study; therefore, TRT 2 or 3 did not alter the subcutaneous fat deposition.

Carcass Composition and GI Dissection

Table 4.4 has the carcass composition of the 18 steers selected based on RFI from each TRT. The HCW, dressing percentage (**DP**), KPH percentage, and LMA did not differ ($P > 0.10$) between TRT or between high and low RFI steers within TRT. However, steers fed TRT 3 were leaner (FT = 1.04 cm) than steers fed TRT 1 (FT = 1.21 cm), with urea as the NPN source, but adjusted FT did not differ ($P = 0.19$) among TRT. This suggests that steers fed SRU deposited fat differently than steers fed urea, and these differences were corrected for by adjusting fat thickness, and some variation due to carcass dressing procedures may have been removed.

Table 4.4. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on carcass composition of beef steers[1,2,3]

	Treatments				Contrast P-value		RFI		
Items	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM	$U_{1.2}$ vs. $O_{1.3}$	$U_{1.2}$ + $O_{1.3}$ vs. $O_{3.1}$	H	L	SEM
HCW, kg	283	280	271	10.73	0.88	0.45	274	282	8.76
Dressing %	61.9	61.4	61.6	0.58	0.62	0.96	61.4	61.9	0.47
KPH %	3.17	3.37	3.05	0.29	0.62	0.53	3.34	3.05	0.23
LMA, cm^2	71.0	72.4	70.4	2.87	0.74	0.73	70.6	71.9	2.35
FT, cm	1.21^{a}	$1.16^{a,b}$	1.04^{b}	0.05	0.57	0.04	1.27^{a}	1.00^{b}	0.04
Adjusted FT, cm	1.31	1.35	1.23	0.06	0.65	0.21	1.45^{a}	1.14^{b}	0.05
Quality grade	Ch^{16}	Ch^{02}	Se^{91}	0.18	0.61	0.44	Ch^{07}	Ch^{00}	0.15
Yield grade	2.98	2.95	2.81	0.31	0.94	0.70	3.16	2.66	0.26
Marbling	Sm^{77}	Sm^{20}	Sm^{15}	0.39	0.32	0.49	Sm^{40}	Sm^{34}	0.31

[1]*N* = 18 steers

[2]$U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% Optigen, $O_{3.1}$= 3.1% Optigen no cottonseed meal, LMA= LM area, FT= fat thickness, RFI = residual feed intake, H = high, L = low

[3]*N* = 6 steers/treatment and *N* = 9 steers/RFI group

[a,b,c] = Within a row means without a common superscript differ ($P < 0.05$)

[x,y,z]= Within a row means without a common superscript tended to differ ($P < 0.10$)

Steers with high RFI, the least efficient steers (FT = 1.27 cm), were fatter than low RFI, more efficient, steers (FT = 1.00 cm). Richardson et al. (2001) showed that selecting against RFI for a single generation brought about a small decrease in body fat content. Nkrumah et al. (2004) found that low RFI steers had less grade fat (8.83 mm) compared to high RFI steers (11.56 mm), this difference in fat was also noted in ultrasound FT with low RFI steers having 16% less FT. Quality grade, yield grade, and marbling score did not differ among TRT or RFI groups.

The majority of studies examining SRU products have not evaluated effects on carcass composition. Tedeschi et al. (2002) found that steers fed Optigen® 1200 to meet 100% of a ruminal N requirement as predicted by the CNCPS model had smaller REA than steers fed urea to meet the same requirement, but the authors observed no other differences in HCW, DP, BF, KPH %, or quality grade. Pinos-Rodriguez et al. (2010) found no difference in HCW or DP between steers fed urea or Optigen® 1200. Duff et al. (2000) examined the effects of a different SRU (i.e. Ruma Pro) on carcass characteristics of beef steers as compared to a standard steam-flaked corn based diet containing urea and also noted no major difference in carcass composition between the treatments.

The composition of the 9 to 11th rib sections is provided in Table 4.5. There were no differences ($P > 0.19$) in rib section weight, lipid content, protein content, N content, moisture percentage, physical muscle, bone, subcutaneous fat, and seam fat among TRT. However, high RFI steers (inefficient) tended ($P = 0.09$) to have more lipid content in their 9 to 11th rib sections than low RFI steers (efficient), but there were no differences ($P > 0.13$) in subcutaneous fat or seam fat between the RFI groups. This increased lipid content in high RFI steers is consistent with findings in carcass composition with low RFI steers being slightly leaner (Basarab et al., 2003; Nkrumah et al., 2004; Tedeschi et al., 2006).

