Determining the Nutritional Status of Mature Beef Cows

by

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Thesis submitted to the faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Animal and Poultry Sciences

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January 9, 2002

Blacksburg, VA

Key Words: Nutrition, Cow, Performance, Forage

Abstract

Improved prediction of forage quality and cow performance may enhance the nutritional management of beef cows. In two 12 mo trials, mature beef cows (n=136) grazing tall fescue pastures were used to compare estimates of forage quality and animal performance. Forage quality was estimated by proximate analysis of forage samples (FOR) or by near infrared reflectance spectroscopy of fecal samples (FNIR). Nutritional Balance Analyzer (NutBal), NutBalPro and 1996 NRC Nutrient Requirements of Beef Cattle (NRC) programs were used to predict animal performance. The objectives were to compare FOR and FNIR estimates of CP and TDN and to evaluate the accuracy of cow performance predicted by FNIR-NutBal, FNIR-NutBalPro and FOR-NRC systems. Initial BW, body condition score (BCS), hip height and breed were used to establish cow biotypes for prediction programs. Every 28 d, cow BW and BCS were measured and forage and fecal samples collected. Weather data, cow status and FOR or FNIR results were entered into NutBal, NutBalPro and NRC programs. Forage CP estimated by FNIR (CPFNIR) or FOR (CPFOR) were similar. In trials 1 and 2, correlation coefficients between CPFNIR and CPFOR were $r = .24$ and $r = .43$, respectively. Forage TDN estimated by FNIR was greater ($P < .05$) and lowly or moderately correlated to FOR estimates. Actual BW change between weigh periods (BWCHG) and ADG were similar to NRC predictions, but less ($P < .0001$) than predicted by NutBal or NutBalPro. The NutBal or NutBalPro mean BCS change between weigh periods (BCSCHG) were greater ($P < .001$) than NRC or Actual BCSCHG. Actual and NRC BCSCHG were similar ($P > .2$, trial 1) or tended ($P < .1$, trial 2) to be similar. Cow performance estimated by NRC was highly correlated to Actual. Absolute differences in animal performance were also investigated for each prediction program. In trials 1 and 2, NutBal and NutBalPro over-predicted BWCHG, ADG and BCSCHG by 40 kg, 1.25 kg/d and .75 BCS, respectively, compared to actual cow performance. It appears that FNIR is a promising predictor of forage CP but not TDN. Also, the FOR-NRC is a satisfactory predictor of cow performance.

Key Words: Nutrition, Cow, Performance, Forage

Acknowledgements

The past six years, which I have spent at Virginia Tech, have been very enjoyable, educational, and provided me with many lasting memories. At this time I would like to take the opportunity to thank numerous individuals for providing me opportunities, friendship, support, and assistance.

First and foremost, I would like to thank my family most importantly my parents, Don and Diane Horsley, for their never-ending financial and moral support. They have always provided me guidance and supported whatever decision I make fully. It is to them who I owe the many successes I have been blessed with since I have been under their wing. Also, I would like to thank my brother, Ryan for his help and support especially over the past four years that we have been living together here at school.

Next I would like to thank Dr. Bill Beal, Dr. Dan Eversole, and Dr. Gary Minish for providing me countless opportunities to gain leadership skills, build on my knowledge of animal production and husbandry, and interact with individuals in various livestock industries. Not only do I thank them for believing in me and allowing me teaching and coaching opportunities, but I also want to thank them for their friendship. Each of them has always welcomed me with open arms.

I have been very involved in the Virginia Tech Livestock Judging Program; first as a team member and most recently as coach. I would like to thank Dr. Eversole and Dr. Minish for providing financial support, that made this very worthwhile activity available to me as well as the teams I coached in 2000 and 2001. Also, a special thank you goes to Dr. Mark Wahlberg for providing me with essential insight regarding both workouts and contests. I would especially like to thank him for his navigational support and words of encourgement. Lastly, I would like to thank the members of the teams I have coached for their dedication, effort, and lifelong friendships.

Also, I would like to thank Dr. John Hall for taking me on as a graduate student and providing me with a research assistantship. The research trials conducted for the completion of my graduate degree required lots of assistance from several individuals. I thank my graduate committee that included Dr. Hall (committee chairman), Dr. Dan Eversole, Dr. Joe Fontenot, and Dr. Mark Wahlberg for providing direction and expertise on the areas focused on in the research trials. A sincere thank you to Dr. Scott Greiner, Mr. Larry Kuehn and Dr. Mike McGilliard for their assistance with statistical procedures and analysis. Also, a special thank you to Mr. Lee Johnson for keeping my computer running and providing me with very valuable insight regarding various computer programs.

Thanks to the Virginia Tech Beef Center and the Buckingham Correctional Facility for providing facilities and cattle for each of the research trials. I sincerely appreciate the help and assistance provided by Mrs. Christie McAvoy and Mr. Chad Joines at the Virginia Tech Beef Center and Mr. Clyde Brown and staff at the Buckingham Correctional Facility. Also, a special thank you to Mr. Jim Myers for providing leadership and direction for the trial conducted at the Buckingham Correctional Facility.

Also, I would like to thank numerous undergraduates and fellow graduate students for assisting in moving cows through the working facilities, collecting fecal and forage samples, and enduring the long rides to the Buckingham Correctional Facility. Jesse

Austin, Emily Bashton, J.T. Begoon, Courtney Belden, Thomas Carper, Jon Collins, Rich Dietz, Emily Horsley, and Ryan Horsley were all individuals that helped during the research trials in various capacities. A sincere thank you to the Forage Laboratory at Virginia Tech and the Grazingland Animal Nutrition Laboratory at Texas A&M University for the analysis of forage and fecal samples, respectively. Lastly, I would like to thank Emily for her support, help, homecooked meals, and for putting up with me and my busy everchanging schedule.

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Introduction

The beef cattle industry has a major impact on the American economy. Beef cattle provide food, employment, and necessary byproducts used in the production of clothing, shoes, and pharmaceuticals for individuals. As of January, 2001, there were over 97 million cattle on more than one million beef cattle operations in the United States. The cattle industry provides over one million jobs, which help boost the United States economy and minimize the unemployment rate. Also, every dollar in cattle sales generates approximately five dollars in additional business activity (NCBA, 2001).

The cattle industry, most importantly the cow–calf sector, is one of the primary agricultural enterprises in Virginia. This is because of the abundance of grazing pastureland and available forage in the state. Virginia has 28,000 cattle farms and ranks 21st among the 50 states in cattle and calves inventory with 1.6 million head. Also, Virginia's cash receipts from cattle and calves were over 320 million, ranking it second behind broilers among all crop and livestock commodities statewide (VDACS, 2000).

Beef cattle spend the majority or all of their life on pasture depending on forage as their main feed resource. Non-grain feed sources including grass, roughage, and crop aftermath, which are generally consumed by grazing, provide at least 83 % of the nutrients consumed and 70 % of the metabolizable energy used by cattle (NCBA, 2001). These non-grain feed sources are much cheaper than grain feed sources which are often fed as supplements or to cattle in a feedlot. Since feed is one of the largest production costs incurred by livestock producers, it is critical for producers to know the forage quality their cattle are grazing to determine when supplementation should occur. By implementing management practices that determine forage quality, the performance of specific cattle can be predicted through the use of accurate animal performance prediction programs. This will help prevent over and under supplementation, yet ensure the nutritional requirements are met to optimize reproduction and milk production in cows and performance in nursing calves, stocker cattle, and feedlot cattle.

Literature Review

Energy and its Relationship to an Animal's Nutritional Requirements

Energy is quantitatively the most important constituent in the animal diet (Pond et al., 1995). It is defined as the ability to perform work and can only be measured in reference to defined, standard conditions as it transforms from one form to another (Pond et al. 1995, NRC, 1996). In terms of nutritional usage, this energy is expressed in calories. A calorie is the amount of heat required to raise 1 g of water from 16.5º to 17.5ºC. Some source of energy is required to allow an animal to perform daily functions and biochemical processes including walking, chewing, digestion, absorption, maintenance of body temperature, and protein synthesis. This needed energy is derived from either partial or complete oxidation of molecules ingested and absorbed from the diet or from metabolism of stored energy in the form of fat, protein, and carbohydrates. In the end, all energy consumed by the animal must be either lost or retained by the animal based on the laws of conservation of energy and the law of initial and final states (Pond et al., 1995).

Energy in relation to animal feed can be expressed in numerous ways. The most common ways energy is expressed include gross energy, total digestible nutrients, net energy, digestible energy, and metabolizable energy. All of these methods of expressing energy can be of significance when determining the value of particular feeds as an energy source for animals, except gross energy (GE) which is of little importance because it does not account for the animal's ability to utilize each specific feedstuff; for example, GE of corn grain and oat straw are 4.40 and 4.50 kcal/g, respectively (Pond et al., 1995). However, concentrates such as corn grain are labeled as energy sources meaning energy from them is used more efficiently for an animal's maintenance and gain functions compared to roughages such as oat straw that are high in fiber (NRC, 1984; Caton and Dhuyvetter, 1997).