Table 4.5. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on the 9-11 rib section composition of beef steers[1,2]

	Treatments				Contrast *P*-value		RFI		
Items	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM	$U_{1.2}$ vs. $O_{1.3}$	$U_{1.2}$ + $O_{1.3}$ vs. $O_{3.1}$	H	L	SEM
9- 11th rib section wt, kg	4.73	4.72	4.54	0.17	0.95	0.40	4.71	4.62	0.14
Lipid, %	41.5	38.5	40.6	2.00	0.32	0.81	42.3^{x}	38.1^{y}	1.64
Protein, %	13.5	14.3	14.0	0.5	0.34	0.86	13.6	14.4	0.4
Nitrogen, %	2.17	2.29	2.25	0.09	0.34	0.86	2.17	2.30	0.07
Moisture, %	44.2	46.0	45.0	1.60	0.44	0.93	43.5	46.6	1.3
Physical muscle, kg	1.90	2.04	1.82	0.11	0.39	0.29	1.88	1.97	0.09
Bone, kg	0.82	0.84	0.85	0.06	0.83	0.84	0.81	0.86	0.05
Subcutaneous fat, kg	1.02	1.00	0.77	0.13	0.91	0.19	0.92	0.94	0.11
Seam fat, kg	0.92	0.79	0.97	0.15	0.55	0.55	1.03	0.75	0.12

[1]*N* = 18 steers

[2]$U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% SRU, $O_{3.1}$= 3.1% SRU no cottonseed meal, RFI = residual feed intake, H = high, L = low

[a,b,c] = Within a row means without a common superscript differ ($P < 0.05$)

[x,y,z]= Within a row means without a common superscript tended to differ ($P < 0.10$)

Table 4.6. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on internal organ measurements of beef steers[1, 2]

	Treatments				Contrast *P*-value		RFI		
Item	$U_{1.2}$	$O_{1.3}$	$O_{3.1}$	SEM	$U_{1.2}$ vs. $O_{1.3}$	$U_{1.2}$ + $O_{1.3}$ vs. $O_{3.1}$	H	L	SEM
GIT fat, kg	$32.6^{x,y}$	33.9^{x}	28.1^{y}	2.12	0.69	0.07	32.1	31.0	1.73
Separable internal fat, kg	2.42^{x}	$2.08^{x,y}$	1.66^{y}	0.27	0.38	0.10	2.19	1.92	0.22
GIT wt, kg	69.2	73.1	70.0	4.27	0.53	0.83	68.3	73.1	3.49
KPH wt, kg	9.3	9.8	8.4	0.79	0.64	0.25	9.43	8.87	0.65
KPH depth, cm	18.7	18.6	17.4	0.70	0.93	0.19	18.7	17.8	0.57
Spleen wt, kg	0.74	0.79	0.74	0.04	0.37	0.60	0.77	0.74	0.03
Heart wt, kg	1.59^{a}	$1.57^{a,b}$	1.42^{b}	0.05	0.78	0.03	1.53	1.52	0.04
Liver wt, kg	5.72	5.63	5.39	0.22	0.78	0.31	5.66	5.50	0.18
Kidney wt, kg	0.93^{a}	$0.85^{a,b}$	0.76^{b}	0.04	0.16	0.02	0.84	0.85	0.03

[1] *N* = 18 steers

[2] $U_{1.2}$=1.2% Urea, $O_{1.3}$= 1.3% SRU, $O_{3.1}$= 3.1% SRU no cottonseed meal, GIT = gastrointestinal tract, RFI = residual feed intake, H = high, L = low

^{a,b,c} = Within a row means without a common superscript differ ($P < 0.05$)

^{x,y,z}= Within a row means without a common superscript tended to differ ($P < 0.10$)

Table 4.6 lists organ measurements as well as GIT composition for the steers from each TRT as well as for the RFI groups. The TRT 2 animals tended to have more GIT tract fat ($P = 0.08$) than TRT 3, while TRT 1 and 3 did not differ ($P = 0.16$). However, TRT 2 and 3 did not differ ($P = 0.30$) in terms of separable internal fat, but TRT 1 tended ($P = 0.07$) to have more separable internal fat than TRT 3. The GIT weight did not differ ($P > 0.48$) among TRT. Kideney, pelvic, and heart fat depth, and spleen weight did not differ ($P > 0.22$) among TRT. Steers fed urea and cottonseed meal as protein sources (TRT 1) had heavier ($P = 0.03$) hearts than steers fed SRU as a protein source (TRT 3). Liver weights did not differ ($P > 0.46$) among TRT, however steers fed urea and cottonseed meal as a protein source (TRT 1) had 18.3% heavier ($P = 0.01$) kidneys than steers fed SRU as a protein source (TRT 3).

In conclusion, these results suggested that when compared to urea, as a NPN source for finishing beef cattle diets, steers fed SRU, as the only source of feed N, were more efficient during the initial feeding period. Overall growth and DMI were not affected by NPN source over the 105-d feeding period. These data also indicated that when SRU was the only source of feed N (TRT 3) steers were slightly leaner, but marbling score and QG were unaffected. These results suggested that feedlot steers may benefit from a SRU product (e.g. Optigen® II) as the only source of feed N without negatively impacting carcass quality. However, more research examining the impacts of longer feeding periods may be warranted.

CHAPTER V

EFFECTS OF A SLOW-RELEASE UREA PRODUCT ON NITROGEN BALANCE OF FINISHING STEERS FED STEAM-FLAKED CORN

OBJECTIVES

Our objectives were to examine the impact of source, (urea or a slow-release urea; **SRU**; Optigen® II) and level (0, 0.75, or 1.5%) of NPN on the N balance of finishing steers.

MATERIALS AND METHODS

All animal procedures were approved by the Texas A&M University Institutional Animal Care and Use Committee (IACUC # 2007-172).

Five ruminally fistulated Holstein steers (average initial BW 212 ± 26) were used in a 5 ×5 Latin square. The study was designed to evaluate the effect of level of inclusion and source of NPN in finishing diets. Steers were housed in a continuously lighted barn and were provided ad libitum access to fresh water and offered a finishing diet (Table 5.1) at 110% of average voluntary intake for the preceding 4 d.

Treatments were arranged in a 3 × 2 factorial with 3 levels of NPN inclusion (0, 0.75% and 1.5%) and 2 sources of NPN (urea and Optigen® II). Levels of each of the sources of NPN were designed to be iso-nitrogenous. Steers were fed once daily at 0630. Treatments were hand mixed into each steer's ration daily. Ingredients and composition of experimental diets are described in Table 5.1.

Experimental periods were 16 d long, with 10 d for adaptation to treatments and 6 d for sample collection. During adaptation periods steers were housed in individual pens. During collection periods, steers were housed in metabolism crates to facilitate total collection of urine and feces.

Table 5.1. Ingredient and nutrient composition of experimental diets[1]

		Urea		SRU	
Items	Control	L	H	L	H
Ingredient, % of DM					
Steam flaked corn[2]	74.1	73.5	72.9	73.4	72.8
Cottonseed hulls	17.5	17.4	17.2	17.3	17.2
Molasses	6.0	5.9	5.9	5.9	5.9
Vitamin/Mineral Premix	2.5	2.4	2.4	2.4	2.4
Urea	0	0.78	1.55	0	0
SRU	0	0	0	0.87	1.73
Nutrient composition[3]					
DM, %	85	85	85	85	85
CP, % of DM	7.2	9.4	11.6	9.4	11.6
NDF, % of DM	24.6	24.5	24.2	24.4	24.2
NPN, % of DM	0	0.78	1.55	0.87	1.73
ME, Mcal/kg	2.63	2.62	2.61	2.62	2.60
Starch, % of NFC	90.1	90.1	90.1	90.1	90.1
Soluble CP[4], % of DM	20	39.2	51.0	39.2	51.0
DIP, % of DM	56	67	73	70	72

[1] SRU = slow-release urea, NFC = non-fiber carbohydrate, DIP = degraded intake protein

[2]Corn amount also contains corn used as carrier for treatments

[3]Nutrient composition values from composites of individual feed ingredients sampled weekly and predicted by the Large Ruminant Nutrition System.

[4]LRNS uses 35% soluble CP for SRU; we assumed solubility equal to urea (100%).

[5]Assuming a fractional passage rate of 6%/h.

Feed and ort samples were collected from d 11 through 14 to correspond to fecal and urine samples collected from d 12 through 15. Orts were collected at approximately 0600 and approximately 200 g were retained for later analysis. Fecal bags and urine buckets were removed and contents weighed at 0615 daily. Feces collected over each 24-h period were thoroughly mixed, and 3% was sampled and frozen (-20◦ C) for subsequent analysis. Urine collected over each 24-h period was thoroughly mixed and 2% was retained as a sample and subsequently frozen (-20◦ C). Urine pH was maintained below 3 by adding 400 mL of 6 M HCl to urine containers prior to collection.

Laboratory Analysis

Partial DM of feed, ort, and fecal samples were determined by drying at 55◦ C for 96 h in a forced air oven. All dried samples were ground with a Wiley mill to pass a 1-mm screen. Ort and fecal samples were composited by steer across days. Feed, ort and fecal samples were dried for 24 h at 105◦ C in a forced air oven to determine DM and then combusted for 8 h at 450◦ C in a muffle furnace for OM determination. Nitrogen content of feed, wet feces, and urine was determined by total combustion (Rapid N Cube, Elementar Americas, Inc, Mt Laurel, NJ). Crude protein was calculated as N × 6.25.

Calculations and Statistical Analysis

Nitrogen retained was calculated as the difference between N consumed (N in feed – N in ORTS) and N excreted in both urine and feces. N absorbed was calculated as the difference between N consumed and N excreted in the feces. Dry matter digestibility

was calculated as (DM consumed – DM in feces) ÷ DM consumed. Organic matter digestibility (**OMD**) was calculated as (OM consumed – OM in feces) ÷ OM consumed. Total digestible organic matter intake (**TDOMI**) OM intake x OMD.

Data were analyzed using PROC mixed of SAS (SAS Int. Inc., Cary, NC). Orthogonal contrasts were used to evaluate differences between SRU and urea, and high and low level of NPN.

RESULTS AND DISCUSSION

Nitrogen Balance

The effect of source and level of NPN inclusion for finishing steers are given in Table 5.2. Steers fed SRU tended ($P = 0.06$) to have lower N intake than those fed urea. As expected, high treatments (**TRT**) of both NPN sources had greater N intake than low. Although not significant, steers fed SRU had lower numerical DMI as compared to steers fed urea, which is reflected in the differences in N intake observed in Table 5.2. Steers fed high SRU tended ($P = 0.08$) to have greater fecal N excretion than low SRU; 46.8 and 36.3 g/d, respectively. There were no differences in fecal N excretion between urea and SRU. As expected, for both urea and SRU, high TRT levels had greater urinary N excretion ($P < 0.05$) than low TRT, while urinary N did not differ between urea and SRU.