Gross energy or heat of combustion is the energy released as heat resulting from the complete oxidation of feed, body tissue, milk, and other substances. The total intake energy (IE) of the feed is the amount of intake multiplied by GE per unit of weight of the feed. Digestible energy (DE), a reflection of diet digestibility, is defined as GE of the feed minus energy lost in the feces. This energy lost in the feces is referred to as fecal energy (FE), which typically accounts for the single largest loss of ingested nutrients. Fecal energy is calculated by multiplying the total amount of feces excreted and the GE content per unit weight of the feces (Pond et al., 1995; NRC, 1996).

Digestible energy and total digestible nutrients (TDN) are very similar estimates of energy content in different feedstuffs. The major downfall to using DE and TDN energy value estimates with ruminants is they both tend to overpredict energy values of high fiber feedstuffs such as straw and hay in comparison to more highly digestible feeds that are lower in fiber like corn and wheat (Pond et al., 1995). Digestible energy and TDN can be converted interchangeably using the following equation:

$$1 \text{ kg TDN} = 4.4 \text{ Mcal DE}.$$

The main difference in these two ways of measuring energy values of feeds is an equation that includes a correction for digestible protein with TDN (Pond et al., 1995; NRC, 1996).

Digestible energy and metabolizable energy (ME) tend to be very strongly correlated. This relationship is dependent on intake level, rate of digestion and passage, and diet composition. Metabolizable energy is equivalent to DE minus energy lost in urine and gases (Pond et al., 1995, NRC, 1996). Metabolizable energy accounts for some energy losses that occur as a result of the animal's digestion and metabolism of feedstuffs. For example, energy lost in the urine includes energy from nonutilized absorbed compounds from the diet, end products of metabolic processes, and end products of endogenous origin; while methane accounts for the primary portion of energy lost in gas (Pond et al. 1995). Typically, energy lost from both urine and gas together is 18% of DE; therefore, the following equation was derived so ME and DE could be converted interchangeably using:

$$ME = 0.82*DE.$$

Metabolizable energy values are most commonly used in diet formulation for poultry since both their urine and feces are excreted together, yet ME is still used with ruminants serving as a starting point for net energy systems. Net energy (NE) can easily be defined as ME minus the heat increment of intake energy (H_iE) (Pond et al., 1995; NRC, 1996).

Maintenance Energy Requirements

Maintenance requirements support the animal's body temperature regulation, essential metabolic processes, and physical activity. Ferrell and Jenkins (1987) concluded that ME required for functions supported by the animal's maintenance requirement accounts for approximately 70% of the total ME required by mature, producing beef cows. In comparison, a minimum of 40% and 90% of ME was required by growing cattle and breeding bulls, respectively, to meet these specific animals maintenance requirements.

Net energy for maintenance is defined as the amount of feed energy intake that results in no net loss or gain of energy from tissues in the body. The net energy system defines animal requirements completely independent of diet composition. Also, the animal's net energy for maintenance requirement is equivalent to the animal's heat production at zero feed intake. An animal's maintenance net energy requirement can be calculated using the following equation:

$$NE_m = H_eM / I_m.$$

In this case, H_eM was equal to the heat production at zero feed intake and I_m is the amount of feed consumed where retained energy (RE) = 0. An animal has met its maintenance requirements for energy when RE = 0 and ME = HE (heat production) (NRC, 1996).

The net energy value of feeds is estimated separately for each different physiological function ie. lactation, pregnancy, maintenance, or gain (NRC, 1996). Net energy (NE) of a feed is measured by determining the RE at two different amounts of IE. Net energy can be calculated using the following equation (NRC, 1996):

$$NE = \Delta RE/\Delta IE.$$

However, using this equation to determine NE assumes there is a linear relationship between RE and feed intake, while in actuality it is curvilinear (Garrett and Johnson, 1983).

Garrett (1980) reported the following equations for converting net energy maintenance (NE_m) and net energy gain (NE_g) using ME values:

$$NE_m = 1.37*ME - 0.138*ME^2 + 0.0105*ME^3 - 1.12, \text{ and}$$

$$NE_g = 1.42*ME - 0.174*ME^2 + 0.0122*ME^3 - 1.65.$$

The main concern associated with the conversion of ME to NE_m and NE_g is the variation in dietary ME of feedstuffs shown by the differences in composition of absorbed nutrients. The differences shown could be explained by differences in intake levels, digestion rates, and/or passage rates (Garrett, 1980; NRC, 1996).

The daily NE_m requirement for cattle can be calculated using the following equation:

$$NE_m = 0.077\text{Mcal} / EBW^{.75},$$

where EBW represents average empty bodyweight or metabolic bodyweight. An animal's energy requirements during lactation have been expressed in NE_m units because it was discovered that efficiencies of ME use for lactation and maintenance are very similar in beef cattle (Pond et al., 1995; NRC, 1996). Also, in a study involving pregnant and nonpregnant Finnish Landrace × Horned Dorset ewes, Robinson et al. (1980) reported that the efficiency of utilization of ME for maintenance and pregnancy vary similarly with changes in ME concentration in the diet. Therefore, animal requirements for lactation and pregnancy have been converted to NE_m equivalents meaning the energy value of feedstuffs will be described only by NE_m and NE_g (NRC, 1996).

Animal maintenance energy requirements are determined by one of three methods. Those methods include long-term feeding trials, calorimetric methods, or comparative slaughter. When using long-term feeding trials, the goal is to determine the quantity of feed required for the animal to maintain its bodyweight (Taylor et al., 1981, 1986). Using calorimetric methods, animals are fed a specific diet at approximately maintenance for 3 wk prior to actual NE_m measurement. Animals are managed in a thermoneutral environment where all energy input and output from the animal can be measured precisely. All energy released via gases, feces, and urine samples is measured. The process of comparative slaughter involves harvesting a representative sample of cattle from the group being studied so their beginning body composition can be determined for energy content. The rest of the cattle are fed generally for a long period of time, i.e. 100-200 d and then they are harvested and their body energy content is measured. Energy retention is calculated as the difference between the beginning and final energy content (Garrett, 1980).

Factors Influencing Maintenance Energy Requirements

The expenditure of maintenance energy by livestock is dependent on animal bodyweight, breed or genotype, sex, age, season, temperature, physiological state, and previous nutrition. An immense amount of research has been conducted on each of these parameters that affect an animal's maintenance energy requirements (NRC, 1996).

Breed/Biotype. Various researchers have studied the effect breed has on the maintenance energy requirements of animals. It has been concluded that between cattle breeds there are differences in animal energy requirements and/or the efficiency of energy utilization. Typically, Continental breeds or dairy influenced cattle have higher NE_m requirements than cattle of British ancestry. Continental breeds, such as Simmental and Chianina, compared to British breeds (i.e. Angus and Hereford) are more excessive in their frame size and bodyweight and harder to maintain nutritionally because of higher metabolic rates. Holstein steers were found to require 23% more feed to maintain body energy in comparison to Hereford steers (Garrett, 1971). Also, Jenkins and Ferrell (1984) concluded that young Simmental bulls and heifers require more feed to maintain their energy status compared to Hereford cattle. In comparison to Angus cows, Simmental cows require 21% more ME (Laurenz et al. 1991). In a study conducted on Angus crossbred cows, it was found that Angus × Holstein cows required 9% greater ME to maintain their energy status compared to Angus × Hereford cows (Thompson et al., 1983). As mentioned earlier, dairy cattle have higher maintenance energy requirements than cattle of British origin; however, no significant difference in maintenance energy requirements was found between dairy breeds in a study using Jersey and Holstein cattle (Ritzman and Benedict, 1938). In conclusion, cattle that have higher growth rates and higher mature weights and/or high milk production have higher maintenance energy requirements (Ritzman and Benedict, 1938; Garrett, 1971; Thompson et al., 1983; Jenkins and Ferrell, 1984; Laurenz et al., 1991).

Sex. The impact of sex of an animal on their maintenance energy requirements is less definitive. In a study involving growing cattle, 341 heifers and 708 steers, Garrett (1980) concluded that NE_m requirements were similar between the heifers and steers. In a study using Hereford and Simmental bulls and heifers, it was found that NE_m requirements for Hereford cattle were similar regardless of sex where as a 9% greater NE_m requirement was detected for the Simmental bulls compared to the heifers (Ferrell and Jenkins, 1985). Hereford × Friesian bulls were reported to have 20% higher basal metabolism values than steers of the same breed cross (Webster et al., 1977). Overall, there tends to be no significant difference in the maintenance energy requirements of heifers and steers of the same breedtype; however, bulls of the same breedtype have been reported to have 9 to 20% higher maintenance energy requirements than steers or heifers (Webster et al., 1977; Garrett, 1980; Ferrell and Jenkins, 1985).

Age. Research dealing with the effect of age on the maintenance energy requirements of animals appears to be inconclusive. Equations have been developed to predict the decrease in maintenance energy requirements by 3 and 8% per year as the animal gets older (Graham et al., 1974; Corbett et al., 1985). In contrast, there was very little influence of age on the maintenance requirements of steers from 15 to 81 wk of age (Blaxter and Wainman, 1966). Studies support the idea that maintenance energy requirements per unit of body size decrease with age, yet the overall maintenance requirements of an animal are not dramatically different for growing or mature producing cattle (Blaxter and Wainman, 1966; Graham et al., 1974; Corbett et al., 1985).

Environment. Ambient temperature plays an active role in the determination of the maintenance energy requirements of animals (NRC, 1996). As a result of the importance of ambient temperature on cattle NE_m, the following equation including previous ambient temperature:

$$NE_m = (0.0007 * (20 – T_p)) + 0.077 \text{ Mcal/BW}^{0.75}$$

is used to determine the NE_m of animals. Like humans, cattle must maintain a constant body temperature. Animals are able to maintain a constant body temperature through the self-monitoring of heat production and dissipation. The "typical" zone of thermoneutrality for cattle is when the ambient temperature is between upper and lower critical temperatures, and animal productivity is not negatively affected by energy being spent by the animal to maintain body temperature. When ambient temperature is within this zone of thermoneutrality, HE is determined strictly by feed intake and how efficiently the feed given is used; thus, body temperature control is through heat dissipation.

In instances when ambient temperature is either above or below the zone of thermoneutrality (heat and cold stress), the maintenance energy requirements of the animal increase. In the case of heat stress, animals tend to reduce feed intake inturn decreasing productivity. Also, respiration and heart rate increases, which are both ways the animal dissipates heat. Panting by an animal is an excellent way to identify if an animal is affected by heat stress (NRC, 1996). If the animal has rapid shallow breathing, then the maintenance energy requirements are increased 7%. In comparison, if an animal is panting very deeply with an open mouth, maintenance energy requirements are increased 11 to 25%. When cattle are suffering from cold stress, the individual animal's metabolism must increase to provide heat to help it maintain its constant body temperature of 39 ˚C (NRC 1996, Taylor and Field, 1998).

There are numerous other physiological and behavioral changes that can help maintain the normal constant body temperatures of animals. Animals can physiologically adapt by changes in hair coat, feed passage rate, and body composition. Surface area and internal and external insulation play large roles in heat loss and retention by the animal. Internal insulation includes subcutaneous fat and skin thicknesses while external insulation is affected by hide thickness, wind, precipitation, and mud in the haircoat. Mader et al. (1997) reported that growing cattle fed in a feedlot with no shelter or windbreak compared to those fed in feedlots with shelter or windbreaks in the winter laid down more subcutaneous fat as a protection mechanism. Also, during the winter and autumn, cattle fed in the unprotected feedlot had higher marbling scores, meaning they deposited more intramuscular fat as well.

Behavioral changes that occur by the animal during cold weather generally include huddling in groups, getting behind windbreaks, or changing posture to minimize heat loss. When the ambient temperature is high, animals typically seek shade, a creek or waterway to stand in, or higher altitudes to take advantage of the wind. Hot temperatures common in the summer months have caused feedlot cattle to stand on the mounds due to the increased air flow across them (Mader et al., 1997). Also, windbreaks were found to have no benefit on cattle performance and cause reductions in gain during the summer. During times of cold and heat stress, environmental factors such as air movement, humidity, precipitation, contact surfaces, and thermal radiation all play a part in the retention or loss of heat by the animal which in turn can cause additional changes in maintenance energy requirements. All animals do not use all the methods mentioned above to maintain their normal constant body temperature; however, the majority of cattle will use some combination of their capabilities mentioned above (NRC, 1996).

Effects on the maintenance energy requirements of animals based on season of year are believed to be related to temperature; since certain temperatures are characteristic of specific seasons. A study using Hereford cattle demonstrated their maintenance requirements to be lowest ($P < .05$) in the fall, which is also characterized by having the most moderate temperatures (Christopherson et al., 1979). Webster et al. (1982) also reported results supporting the idea that cattle maintenance requirements were lowest during the fall. Birkelo et al. (1989) reported that cattle NE_m requirements were highest in the summer and lowest in the fall with NE_m requirements during this time being 90.7% of the summer requirement. The NE_m requirements during the winter and spring were fairly similar being 95.6 and 96.2% of the summer NE_m requirements, respectively. For the most part, studies support the idea that cattle maintenance requirements are highest in the summer and lowest in the fall (Christopherson et al., 1979; Webster et al., 1982; Birkelo et al., 1989).

Physiological State. The physiological state of beef cattle can directly affect their maintenance energy requirements. During gestation indirect evidence suggests maintenance requirements are above normal in cows (Ferrell and Reynolds, 1985). Also, studies show lactating beef and dairy cattle have increased maintenance energy requirements to the magnitude of 10 to 49%, with an average of 20% above non-lactating cows (Ritzman and Benedict, 1938; Flatt et al., 1969; Neville and McCullough, 1969; Moe et al., 1970; Neville, 1974; Ferrell and Jenkins, 1987).

Activity. Increased cattle movement also increases maintenance energy requirements as evidenced through research conducted on grazing cattle compared to penned cattle. Grazing cattle were found to have 10 to 50% greater maintenance energy requirements compared to pen fed cattle depending on grazing conditions including terrain, pasture size, and water location (CSIRO, 1990).

An animal's previous nutrition, time period on the previous plane of nutrition, and compensatory gain all play active roles in the animal's future maintenance energy requirements (NRC, 1996). Compensatory gain is accelerated gain or growth following a time period of limited or little feed intake (Ensminger and Olentine, 1978). This accelerated growth is characterized by increased feed intake resulting in increased gut fill, liveweight, average daily gain, and efficiency of energy use. Research conducted on a wide range of animal species including rats, swine, cattle, and sheep has suggested that maintenance energy requirements are decreased after periods of low nutritional intake (Walker and Garrett, 1970; Foot and Tulloh, 1977; Gray and McCracken, 1980; Corbett et al., 1982). In conclusion, animal maintenance requirements are reduced 10 to 50% both during and following time periods of reduced feed intake with an expected recovery time of 60 to 90 d.

Determination of maintenance energy requirements is a very complicated and interdependent process for the animal. However, by understanding the factors affecting maintenance requirements of animals, a producer can better meet their animals' needs and optimize their performance under all possible scenarios.

Understanding Cattle Energy and Protein Requirements

Understanding and knowing the necessary protein and energy requirements for cattle is critical to the operation of a successful beef cattle enterprise. Depending on the age, sex, and stage of production of the animal; their requirements for energy and protein may vary considerably.

Requirements for Growing Cattle. Feeder calves and replacement heifers are both considered growing cattle. However, they will be fed different diets to attain different performance goals. Calves that are going to be finished in a feedlot are typically either sent straight to the feedlot at weaning or backgrounded on available forage and acclimated to a feedbunk and then shipped to the feedlot or kept as stockers.

Yet, heifers kept as replacements will be fed on a more labor intensive and rigorous feeding program so they attain a certain average daily gain to reach their individual 2 year old calving target weight based on their genotype and frame size (Gill and Allaire, 1976). Overfeeding replacement females with excess energy is detrimental to mammary development because parenchyma tissue growth is halted before full ductal development occurs (Harrison et al., 1983; Van Amburgh et al., 1991). Typical dairy and beef (*Bos indicus* and *Bos taurus*) breed replacement heifers are fed to reach puberty between 9 to 14 months of age at 55, 60, and 65% of their expected mature bodyweights respectively (NRC, 1996). Once heifers reach the certain percentage of their expected mature bodyweight based on their genotype, they have reached ideal breeding weight.

Once a heifer is bred her nutritional requirements will increase until calving. Average required CP, TDN, and NE_m values for early to mid to late gestation were 7.2, 7.4, 8.0 %CP, 50.8, 51.7, 56.2 %TDN, and .47, .48, .55 NE_m, respectively. The anticipated ADG for replacement heifers during early, mid, and late gestation should be .45, .45 to .57, and .68 to 1.02 kg/d (Hall et al., 2001). When heifers calve as 2-year-olds, they should be 90% of their anticipated mature weight. Heifers that calve at weights considerably less than 80% of their expected mature weight oftentimes have limited milk production and lower conception rates compared to heifers that reached their targeted weight (NRC, 1996).