In contrast to these results, when Taylor-Edwards et al. (2009b) fed a SRU and urea to Angus and Holstein steers, fecal N excretion was greater for steers fed SRU, while N intake and urinary N did not differ among treatments. Taylor-Edwards et al.

(2009b) had slight differences in CP content of their SRU and urea diets with 12.7% CP in the SRU diet compared to 13.0% CP in the SRU diet. This is reflected in the fact that SRU fed steers consumed slightly more feed, but slightly less N. In the current experiment, treatments were designed to be iso-nitrogenous, as Optigen® II contains 41% N as compared to 46% N in urea. Galo et al. (2003) fed lactating Holstein females a diet with or without a coated urea product (Optigen 1200) and found that cows fed SRU had greater N intake and urinary N, but lower fecal N.

N absorption differed ($P < 0.05$) for both source and level of NPN. Urea fed steers absorbed more N than SRU fed steers. It is likely that this difference in N absorption is due to a greater N intake by the urea fed steers as fecal N did not differ among the treatments. N retention did not differ between high SRU and low SRU (58.0 vs. 46.0 g/d), while steers fed high urea tended ($P = 0.08$) to have greater N retention than steers fed low urea (78.3 vs. 55.9 g/d). Steers fed urea tended ($P = 0.09$) to retain more N than SRU fed steers. In agreement with these results, Taylor-Edwards et al. (2009b) found steers fed SRU tended to have lower N retention than steers fed urea. This is contrary to the hypothesis that SRU would release urea at a slower rate to allow more efficient utilization of NH_3 and therefore allow for greater N utilization and retention. Owens et al. (1980) found no difference in N retention for steers fed urea as compared to a coated SRU product. This difference in N retention is largely attributable to difference in N intake.

Table 5.2. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on N balance of finishing steers.[1,2]

		Treatment means					Contrast P-values		
		SRU		Urea			H x L	H x L	SRU x
Items	Control	L	H	L	H	SEM	SRU	Urea	Urea
Nitrogen (N), g/d									
Intake	96.5	104	142	127	164	15.51	0.03	0.03	0.06
Fecal	40.6	36.3	46.8	44.6	46.3	5.60	0.08	0.76	0.33
Urinary	17.3	22.1	37.1	26.7	39.8	4.43	0.001	0.003	0.17
Absorbed	55.4	68.1	95.1	82.6	118	11.0	0.04	0.01	0.04
Retained	36.8	46.0	58.0	55.9	78.3	9.88	0.31	0.08	0.09
N retained/N intake	0.38	0.45	0.41	0.44	0.46	0.04	0.38	0.66	0.56
N absorbed/N intake	0.56	0.66	0.67	0.65	0.71	0.02	0.86	0.03	0.41
N retained/N absorbed	0.66	0.68	0.61	0.68	0.65	0.05	0.25	0.61	0.60
N retained, g/ TDOMI, kg	8.52	9.71	11.8	10.9	13.3	1.15	0.14	0.10	0.19

[1] SRU = slow-release urea, TDOMI = total digestible organic matter intake, L = low treatment, H = high treatment

[2]Greatest SEM among treatment LS means

The ratio of N retained to N intake did not differ for source or level of NPN. The ratios of N retained to N absorbed and N retained to TDOMI also did not differ for source or level of NPN, with the exception of high and low urea. The ratio of N retained per g of TDOMI tended ($P = 0.10$) to be greater for steers fed high urea as compared to low urea. However, the ratio of N absorbed to N intake differed between high and low urea ($P = 0.03$), but not between high and low SRU or between urea and SRU. In agreement with these results, Taylor-Edwards et al. (2009b) also found no difference in N retention as a % on N intake.

Intake and Digestibility

Intake and digestibility means are given in Table 5.3. Source of NPN tended to affect DMI, as steers fed urea had greater DMI than steers fed SRU. Previous research has shown either no differences in DMI between urea and SRU (Galo et al., 2003) or observed an increase in digestible DMI for SRU fed steers (Owens et al., 1980). This discrepancy is likely due in part to differences in CP content of diets and growth rates of animals. There were no differences in DMI among level of treatment. However, OM intake also tended to be lower for SRU fed steers. It is possible that SRU may slightly depress intake in this diet, as the basal diet only contained 7.2% CP. This depression in intake was also noted in evaluating the effects of this SRU on performance and carcass characteristics (see CHAPTER IV). In contrast to these results, Taylor-Edwards et al. (2009b) found no difference in DMI or OM intake.