Requirements for Mature Cows. It is important to constantly monitor cattle year-round as temperature and many other environmental factors are constantly changing and can drastically affect their nutrient requirements during different stages of production. During a mature beef cow's annual production cycle, their nutritional requirements change. Their annual production cycle can be broken down into four individual phases: early lactation through breeding, late lactation through weaning, weaning through 60-90 days pre-calving, and 60-90 days pre-calving through calving. Average required diet nutrient density values for CP, TDN, and NE_m are as follows for the each of the four phases; 10.5, 8.7, 6.6, 8.6 %CP, 59.2, 55.1, 47.4, 54.6 %TDN, .60, .53, .41, .92 NE_m, respectively. As would be anticipated, nutritional requirements are highest close to calving and during early lactation while nutritional requirements are the lowest after weaning until 60-90 days precalving (Hall et al., 2001).

Supplementation is a concept used by producers that enables mature beef cows to meet their nutritional requirements for maintenance, gestation, and milk production when forage quality and/or quantity is limited. Therefore, supplementation is used to enable animals to meet their nutritional requirements during specific stages of production. As both forage quality and quantity decrease due to weather, overstocking, or poor management, the possibility of extended supplementation is increased.

Monitoring the Nutritional Status of Beef Cattle using Body Condition Scores (BCS)

Monitoring the nutritional status of beef cattle is critical to enhance cow reproductive efficiency, limit the emission of excess nutrients into the environment, and optimize overall cow performance. The simplest and most economical way to assess the nutritional status of cows is to body condition score (BCS) (Eversole et. al, 2000). Body condition scoring is a management tool used extensively by beef, dairy, and sheep producers. Using this management tool, body condition scores are derived and assigned by physically handling and/or visually appraising animals for evidence of fat. Areas of utmost importance when analyzing cattle for deposition of fat are the brisket, spine, ribs, hooks, pins, and tail head (Evans, 1978; Hady et. al, 1994; Gallo et. al, 1996; Eversole et al., 2000).

Body condition scores are subjective measurements (Evans, 1978; Hady et. al, 1994; Gallo et. al, 1996). By scoring animals instead of measuring animals for actual amounts of fat, there tends to be a high degree of subjectivity which results in assessor bias. Some assessors may have a tendency to consistently score animals high or low. Therefore, research suggests that 2 to 3 individuals BCS independently, which will help remove the possibility of assessor bias (Evans, 1978). However, trained evaluators should not disagree by more than one score (Herd and Sprott, 1986).

Body condition scoring systems vary among species and at times can even differ within species. For beef cattle, scores generally range from 1-9, with 1 being an extremely thin, emaciated appearing animal and 9 being a very obese individual (Herd and Sprott, 1986; Taylor and Field, 1998; Eversole et al., 2000; Minick et al., 2001). Houghton et al. (1990) described a 1-5 cattle BCS system where $^{-}$, $^{\circ}$, and $^{+}$ were used to improve accuracy. This BCS system developed by Purdue University personnel was relatively similar to the 1-9 system described previously.

Cow weight has been studied to determine its relationship to BCS. Actual cow bodyweight alone was determined as a fairly inaccurate predictor of BCS since cows can differ significantly in their type and size (Klosterman et al., 1968). Based on percentage of cow bodyweight and using the coefficient of 1.00 for the cow at BCS 5, Herd and Sprott (1986) developed coefficients of .74 and 1.36 to be multiplied by the bodyweight at a BCS 5 in order to determine the bodyweight of cows at a BCS 1 and 9, respectively. Values between .74 and 1.36 were used to determine cow bodyweight at other BCS. Yet, once cow bodyweight at BCS 5 is determined with relative accuracy, percentages of that animal's BCS 5 bodyweight can be used to determine amount of bodyweight change is needed to change a cow one BCS. The lower the actual BCS the less bodyweight gain is required for a one BCS increase (Herd and Sprott, 1986; NRC, 1996). Herd and Sprott

(1986) reported that a cow must gain 5.8, 8.0, and 10.2% of their bodyweight at a BCS 5 to go from a BCS 1 to a BCS 2, BCS 5 to a BCS 6, and BCS 8 to a BCS 9, respectively.

Due to the inaccuracy of using bodyweight solely as a predictor of cow BCS, weight to height ratio (WHR) has been evaluated as a possible way to determine cow BCS (Klosterman et al., 1968; Herd and Sprott, 1986; Houghton et al., 1990). Using cow WHR at a BCS 1, 5, and 9, the cow should weigh 18.08, 25.54, and 33.30 kg/cm (Herd and Sprott, 1986). Klosterman et al. (1968) reported accurate and similar WHR for Charolais and Hereford cattle that were different in height at their hooks. Although using WHR to determine BCS is less subjective compared to visually predicting cow BCS, it is not as widely used practice since it requires facilities to physically restrain the animals. This method is neither as time, labor, or cost efficient (Houghton et al., 1990).

The amount of body fat cattle have is directly related to their body condition score. Comparisons were made among thin (BCS 3), average (BCS 5), and fat (BCS 7) cows that were considered a BCS 5 at 498.95 kg (Herd and Sprott, 1986). Body fat represented 30.39, 71.21, and 124.74 kg of the empty bodyweight for the BCS 3, 5, and 7 cows, respectively. As BCS increases, the percentage of fat composing the cow's body steadily increased from 8, 16, to 24% of the cow's empty bodyweight composition. Percentages of protein and water of the cow's empty bodyweight decrease as the cow gains body condition. Percentages of protein and water for BCS 3, 5, and 7 cows were 20, 18, and 17% protein and 67, 61, and 55% water. From a BCS 3 to a BCS 5 and a BCS 5 to a BCS 7 there was a difference of 40.82 and 53.52 kg, respectively. However, the differences in the amount of protein and water of the cows empty bodyweight were identical as 4.54 kg of protein and 15.42 kg of water were calculated as the difference betweeen BCS 3 and 5 and BCS 5 and 7 cows (Herd and Sprott, 1986). On the average BCS 1, 5, and 9 cows are approximately 3.77, 18.89, and 33.91% body fat (NRC, 1996).

As animals fatten their caloric intake increases. Herd and Sprott (1986) reported that as beef cows increase in BCS, their caloric value per kilogram of bodyweight gain increases. For beef cows to go from a BCS 1 to a BCS 2, BCS 5 to a BCS 6, and BCS 8 to a BCS 9 values of 1.22, 1.46, and 1.65 Mcal/kg of bodyweight gain, respectively, were reported. In order for animals to gain body condition, they must have a higher caloric intake which may be achieved through increasing feed intake or by consuming a more energy dense diet (Herd and Sprott, 1986).

Cows at either end of the BCS spectrum are undesirable as they are more apt to experience metabolic problems and diseases, decreased milk yield, low conception rates, and calving difficulty (Ferguson and Otto, 1989). Excessively conditioned cows are more susceptible to calving problems and having lower dry matter intake during early lactation. Also, cows in poor body condition may not have adequate reserves to maximize milk production and typically will not breed back as readily (Roche et al., 1992; Wright et al., 1992). Crossbred cows that were fed to maintain BCS had heavier calves at weaning than cows that were fed to lose bodyweight during lactation (Richards et al., 1986).

Cattle producers strive to maintain a 12-month calving interval, which means cows must be rebred within 83 d of calving (NRC, 1996). Cows in low body condition (BCS 1 to 3) commonly do not get rebred during this window resulting in low pregnancy rates in beef females. Other factors contributing to when ovulation occurs include response to calf suckling and energy balance control (Roche et al., 1992; Wright et al., 1992). Herd and Sprott (1986) studied the percentage of cows pregnant 60 and 180 d after calving and found cows that calved at a BCS 5 or more had higher pregnancy rates. Over three production years, crossbred cows that calved at a BCS 5 or greater had less days to estrus ($P < .01$) and pregnancy ($P < .05$) compared to BCS 4 or lower cows (Richards et al., 1986). Also, Wright et al. (1992) found conception rates to be maximized using BCS 5 cows, which are deemed exactly average in their condition.

Role of Forages in Cattle Performance

Forages are the single largest feed resource used for overall cattle production. The cow/calf and backgrounding sectors of the cattle industry are predominant in Southeastern USA (DeRouen et al., 1991). Typically, these sectors depend heavily on forage as their predominant feed source unless the available forage is inadequate to meet the cattle nutritional requirements. In that case, supplementation generally occurs.

A wide range of forage species are either grazed or fed to cattle. These forage species are commonly classified into one of three categories: cool season grasses, warm season grasses, or legumes. Each of the categories can be further subdivided into annuals and perennials. Common cool season grasses grown in Virginia include tall fescue (*Festuca arundinacea*), orchardgrass (*Dactylis glomerata)*, Kentucky bluegrass (*Poa pratensis*), and various small grain species. Some of the more widely grown warm season grasses include switchgrass (*Panicum virgatum*) and bermudagrass (*Cynodon dactylon*). Oftentimes, legumes such as white clover (*Trifolium repens*), red clover (*Trifolium pratense*), or ladino clover (*Trifolium repens f. giganteum*) are interseeded in pastures with the cool and warm season grasses.