Steers fed SRU also had lower TDOMI ($P = 0.05$) than steers fed urea, but there were no differences in TDOMI between high and low levels of urea or SRU. Organic

Table 5.3. Effects of the inclusion of urea or SRU in steam-flaked corn based rations on intake and digestibility of finishing steers.[1,2]

	Treatment means						Contrast P-values		
		SRU		Urea			H x L	H x L	SRU x
Items	Control	L	H	L	H	SEM	SRU	Urea	Urea
DMI, kg/d	7.16	6.82	7.26	7.49	8.14	0.71	0.49	0.31	0.10
TDOMI, kg/d	4.41	4.76	4.84	5.10	5.76	0.46	0.85	0.13	0.05
OM digestibility, %	63.98	73.7	69.9	71.4	73.8	2.81	0.24	0.43	0.70
OM intake, kg/d	6.85	6.53	6.96	7.17	7.81	0.68	0.48	0.30	0.10

[1] SRU = slow-release urea, L = low treatment, H = high treatment, TDOMI = total digestible organic matter intake, DMI = dry matter intake, OM= organic matter

[2]Greatest SEM among treatment LS means

matter digestibility did not differ for source or level of NPN. There were no differences in OMD among source or level of treatment. Previous studies have also found SRU did not have an effect on digestibility (Owens et al. 1980; Galo et al. 2003; Taylor-Edwards et al. 2009b; Oltjen et al. 1968).

In summary, high levels of either NPN source had greater N intake and urinary N excretion, as well as N absorption and no major differences were observed between SRU and urea, suggesting that SRU can replace urea at different levels of N intake.

CHAPTER VI

CONCLUSIONS

Evaluations of 4 years of data collection indicate that the CVDSbc estimations of energy efficiency index (**EEI**) and peak milk appear to be heritable and repeatable across years, as indicated by strong correlations of EEI and peak milk across years. Cows with a lower EEI (more efficient) have a greater model-predicted peak milk and greater milk expected progeny differences (**EPD**). This indicates a potential to wean heavier calves. This is further supported by the positive relationship between peak milk and weaning weight (**WW**) EPD. For most years, the positive relationship between EEI and internal fat (**IFAT**) indicate that more efficient cows have less internal fat and are leaner. These results indicate that EEI may be a useful tool in selecting and ranking cows that are more efficient at converting available forage to more weight of weaned calf.

The evaluation of a slow-release urea (Optigen® II) and its effects on performance, carcass characteristics and N balance of finishing steers indicated that when compared to urea, as a NPN source for finishing beef cattle diets, steers fed SRU, as the only source of feed N, were more efficient during the initial feeding period. Overall growth and DMI were not affected by NPN source over the 105-d feeding period. These data also indicated that when SRU was the only source of feed N (treatment 3) steers were slightly leaner, but marbling score and quality grade (**QG**) were unaffected. These results suggested that feedlot steers may benefit from a SRU product (e.g. Optigen® II) as the only source of feed N without negatively impacting

carcass quality. However, more research examining the impacts of longer feeding periods may be warranted. High levels of either NPN source had greater N intake and urinary N excretion, as well as N absorption and no major differences were observed between SRU and urea, suggesting that SRU can replace urea at different levels of N intake.

LITERATURE CITED

Aguiar, A. D., L. O. Tedeschi, F. M. Rouquette, Jr., K. C. McCuistion, J. A. Ortega-Santos, R. C. Anderson, D. DeLaney, and S. Moore. 2011. Determination of nutritive value of forages in south Texas using an in vitro gas production technique. Grass and Forage Science. doi: 10.1111/j.1365-2494.2011.00809.x

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., 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.

Bach, A., S. Calsamiglia, and M. D. Stern. 2005. Nitrogen metabolism in the rumen. J. Dairy Sci. 88(E Suppl.):E9–E21.

Bartley, E.E., A.D. Davidovich, G.W. Barr, G.W Griffel, A.D Dayton, C.W. Deyoe, and R.M. Bechtle. 1976. Ammonia toxicity in cattle I. Rumen and blood changes associated with toxicity and treatment methods. J. Anim. Sci. 43:835-841.

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.

Basarab, J.A., D. McCartney, E.K. Okine, and V.S. Baron. 2007. Relationships between progeny residual feed intake and dam productivity traits. Can. J. Anim. Sci. 87:(4)489-502

Breuer, K., P. H. Hemsworth, J. L. Barnett, L. R. Matthews, and G. J. Coleman. 2000. Behavioural response to humans and the productivity of commercial dairy cows. Appl. Anim. Behav. Sci. 66:273–288

Bullock, K. D., J. K. Bertrand, L. L. Benyshek, S. E. Williams, and D. G. Lust. 1991. Comparison of real-time ultrasound and other live measures to carcass measures as predictors of beef cow energy stores. J. Anim. Sci. 69:3908-3916.

Burrow, H. M. 1997. Measurements of temperament and their relationships with performance traits of beef cattle. Anim. Breed. Abstr. 65:477–495

Burrow, H.M. 2001. Variances and covariances between productive and adaptive traits and temperament in a composite breed of tropical beef cattle. Live. Prod. Sci. 70:213-233

Burrow, H. M., G. W. Seifert, and N. J. Corbet. 1988. A new technique for measuring temperament in cattle. Proc. Aust. Soc. Anim. Prod. 17:154–157.

Clark, J.H., T.H. Klusmeyer, and M.R. Cameron. 1992. Symposium: Nitrogen metabolism and amino acid nutrition in dairy cattle. J. Dairy. Sci. 75: 2304-2323.