Forages are designated to a classification category based on their utilized photosynthetic pathway, preferred growing environment and season, and nutritive quality (Bertrand and Dunavin, 1975; Brown, 1978; Reid et al., 1988, 1990; Waller and Lewis, 1979). Forages classified by photosynthetic pathways, determined by the anatomical structure of the leaf, are generally considered as C_3 or C_4 plants. Generally, cool season grasses and legumes utilize the C_3 photosynthetic pathway, thus they are referred to as C_3 plants; while warm season grasses are involved with both the C_3 and C_4 photosynthetic pathway, they are referred to as C_4 plants. The C_4 plants have two to threefold greater net photosynthetic rates and higher photosynthetic efficiency compared to C_3 plants (Waller and Lewis, 1979). Leaves of C_4 plants have well defined parenchymatic bundle sheaths that contain large amounts of chloroplasts and starch. These bundle sheath cells of the C_4 plants are surrounded by mesophyll cells that contain chloroplasts. In C_4 plants, the bundle sheath cells utilize the C_3 photosynthetic process and chloroplasts in the mesophyll cells utilize the C_4 photosynthetic process. The mesophyll cells surrounding the bundle sheath cells are believed to minimize the loss of CO_2 through C_3 respiration, allowing for more efficient CO_2 fixation and lower transpiration rates observed in C_4 plants (Brown, 1978; Mullahey et al., 1992; Waller and Lewis, 1979).

Not only does the anatomical structure of the plant leaf play a significant part in determining the photosynthetic pathway; but it also affects the degradability and digestibility of the plants by animals. Parenchymal bundle sheaths are more prevalent in warm season forages making up greater than 50% of the total vascular tissue area. Akin and Burdick (1975) reported that 25% more of the slower digested tissues, bundle sheath and epidermis cells, were found in warm season grass species compared to cool season grass species. Also, mesophyll and phloem, both highly digestible forms of tissue, were 22% more prevalent in cool season grasses. Depending on cool season forage species, mesophyll percentage of the total vascular tissue ranged from 52.8 to 64.7% in comparison to 23.5 to 52.4% in warm season forage species. The combination of higher amounts of mesophyll and phloem and decreased amounts of bundle sheath and epidermis cells allows cool season grasses to be more highly digestible (Akin and Burdick, 1975; Mullahey et al., 1992).

Cool season and warm season grasses have very different preferred growing conditions. Based on their preferred growing climate, cool season and warm season forages are often referred to as temperate and tropical grasses, respectively. Cool season grasses flourish in growth during the spring and fall under cooler conditions; compared to warm season grasses that grow predominantly in the summer months during higher temperatures. Baker and Jung (1968) concluded orchardgrass and Kentucky bluegrass have higher growth rates during day temperatures of 18.3 and 21.6˚C, compared to bromegrass; while bromegrass had higher growth rates when day temperatures were 28.2, 31.5, and 34.8 ˚C. In agreement with the previous study, Black (1971) reported warm season forages to yield at least two times more DM than cool season forages in dry, sunny, warm climates.

Due to cool season forages and warm season forages having different preferred growing seasons and temperatures, it is only logical to believe complementation of these forage types could possibly allow adequate forage quantity year round or at least help minimize the amount of supplementation needed. DeRouen et al. (1991) reported that cows grazing bahiagrass pastures that had been interseeded with cool season annuals and legumes required significantly less supplemented hay and protein with amounts of 1090.9 ± 25.4 vs. 761.1 ± 29.0 kg hay/cow/year and 101.2 ± 4.5 vs. 78.5 ± 2.3 kg protein supplement/cow/year for the cool season annual and legumes nonsupplemented vs. supplemented cows. So, the complementation of cool and warm season forages could lengthen a grazing season, resulting in a reduction of both energy and protein supplementation and hay fed (Hoveland et al., 1977; DeRouen et al., 1991).

Available plant growing environment plays a major role in determining the ability of a certain plant species to survive and flourish. Along with the already mentioned daily ambient temperature; annual precipitation and soil type are other critical elements composing a plants growing environment. Generally, cool season grasses are grown in areas located more in the northern half of the United States while warm season grasses are grown in the south. As a result of these geographic preferences, the cool season grasses receive higher annual precipitation compared to warm season grasses. Cool season grasses including timothy, tall fescue, and orchardgrass were reported to grow well on moderately to somewhat poorly drained soils including Etowah and Tygart soil types respectively (Fribourg et al., 1982). Compared to common bermudagrass, timothy had significantly higher annual DM yields on both Etowah and Tygart soil types. Frigbourg et al. (1982) also studied the yield of cool season annuals for both hay and grain and noticed highest yields in both cases on Etowah and Captina soils, which are both adequately drained soil types. Both hay and grain production was lowest for most all forage grasses and small grains on Dandridge soils that are characterized as excessively drained soils.

Cool season grasses are higher in nutritive quality compared to warm season grasses; however, legumes have the overall highest nutritive quality. Average CP and TDN values for typical cool season grasses grazed in Virginia including tall fescue, orchardgrass, and Kentucky bluegrass are 11.1, 9.5, and 15.2% and 62.0, 62.0, and 66.0%, respectively. Warm season grasses on the average have lower CP and TDN values compared to cool season grasses and legumes evidenced by bermudagrass, switchgrass, and bahiagrass having values of 9.1, 5.7, and 7.9 %CP and values of 59.0, 52.0, and 53.0 %TDN, respectively. However, legumes are highest in CP and TDN with red clover, white clover, and ladino clover having CP values of 17.0, 24.1, and 24.9% and TDN values of 67.5, 72.0, and 75.0%, respectively (Ensminger and Olentine, 1978). Reid et al. (1990) also reported higher CP% values for cool season grasses (ie. orchardgrass and timothy mix) than warm season grasses (ie. switchgrass and flaccidgrass). Also, various research studies reported higher levels of cell wall constituents of low biological availability through higher NDF% values for warm season grasses compared to cool season grasses (Vona et al., 1984; Reid et al., 1988, 1990; Pond et al., 1995). Vona et al. (1984) and Reid et al. (1988) each reported higher ADF values, which is associated with the amount of carbohydrates that are not solubilized by acid detergent (Pond et al., 1995), for warm season grasses vs. cool season grasses. In analyzing cool season grasses, warm season grasses, and legumes one can conclude that cool season grasses are generally adequate in quality to meet an animal's nutritional requirements for CP and TDN, warm season grasses are high in fiber, and legumes are highest in nutritive quality compared to both types of grasses.

The maturity of forages also strongly impacts their nutrient content. Ely et al. (1953) conducted a trial on harvesting orchardgrass at different forage heights ranging from 15.24 to 35.56 cm. As plants matured their dry matter digestibility and crude protein levels decreased while the forage's lignin and crude fiber levels increased (Ely et al., 1953; Pond et al., 1995). All in all, accurate and precise estimates of diet quality are essential for the accurate assessment of animal intake and digestibility by the animal. Due to the active role each of these factors has in predicting animal performance, it is critical to be able to precisely estimate animal diet quality.

Supplemental Effects on Cattle

In a forage-based cow-calf system, most if not all the dietary nutrients should be supplied by forage. However, sometimes supplementation must occur. Supplementation is the process of feeding another feedstuff along with the current diet to help the animal meet its nutritional requirements. Supplementation can occur for vitamins, minerals, and most notably energy and protein. Common protein and energy supplements for cattle are grains, oilseeds, readily digestible fiber sources, silages, and high-quality forages (Caton and Dhuyvettter, 1997). The most common time for energy and protein supplementation is during the winter months when forage growth is generally nonexistent, resulting in minimal forage availability. Also, all cattle should be supplemented differently based on age, mature size, body condition score and stage of production which are all critical aspects to consider when supplementing. For example, less supplementation would be required for a BCS 5 cow to gain 1 BCS than a BCS 7 cow to become a BCS 8. A BCS 8 cow has excess body fat and energy content, thus its nutritional requirements would be higher and harder to maintain (NRC, 1996).

Supplementation has effects on grazing behavior, forage intake, digestion, and animal weight change in ruminants. In research studies conducted using sheep and cattle, it was concluded that when these animals are grazing a low quality forage (< 7.0% CP) and receive a protein supplement their voluntary forage intake increases. In a study using cottonseed meal (CSM) supplemented to mature, nonpregnant, Rambouillet ewes fed a low quality prairie hay (6.3% CP), an increase in daily voluntary intake of the hay from 23.7 to 28.3 g/kg of bodyweight was detected for the supplemented ewes (Krysl et al., 1987). McCollum and Galyean (1985) reported a significant increase in hay intake from 16.9 to 21.5 g dry matter/kg bodyweight in nonsupplemented vs. supplemented (800 g CSM) British crossbred cows grazing (6.1% CP) prairie hay. In contrast, crossbred beef cows in drylot required at least 627 kg/cow more hay DM to maintain their BCS than cattle grazing stockpiled grasses or corn crop residues (Hitz and Russell, 1998).

In contrast to protein supplementation, when energy supplements are fed to ruminants grazing low quality forage (< 7.0% CP) a decrease in their forage intake has occurred. Energy supplements such as corn grain supplemented at either .91 or 1.81 kg/hd/d to mature gestating crossbred cows grazing low quality meadow hay (7.0% CP) resulted in decreased hay intake yet increased total DM intake for the supplemented vs. nonsupplemented cows (Sanson and Clanton, 1989). Feeder steers and heifers grazing Kentucky 31 Tall Fescue pastures supplemented with whole corn grain and ground pelleted corn had decreased forage OM intakes of 19 and 6%, respectively, compared to nonsupplemented calves. Although a decrease in forage intake was found, total OM intakes were greater ($P<.01$) for the supplemented animals with reported values of 7.6, 6.9, and 5.6 kg/d for the ground pelleted corn supplemented, whole grain supplemented, and nonsupplemented group, respectively (Hannah et al., 1989). Also, Chase and Hibberd (1987) reported decreases in hay intake and total DM intake as amount of supplemental ground corn increased from 0, 1, 2, or 3 kg/d for mature nonpregnant Hereford cows. Hay intakes for the different supplement amounts were 8762, 8177, 6402, and 5605 g/d, respectively; depicting a linear decrease as amount of ground corn supplemented increased (Chase and Hibberd, 1987).

Decreased forage intake where corn has been used as a supplement may be a result of increased starch availability. Increased levels of starch cause a decline in ruminal pH that changes bacteria in the rumen toward greater amylolytic and lower cellulolytic population. This shift of bacteria is believed to reduce fiber digestion resulting in a negative effect on forage intake (Caton and Dhuyvetter, 1997). In general, cattle and sheep fed a protein supplement increase hay intake resulting in higher total DM intake levels; whereas, supplemental energy feeds decrease hay intake and either have no effect or increase total DM intake by the animal (McCollum and Gaylean, 1985; Chase and Hibberd, 1987; Krysl et al., 1987; Sanson and Clanton, 1989; Sanson et al., 1990; Horney et al., 1996).

Main factors associated with the regulation of forage intake are rate of passage, rate of digestion, and/or gut fill. A significant increase ($P<.05$) in gastrointestinal fill was found for cottonseed meal supplemented ewes (14.3 g/kg BW) compared to 12.9 g/kg BW for control ewes (Krysl et al., 1987). However, McCollum and Gaylean (1985) reported a tendency for lower estimated gastrointestinal fill with values of 8.4 vs. 9.0 g/kg bodyweight for cottonseed meal supplemented vs. unsupplemented steers. Krysl et al. (1987) reported higher particulate passage rates for the supplemented vs.

unsupplemented ewes. Also, a tendency for higher passage rate (%/h) was found for British crossbred beef steers supplemented with either a 43% CP supplement based on CSM or a 22% CP supplement based on corn grain and cottonseed meal (Freeman et al., 1992). All passage rate estimates reported were greater for protein supplemented vs. nonsupplemeted steers (McCollum and Gaylean, 1985; Krysl et al.,1987; Freeman et al., 1992; Marston and Lusby, 1995).

Grains used as supplemental feeds improve total diet digestibility; yet decrease forage digestibility. Sanson and Clanton (1989) conducted a study using different levels of whole corn grain as supplements for crossbred steers receiving low quality meadow hay (5.2% CP). They reported a decrease in hay digestible DM as whole corn supplementation (percent of BW) increased. However, there was a continuous increase in daily total digestible dry matter intake with values of 3.2, 4.0, 4.1, and 4.7 kg/d for the supplemented steers as their supplement amount increased from 0, .25, .50, to .75% of bodyweight (Sanson and Clanton, 1989). Also, supplemented steers had higher estimated ME intake/day than nonsupplemented steers. Chase and Hibberd (1987) reported higher total diet digestibility of DM and OM with increasing amounts of corn supplementation. This was evidenced through significantly lower NDF, ADF, hemicellulose, and cellulose levels as supplementation amounts of corn grain increased (Chase and Hibberd, 1987). Higher apparent DM and apparent OM digestibility was reported for steers supplemented with corn gluten meal and corn grain regardless of amount compared to the nonsupplemented group (Freeman et al., 1992). Significant increases in total diet digestibility of animals supplemented with concentrates occurs as a result of grains being more highly digestible than forages; with forages being higher in fiber content (Chase and Hibberd, 1987; Sanson and Clanton, 1989; Freeman et al., 1992).

Supplementation generally has a positive influence on livestock causing them to either maintain or gain bodyweight (Freeman et al., 1992; DeRouen et al., 1991; Forcherio et al., 1995). Freeman et al. (1992) reported bodyweight changes for crossbred steers of –6.7, 8.6 and 9.9 kg/21d for the nonsupplemented, 43% CP supplement based on cottonseed meal, and 22% CP supplement based on corn grain and cottonseed meal groups, respectively. They observed a significant increase in bodyweight for supplemented vs. nonsupplemented steers. Similarly, DeRouen et al. (1991) used cool season annuals with legumes (rye or wheat with crimson clover and arrowleaf clover) interseeded as supplements for purebred Angus cows grazing Argentine bahiagrass pastures. Calves raised in pastures where cool season annuals and legumes were interseeded and used as supplements had 6 to 7% heavier weaning weights. At weaning, cows grazing pastures where cool season annuals and legumes were used as supplements weighed 21.77 kg more. Also, supplemented cows produced 5.9 kg more calf per 453.59 kg cow weight (DeRouen et al., 1991). Late gestation crossbred beef cows with *ad libitum* access to ammoniated wheat straw supplemented with 2 kg/d of 12%, 20.1%, or 31.7% CP supplements had increased ($P < .01$) cow weight gains and improved ($P < .01$) BCS. Cow weight gains for the non-supplemented, 12%, 20.1%, and 31.7% supplement were 32.7, 60.7, 62.8, and 72.4 kg, respectively (Fike et al., 1995). Hitz et al., (1998) reported mid-gestation crossbred beef cows grazing stockpiled tall fescue and alfalfa had greater ($P < .05$) BW gains than those grazing stockpiled smooth bromegrass with red clover, corn crop residues, or those in drylot.

As would be expected, when grazing animals are supplemented to help them meet their nutritional requirements, their time spent grazing is reduced. Hannah et al., (1989) reported significant decreases in grazing time for steers grazing tall fescue supplemented with either ground corn or corn gluten feed compared to nonsupplemented steers. Nonsupplemented steers spent 7.8 h/d grazing while the ground corn supplemented and corn gluten supplemented steers spent 4.2 and 4.9 h/d grazing respectively. Krysl and Hess (1993) concluded protein supplementation caused a significant reduction in time spent grazing of approximately 1.5 h/d. They also reported decreases in grazing time as supplemental starch amount increased (Krysl and Hess, 1993). Gekara et al. (2001) fed a concentrate supplement composed of predominantly ground yellow corn and solvent-extracted soybean meal (44%CP) to grazing cattle and reported a tendency for reduced grazing time as the cattle received increasing amounts of the supplement. Also, supplemented grazing animals will have reduced energy expenditures as a result of their decreased time walking and standing that is associated with grazing. Not only does supplementation allow animals to meet their energy requirements sooner; but it also may reduce the maintenance energy requirements of grazing animals (Hannah et al., 1989; Caton and Dhuyvetter, 1997). Overall, supplementation affects animal intake, digestibility, and performance. Therefore, knowing when and what amount to supplement both can have a significant impact on the profitability of the forage based cow-calf enterprise.

Systems for Predicting Animal Requirements and Performance

Nutritional profiling systems are used to help determine the forage quality in the pastures cattle are currently or will soon be grazing and then compare the forage quality predictions with specific animal needs. These systems can assist in determining when supplementation is necessary, what amount of supplementation is needed, and they also can determine the least cost analysis for specified supplements. Two of the most common nutritional profiling systems that are being used currently include the Handplucked Forage Sampling / 1996 Nutritional Requirements of Beef Cows, National Research Council (NRC96) system and the Fecal Near Infrared Reflectance Spectroscopy (NIRS) / Nutritional Balance Analyzer (NUTBAL) system (NRC, 1996; Nutritional Balance Analyzer, 1996). Both of these systems have the ability to predict animal performance based on the animal's current plane of nutrition and phenotypic characteristics.

Fecal Near Infrared Reflectance Spectroscopy (NIRS) / Nutritional Balance Analyzer (NUTBAL) System. The newest method of monitoring the nutritional status of free-grazing animals is through the use of the Fecal NIRS / NUTBAL system (Nutritional Balance Analyzer,1996). This system was developed in the Grazingland Animal Laboratory in the Rangeland Ecology and Management Department of Texas A&M University in College Station, TX.