DiCostanzo, A., J.C. Meiske, S.D. Plegge, T.M. Peters, and R.D. Goodrich.1990. Within-herd variation in energy utilization for maintenance and gain in beef cows. J. Anim. Sci. 68:2156-2165

DiCostanzo, A., J.C. Meiske, and S.D. Plegge. 1991. Characterization of energetically efficient and inefficient beef cows. J. Anim. Sci. 69:1337-1348

Dillard, E. U., M.KM. Yusuff, and O. W. Robinson. 1978. Milk production in Hereford cows II. Heritabilities and repeatabilities. J. Anim. Sci. 47:137-141.

Duff, G.C., D.A. Walker, K.J. Malcom-Callis, M.W. Wiseman, J.D. Rivera, M.L. Galyean, and T. H. Montgomery. 2000. Effects of a slow-release urea product on feedlot performance and carcass characteristics of beef steers. Pages 506-509 in Proc. Western Section, Am. Soc. of Anim. Sci., Vol 51.

Ferrell, C. L. 1988. Contribution of visceral organs to animal energy expenditures. J. Anim. Sci. 66(Suppl. 3):23-34.

Ferrell, C. L., and T. G. Jenkins. 1982. Efficiency of cows of different size and milk production potential. Pages 12–24 in USDA, ARS, Germplasm Evaluation Program Progress Report No. 10:12.MARC, Clay Center, NE.

Ferrell, C. L., and T. G. Jenkins. 1984. Energy utilization by mature, nonpregnant, nonlactating cows of different types. J. Anim. Sci. 58:234-243.

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

Fonnesbeck, P.V., L.C. Kearl, and L.E. Harris. 1975. Feed grade biuret as a protein replacement for ruminants: A review. J. Anim. Sci. 40:1150-1184

Fox, D.G., C.J. Sniffen, and J. D. O'Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. J. Anim. Sci. 88:1475-1495

Fox, D. G., C. J. Sniffen, J. D. O'Connor, J. B. Russell, and P. J. Van Soest. 1992. A net-carbohydrate and protein system for evaluating cattle diets. III. Cattle requirements and diet adequacy. J. Anim. Sci. 70:3578–3596.

Fox, D.G., L.O. Tedeschi, and M. J. Baker. 2004a. Identifying differences in efficiency in beef cattle. Cornell University Department of Animal Science. Animal Science Mimeo 225, Cornell University, Ithaca, NY.

Fox, D. G., L. O. Tedeschi, T. P. Tylutki, J. B. Russell, M. E. Van Amburgh, L. E. Chase, A. N. Pell, and T. R. Overton. 2004b. The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion. Anim. Feed Sci. Technol. 112, 29–78.

Galo, E.,S.M. Emauele, C.J. Sniffen, J.H. White, and J.R. Knapp. 2003. Effects of a polymer-coated urea product on nitrogen metabolism in lactating Holstein dairy cattle. J. Dairy. Sci. 86: 2154-2162

Galyean, M. L. 1996. Protein levels in beef cattle finishing diets: Industry application, university research, and systems results. J. Anim. Sci. 74:2860–2870.

Goering, H. K., and P. J. Van Soest. 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures, and Some Applications). Pages 1-20 in Agricriculture Handbook. No. 379. ARS-USDA, Washington, DC.

Golombeski, G. L., K. F. Kalscheur, A. R. Hippen, and D. J. Schingoethe. 2006. Slow-release urea and highly fermentable sugars in diets fed to dairy cows. J. Dairy Sci. 89:4395–4403

Grandin, T. 1993. Behavioral agitation during handling of cattle is persistent over time. Appl. Anim. Behav. Sci. 36:1–9.

Hatfield, E. E., U. S. Garrigus, R. M. Forbes, A. L. Neumann and W. Gaither. 1959. Biuret- a source of NPN for ruminants. J. Animal Sci. 18:1208-1219

Hoppe, S., H. R. Brandt, S. Konig, G. Erhardt, and M. Gauly. 2010. Temperament traits of beef calves measured under field conditions and their relationships to performance. J. Anim. Sci. 88: 1982-1989.

Houghton PL, Lemenager RP, Horstman LA, Hendrix KS, Moss GE. 1990. Effects o f body composition, pre-and postpartum energy level and early weaning on reproductive performance of beef cows and preweaning calf gain. J Anim Sci. 68: 1438-1446.

Jenkins, T. G., L. V. Cundiff, and C. L. Ferrell. 1991. Differences among breed crosses of cattle in the conversion of food energy to calf weight during the preweaning interval. J. Anim. Sci. 69:2762.

Jenkins, T. G. and C. L. Ferrell. 1994. Productivity through weaning of nine breeds of cattle under varying feed availabilities. I. Initial estimates. J. Anim. Sci. 72:2787-2797.

Jenkins, T. G., and C.L. Ferrell. 2002. Beef cow efficiency-revisited. Pages 636-642 in: Beef Improvement Federation Annual Meeting, 34. Omaha, NE, p. 636-642

Jenkins, T.G., and C.L. Ferrell. 2004. Preweaning efficiency for mature cows of breed crosses from tropically adapted *Bos indicus* and *Bos taurus* and unadapted *Bos taurus* breeds. J. Anim. Sci. 2004. 82:1876–1881.

Johnson, D. E. 1984. Maintenance requirements for beef cattle: Importance and physiological and environmental causes of variation. Page 6 in Proceedings of Beef Cow Efficiency Forum, Fort Collins, CO.

Johnson, D.E., C.L. Ferrell, and T.G. Jenkins. 2003. The history of energetic efficiency research: Where have we been and where are we going. J. Anim. Sci. 81(E. Suppl. 1) E27-E38.

Kellner, O. 1909. The Scientific Feeding of Animals. MacMillan Company, New York.

Kunkle, W. E., R. S. Sand, and D. O. Rae. 1994. Effect of body condition on productivity in beef cattle. Pages 167-178 in: M. J. Fields and R. S. Sand. Factors Affecting Calf Crop. CRC Press, Boca Raton, FL.

Lapierre, H., and G. E. Lobley. 2001. Nitrogen recycling in the ruminant: A review. J. Dairy Sci. 84(Suppl. E):E223–E236.

Lyons, R. K., and J. W. Stuth. 1992. Fecal NIRS equations for predicting diet quality of free-ranging cattle. J. Range Manage.45:238-244.

Lyons, R.K., J.W. Stuth, J.E. Huston, and J.P. Angerer. 1993. Predictions of nutrient composition of the diets of supplemented versus unsupplemented grazing beef cows based on near-infrared reflectance spectroscopy of feces. J. Anim. Sci. 71:530-538

MacNeil, M.D., J. D. Nkrumah, B.W. Woodward, S.L. Northcutt. 2010. Genetic evaluation of Angus cattle for carcass marbling using ultrasound and genomic indicators. J. Anim. Sci. 2010. 88:517–522

Mader, C. J. Y.R. Montanholi, Y.J. Wang, S.P. Miller, I.B. Mandell, B.W. McBride, and K.C. Swanson. 2009. Relationships among measures of growth performance and efficiency with carcass traits, visceral organ mass, and pancreatic digestive enzymes in feedlot cattle. J. Anim. Sci. 2009. 87:1548–1557.

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

McGrann, J.M. 1999. Cow-calf standardized performance analysis (SPA) in the southwest http://agecoext.tamu.edu/spa/standperformance.htm. Accessed October 15, 2005.

Meyer, K., M. J. Carrick, and B.J.P. Donnelly. 1994. Genetic parameters for milk production of Australian beef cows and weaning weight of their calves. J. Anim. Sci. 71:1155-1165.

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.

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

Nkrumah, J. D., D. H. Crews Jr., J. A. Basarab, M. A. Price, E. K. Okine, Z. Wang, C. Li, and S. S. Moore. 2007. Genetic and phenotypic relationships of feeding behavior and temperament with performance, feed efficiency, ultrasound, and carcass merit of beef cattle. J. Anim. Sci. 85:2382–2390.

NRC. 1996. Nutrient Requirements of Beef Cattle, updated 6th Ed. National Academy Press, Washington D.C.

NRC. 2000. Nutrient Requirements of Beef Cattle, updated 7th Ed. National Academy Press, Washington D.C.

Oltjen, R. R. 1968. Effects of feeding ruminants non-protein nitrogen as the only nitrogen source. J. Anim. Sci. 28:673-681.

Oltjen, R. R., L. L. Slyter, A. S. Kozak, and E. E. Williams, Jr. 1968. Evaluation of urea, biuret, urea phosphate and uric acid as NPN sources for cattle. J. Nutr. 94:193-202.

Owens, F.N., K.S. Lusby, K. Mizwicki, and O. Forero. 1980. Slow ammonia release from urea: rumen and metabolism studies. J. Anim. Sci. 50: 527-531

Pell, A. N., and P. Schofield. 1993. Computerized monitoring of gas production to measure forage digestion in vitro. J. Dairy Sci. 76:1063–1073.

Pinos-Rodriguez, J M, L.Y. Pena, S.S. Gonzales-Munoz, R. Barcena, and A. Salem. 2010. Effects of a slow-release coated urea product on growth performance and ruminal fermentation in beef steers. Italian Journal of Animal Science 9:16-19.

Pitchford, W. S. 2004. Genetic improvement of feed efficiency of beef cattle: What lessons can be learnt from other species. Aust. J. Exp. Agric. 44:370–382.

Randel, R.D. 1990. Nutrition and postpartum rebreeding in cattle. J. Anim. Sci. 68:853-862

Reynolds, C.K. and N.B. Kristensen. 2008. Nitrogen recycling through the gut and the nitrogen economy of ruminants: an asynchronus symbiosis. J. Anim. Sci. 86(E. Suppl.):E293-E305 doi:10.2527/jas.2007-0475

Reynoso-Campos, O., Fox, D.G., Blake, R.W., Barry, M.C., Tedeschi, L.O., Nicholson, C.F., Kaiser, H.M., Oltenacu, P.A, 2004. Predicting nutritional requirements and lactation performance of dual-purpose cows using a continuous model. Agric. Syst., 20:67-83

Ribeiro, F. R. B., L. O. Tedeschi, J. R. Stouffer, and G. E. Carstens. 2008. Technical note: A novel technique to assess internal body fat of cattle by using real-time ultrasound. J. Anim. Sci. 86:763–767.

Richardson, E. C., R. M. Herd, V. H. Oddy, J. M. Thomspon, 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.

Schofield, P., and A. N. Pell. 1995. Measurement and kinetic analysis of the neutral detergent-soluble carbohydrate fraction of legumes and grasses. J. Anim. Sci. 73:3455–3463.