In this system, fresh fecal samples are collected and analyzed using NIRS fecal profiling equations that were developed in 1992 to predict dietary crude protein percent (CP%), *in-vivo*-corrected digestible organic matter percent (DOM%), fecal nitrogen percent (N%), and fecal phosphorous percent (P%) of forages (Lyons and Stuth, 1992; Lyons et al., 1995). The NIRS nutritive value predictions are also designed to include forage and roughage types of supplements, but not concentrate type supplemental feeds. NIRS determines the nutritive value of the forage consumed by determining the amount of specific chemical bonds in each fecal sample. Chemical bonds representative of the secondary products of the ingested diet are used to determine quality of the original feedstuff fed. The secondary byproducts are byproducts of digestion that may include plant residue, microbial bodies, secondary metabolites, and sloughed tissue. Each specific chemical bond absorbs NIR light at a characteristic region, generally in the 1100 to 2500 nanometers (nm) region of the NIR band. Generally, wavelength differences among cool season grasses, warm season grasses, and legumes occur in the spectra region from 1900 to 2350 nm (Peterson et al., 1987; Coleman et al., 1990).

Calibration equations for NIRS fecal analysis results for CP% and DOM% were derived using diet:fecal pairs from esophageal fistulated or stall fed animals consuming a wide range and variety of forage species. These calibration equations using the diet:fecal pairs, have established 8 to 12 specific wavelengths that are believed to explain 85 to 95 percent of differences in diet quality. These equations have standard errors similar to those of wet chemistry techniques used to determine the nutritive value of the feeds consumed by test animals. Therefore, the use of NIRS on feces to precisely and accurately predict the quality of forage consumed by animals has shown significant promise (Ward et al., 1982; Lyons and Stuth, 1992; and Lyons et al., 1993).

Various types of NIRS machines have been used to predict forage quality. The two main types include those with scanning monochromators (ie. 6100) and those which use scanning or discrete filter instruments (ie. 51A and 102). It has been concluded that results using scanning or discrete filters have been either satisfactory or unacceptable compared to results reported from scanning monochromators. In contrast to other studies, Shenk and Westerhaus (1985) studied the effect of different types of NIR machines on predicting certain nutritive values and found all machines to be very similar and acceptable in their estimates. They reported CP, DM, and ADF values very accurately for hay, haylage, corn silage, and corn grain with standard error of validations (SEV) depending on instrument from .36 to .85%, .19 to .87%, and 1.22 to 2.53%, respectively, for each of the nutritive parameters. Regardless of NIRS machine all results were acceptable; although the 6100 generally had slightly lower (SEV) and higher R^2 values (Shenk and Westerhaus, 1985).

In a study involving Hereford × Brahman cows, Lyons et al. (1993), concluded that supplemental feeding (20% range cubes) has significant effects on NIRS predictions of forage quality. Forage quality differences were detected more for CP than DOM between supplemented and non-supplemented cows that were all grazing the same pastures. The DOM prediction was within 1.27 percentage units and CP was within 2.2 percentage units of estimates for the non-supplemented cows. To alleviate the effects of supplemental feeding on the ability of NIRS to accurately predict forage quality, it was recommended producers withdraw supplemental feeds from their cattle 48 h prior to the collection of fecal samples that are to be analyzed using NIRS (Lyons et al., 1993).

The results from the Fecal NIRS are then inputted into NUTBAL, which is the computer program used in conjunction with Fecal NIRS to help make nutritional decisions on grazing animals. In the future, Fecal NIRS could be used to determine the parasitic status and reproductive status in animals.

Handplucked Forage / National Research Council (1996) (NRC96). The National Research Council (NRC) which consists of scientists and engineers was established in 1916. Within the NRC there are numerous subdivisions, boards, and committees. The Commission on Natural Resources, the Board on Agricultural and Renewable Resources and the Committee on Animal Nutrition are the respective subdivision, board, and committee that are in close connection with the nutrition of domestic animals. Through individuals serving on the various committees mentioned, a series of publications on nutritional requirements of domestic animals was derived and are steadily revised approximately every 5 to 10 years. Publications exist for the nutrient requirements of poultry, swine, dairy cattle, beef cattle, sheep, horses, mink and foxes, dogs, rabbits, laboratory animals and fish (Naber and Oltjen, 1978). The most recent publication for beef cattle was in 1996.

Along with the publication, there is an animal performance prediction computer program which requires the input of animal and environmental characteristics for the given production system. Also, the program is adapted to use the animal feedstuff quality estimates (CP and TDN) using wet chemistry analysis (NRC, 1996). This most recent update of the animal performance prediction program attempts to more accurately evaluate and determine an animal's partitioning of energy and metabolizable protein requirements according to various animal types and environmental conditions (Block et al., 2001).

NRC nutrient requirements have been developed predominantly from cattle of similar biological type under very little environmental stress (Cunha, 1987; Fox et al., 1988). However, the seventh revised version of NRC (1996) contains models to better account for variations in animal breedtype, feed, and environmental conditions. The NRC (1996) computer model has two levels; Level 1 is based on equations for the prediction of DMI and partitioning of animal net energy requirements similar to NRC (1984). Level 2 is mechanistic and gives a better interpretation of the results. It was adapted from the Cornell Net Carbohydrate and Protein System (CNCPS) (Fox et al., 1992; Block et al., 2001). In the CNCPS, various prediction models were modified or adjusted to allow for more accurate and precise predictions of animal performance under a wide range of environmental conditions. The nutrient requirements for breeding and growing cattle were related to and calculated based on the bodyweight, frame size, breed, previous plane of nutrition, and stage of production (Fox et al., 1988; Fox et al., 1992). Environmental conditions and diet quality estimates along with the factors mentioned to determine the nutrient requirements will allow for the most accurate and precise prediction of animal performance (NRC, 1996).

Only a few studies have assessed the accuracy of the NRC96 Beef Program (CSIRO, 1998; Andrae et al., 2000; Lalman et al., 2001). In addition, to our knowledge, very few studies have compared the accuracy of animal performance predictions made by the Handplucked Forage/ NRC96, Fecal NIRS / NutBal, and Fecal NIRS / NutBal Pro animal performance prediction systems to actual animal performance.

Objectives

The objectives of the present trials were: 1) To evaluate the accuracy of the Fecal NIRS / NutBal, Fecal NIRS / NutBal Pro, and Handplucked Forage / NRC 96 systems by comparing predicted cow performance results with actual cow performance. 2) To compare estimates of forage quality from fecal versus handplucked forage samples.

Experimental Procedures

Two research trials were conducted to determine mature beef cow productivity and performance using the Fecal NIRS / NutBal, Fecal NIRS / NutBal Pro and Handplucked Forage / NRC 96 performance prediction systems (NRC, 1996; Nutritional Balance Analyzer, 1996). Each of the trails lasted a minimum of 1 yr. Trial 1 was conducted from August 13, 1999 through August 16, 2000 at the Virginia Tech Beef Cattle Center and Kentland Research Farm, located in Blacksburg, VA (37°13’N; 80°24’W) and McCoy, VA (37°13’N; 80°35’W), respectively. Trial 2 was conducted at the Buckingham Correctional Facility in Buckingham County, VA (37°37’N; 78°28’W) from November 17,1999 until December 6, 2000. Mature beef cows were used for each of the trials. In each trial, the cows were blocked by breedtype and bodyweight (BWT) and then randomly allotted into one of two groups so replication could occur.

Trial 1

In Trial 1, 70 mature purebred beef cows from the Virginia Tech Beef Cattle Center were used. Of these 70 mature purebred beef cows, there were 5 Gelbvieh, 15

Hereford, and 50 Angus cows which remained in the trial for extended periods of time. These cows were randomly allotted into one of two replicates (n = 35 / replicate) at the beginning of the trial on August 13, 1999, in which they remained for the duration of the study. Numerous cows did not remain in their research group for the entire trial time period because they were consigned to Breed Association Production Sales or for various other reasons. At the beginning of the trial approximately 15 cows from each group were randomly selected to be rectally palpated without the use of a lubrication agent each weigh day to obtain a fresh fecal sample.

Only mature beef cows were used in Trial 1. Cows averaged 65.8 ± 2.1 mo of age, 623.5 ± 9.1 kg, and 5.9 ± .1 BCS at the beginning of the trial. Frame score was calculated based on hip height measurements (BIF, 1996) and averaged to be 6.5 ± .2 for the purebred cows. These cows were estimated to weigh 585.1 kg at a body condition score of 5.0 (Eversole et al., 2000). The weigh-suckle-weigh procedure was performed on d 175 to aid in the estimation for peak milk production of 11.3 kg/d. Cows grazed predominantly tall fescue (*Festuca arundinacea*) pastures interseeded with ladino clover (*Trifolium repens f. giganteum*) for the entire trial. These pastures ranged in size from 8.1 to 28.4 ha, with the majority being approximately 12.2 ha. Cool season forage species round hay bales and corn silage mixed with poultry litter were used as supplemental feeds for the cows around the time of calving and during early to mid lactation. Sample days that these cows received supplementation included 03/10/00, 03/22/00, 04/10/00, 04/19/00, 05/09/00, 05/17/00, 05/31/00. Cows were rebred in mid April through the end of May using artificial insemination. All calves had access to creep feed the last six weeks until they were weaned on August 16, 2000 at an average of 202 d of age.