Selk, G. E., R. P. Wettemann, K. S. Lusby, J. W. Oltjen, S. L. Mobley, R. J. Rasby, and J. C. Garmendia. 1988. Relationships among weight change, body condition and reproductive performance of range beef cows. J. Anim. Sci. 66:3153−3159

Spitzer J.C., Morrison D.G., Wettemann R.P., Faulkner L.C.. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. J Anim. Sci. 73:1251-1257.

Taylor-Edwards, C. C., G. Hibbard, S. E. Kitts, K. R. McLeod, D. E. Axe, E. S. Vanzant, N. B. Kristensen, and D. L. Harmon. 2009a. Effects of slow-release urea on ruminal digesta characteristics and growth performance in beef steers. J. Anim. Sci. 87:200–208.

Taylor-Edwards, C. C., G. Hibbard, S. E. Kitts, K. R. McLeod, D. E. Axe, E. S. Vanzant, N. B. Kristensen, and D. L. Harmon. 2009b. Influence of slow-release urea on nitrogen balance and portal-drained visceral nutrient flux in beef steers. J. Anim. Sci. 87:200–208

Tedeschi, L. O., M. J. Baker, D. J. Ketchen, and D. G. Fox. 2002. Performance of growing and finishing cattle supplemented with a slow-release urea product and urea. Can J. Anim. Sci. 82:567–573.

Tedeschi, L.O., D.G. Fox, and M.J. Baker. 2004. In: Proceedings of the New York Beef Cattle Winter Management meeting. Cornell Animal Science Department Mimeo 224, Cornell University, Ithaca, NY.

Tedeschi, L. O., D. G. Fox, M. J. Baker, and D. P. Kirschten. 2006a. Identifying differences in feed efficiency among group-fed cattle. J. Anim. Sci. 84:767-776.

Tedeschi, L. O., D. G. Fox, M. J. Baker, and K. Long. 2006b. A model to evaluate beef cow efficiency. Pages 84–98 in Nutrient Digestion and Utilization in Farm Animals: Modeling Approaches. E. Kebreab, J. Dijkstra, A. Bannink, W. J. J. Gerrits, and J. France, ed. CABI Publ., Cambridge, MA.

Tedeschi, L. O., P. Schofield, and A. N. Pell. 2008a. Determining feed quality for ruminants using in vitro gas production technique. 1. Building an anaerobic fermentation chamber. Page 16-31 in The 4th Workshop on Modeling in Ruminant Nutrition: Application of the Gas Production Technique, Embrapa. Juiz de Fora, MG, Brazil.

Tedeschi, L. O., P. Schofield, and A. N. Pell. 2008b. Determining feed quality for ruminants using in vitro gas production technique. 2. Evaluating different models to assess gas production measurements. Page 32-47 in The 4th Workshop on Modeling in Ruminant Nutrition: Application of the Gas Production Technique, Embrapa. Juiz de Fora, MG, Brazil.

Tedeschi, L.O., and D.G. Fox. 2009. Predicting milk and forage intake of nursing calves. J. Anim. Sci. 87:3380-3391

Tedeschi, L. O., P. J. Kononoff, K. Karges, and M. L. Gibson. 2009. Effects of chemical composition variation on the dynamics of ruminal fermentation and biological value of corn milling (co)products. J. Dairy Sci. 92:401–413.

Thompson, L.H., M.B. Wise, R.W. Harvey, and E.R. Barrick. 1972. Starea, urea, and sulfur in beef cattle rations. J. Anim. Sci. 35: 474-480.

Tikofsky, J. and G. A. Harrison, 2007. Optigen II: Improving the efficiency of nitrogen utilization in the dairy cow. Pages 373-380 in Nutritional Biotechnology in the Feed and Food Industries. Proc. Alltech's 23rd Annual Symp. T. P. Lyons and Jacques, K. A., eds. Alltech Inc., Lexington, KY, USA.

USDA. National Agricultural Statistics Survey. 2011. http://www.nass.usda.gov /QuickStats/index2.jsp. Accessed August 10, 2011.

Vasconcelos, J. T. and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772-2781.

Voisinet, B.D., T Gardin, and J.D. Tatum. 1997. Feedlot cattle with calm temperaments have higher ADG than cattle with excitable temperaments. J. Anim. Sci. 75:892-896

Wahrmund, J.L., and M.J. Hersom, 2007. Evaluation of dried distillers grains or soybean hulls with and without Optigen® II to background beef calves. J. Anim. Sci. 85(Suppl. 1):524 (abstr.)

Waterlow, J.C. 1999. The mysteries of nitrogen balance. Nutrition Research Reviews. 12:25-54

Williams, W. L., L. O. Tedeschi, P. J. Kononoff, T. R. Callaway, S. E. Dowd, K. Karges, and M. L. Gibson. 2010. Evaluation of in vitro gas production and rumen bacterial populations fermenting corn milling (co)products. J. Dairy. Sci. 93:4735-4743.

Wistrand, G.C. and J.K. Riggs. 1966. Milk production of Santa Gertrudis cows as measured by calf nursing and machine milking methods. J. Anim. Sci. 25:263

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