Cows were weighed approximately every 28 d, resulting in 14 individual weigh periods. On each weigh day, all cows were identified, weighed, and body condition scored (Eversole et al., 2000). At least two experienced cow BCS evaluators assessed the BCS of the cows to help eliminate assessor bias (Evans, 1978). Also, all calves were identified and weighed. Climatic data including daily high and low temperatures, relative humidity, and average windspeed were received from the Virginia State Climatology Office. Averages for each climatic data parameter were calculated for each sample day. Fecal samples were collected from the available cows that were randomly selected to be rectally palpated each weigh day. Also, forage samples from pastures the cows had been grazing prior to each weigh day were taken for each replicate. Approximately 14 d after each weigh period fresh fecal samples were randomly collected from 10 cows in each replicate. Handplucked forage samples were collected from pastures on the same day as the fecal samples. All fecal and forage samples were collected and analyzed as is described in the Forage and Fecal Sample Collection and Analysis sections. Overall both forage and fecal samples were collected approximately every 14 d, resulting in 27 total sample days.

Trial 2

Sixty-four mature predominantly Angus x Gelbvieh crossbred beef cows were randomly allotted into two replicates of 32 cows each on November 17, 1999. All cows in this trial remained in their assigned group until the completion of the trial on December 6, 2000.

These cows were ≥ 60 mo of age, averaged 566.9 ± 7.7 kg, and 5.3 ± .1 at the beginning of the research trial. The frame score of these cows was visually estimated as 6 by two trained extension personnel. Estimated weight at BCS 5 was 553.4 kg. Peak milk production was estimated to be 10.0 kg/d after the weigh suckle weigh procedure was performed on d 127. Throughout the study these cattle grazed predominantly tall fescue (*Festuca arundinacea*) and orchardgrass (*Dactylis glomerata*) pastures interseeded with ladino clover (*Trifolium repens f. giganteum*). All pastures were approximately 10.1 to 12.2 ha in size. Supplemental feeds including rye haylage, ground corn, and cool season forage round hay bales were provided for the cows during lactation in the early winter months which included the following sample days: 01/18/00, 02/24/00, and 03/20/00. Cows calved from September 28, 1999 to November 10, 1999 with an average calving date of October 9, 1999. Cows were rebred on January 20, 2000 using artificial insemination and then exposed to clean-up bulls for 45 d. All calves received creep feed until they were weaned on June 7, 2000 at an average of 242 d of age.

In this trial, there were 11 individual weigh days throughout the trial. In contrast to Trial 1, there were no sample days between weigh days; therefore only 11 sample days existed for the entire study. Weigh day activities were identical to those for Trial 1. Collection and analysis of both fecal and forage samples were performed as described in the Forage and Fecal Sample Collection and Analysis sections. All calculations for cow BCS, BWT, and ADG were figured in the same manner as discussed in the Calculated Cow Performance Parameter Prediction section.

Forage Sample Collection and Analysis

Handplucked forage samples were collected on each sample day. Grab samples were taken every 25-30 paces in a crisscross pattern using handheld forage clipping shears. Forage was removed to 2.5 cm from the ground. Height of grazable forage was measured using a forage measuring stick. Also, available forage per cm per ha was visually estimated. Actual average forage grazing height was multiplied by estimated available forage per cm to determine available forage per acre. The samples were placed into a labeled plastic bag, sealed, double bagged, and sealed once again to prevent moisture leakage. The samples were then taken to the Virginia Tech Forage Testing Laboratory for analysis. Each pasture sample was subsampled and subsamples were dried and then ground using a Wiley mill to pass through a 1 mm-mesh screen (Thomas Wiley, Laboratory Mill Model 4, Arthur H. Thomas Co., Philadelphia, PA.) for chemical analysis. Ground forage samples were analyzed for DM and CP (AOAC, 1990), ADF (Van Soest, 1963), and NDF (Van Soest and Wine, 1968). TDN, NE_m and NE_g were calculated from fiber and CP analysis. The TDN estimate was calculated using one of the following formulas:

$$TDN = 49.71 + .7330*CP$$

or

$$TDN = 89.8 - .7680*(ADF - 1).$$

Fecal Sample Collection and Analysis

The fecal sampling procedure used required measuring 30 ml of fresh fecal material from each sampled cow or patty into a sealable plastic Ziploc bag. Fecal samples collected on the same day from cows in the same replicate were pooled. Each bag was then put into a Styrofoam cooler with an ice pack. The cooler was then taken to a laboratory where each sample was emptied out of the bag into a plastic pan. Each sample was mixed thoroughly and then divided in half and placed in pre-labeled Ziploc bags and frozen at -20°C. One of the two frozen samples from each replicate representing each collection day along with the GANLAB-NIRS Analysis Fecal Sample Information Form filled out for that specific sample were placed in a Styrofoam cooler with a frozen ice pack. These coolers were sealed and mailed by Second Day Air to the Grazingland Animal Nutrition Lab (GANLAB) at Texas A&M University in College Station, TX.

GANLAB is a laboratory that specializes in using NIRS analysis of fecal samples to predict the forage quality consumed by various grazing animal species. Once the fecal samples arrive at GANLAB, they have thawed. Once removed from the bag, the fecal sample was placed into a correctly labeled paper tray. Next, the tray with the fecal sample was placed inside a Lindberg/Blue M Forced Air Oven (GS Blue M Electric, Blue Island, IL) where the sample was dried at 60°C for 16-20 h. The fecal samples were removed from the forced air oven and ground to 1 mm in size by a Cyclotec 1093 Sample Mill (Foss International, Hoganas, Sweden). Ground fecal samples were dried at 60°C for another 16-20 h. Approximately 15 ml of representative sample was packed into a small ring sample cup. The small ring sample cup was then placed into a Foss 6500 NIR machine (Foss, Eden Prairie, MN) that formed a line spectra typically in the 1100 to 2500 nanometers (nm) region of the NIR band for the sample. This line spectra was applied to prediction equations that derived the CP%, DOM%, Fecal N%, and Fecal P% for the forage represented in the fecal sample. The predicted forage quality estimates are printed, analyzed, and then recorded on the GANLAB-NIRS Analysis Fecal Sample Information Form that was received with the respective sample. Sample information forms were either mailed or faxed back to the client of the sample. Once GANLAB received the sample, it took 3 d for the analysis of the fecal sample and determination of the results that were sent back to the client.

Use of Cow Performance Prediction Programs

Forage quality results based on fecal samples were used in NutBal and NutBal Pro and forage quality results based on handplucked forage samples were input into NRC 96. Each of the three prediction programs was used to predict cow performance for each trial. In addition to forage quality results, all programs used climatic conditions, cow breedtype, current cow BCS and stage of production as inputs to the computer performance programs and played significant roles in predicting cow performance. Output presented by NRC 96 stated the number of days required for the specific cow herd, under the defined environmental conditions, to gain or lose one BCS. NutBal predicts only ADG; while NutBal Pro predicts both BCS in 30 d and ADG.

In predicting animal performance for cows in Trial 1 and Trial 2, a continuous method was used when possible for all three programs. In the continuous method, the predicted cow BCS and BWT for the next sample day were used as inputs for the next period as long as the same cows were present from one weigh period to the next. As a result of the continuous method, results predicted by any of the programs tested were additive as the experiment progressed.

However, for the first weigh day as well as various other weigh days, when cows were moved either in or out of their groups; average actual BCS and BWT were used since there was a different cow base from the previous weigh day's group. In Trial 1, actual BCS and bodyweight for Kentland 1 were used as inputs for the prediction programs for seven of the 14 weigh days. Those weigh days included 08/13/99, 09/08/99, 11/03/99, 02/23/00, 03/22/00, 04/19/00, and 05/17/00. Also, actual BCS and BWT were used for Kentland 2 cows for six of the 14 total weigh days including all weigh days mentioned for Kentland 1 except 04/19/00. In contrast to Trial 1, actual BCS and BWT were only used for the first weigh day in Trial 2 on 11/17/99 for both Buckingham 1 and Buckingham 2. All cows in Trial 2 remained in their designated groups for the duration of the study.

The Handplucked Forage / NRC 96 animal performance prediction system was the only system to predict animal performance in terms of number of days to gain or lose one BCS. Using the previously mentioned, continuous method of predicting animal performance, predicted BCS's were input into the NRC 96 program for most sample days. Predicted BCS's were calculated using the following formula:

Predicted BCS = (number of days between samples / number of days to gain or lose 1 BCS) + BCS input.

Preliminary predicted ADG was calculated using the following formula:

Preliminary predicted ADG = (45.36 kg / number of d to gain or lose 1 BCS).

45.36 kg was used as the denominator since it is the average of BWT gained or lost by a typical cow to gain or lose one BCS (NRC, 1996). Also, it is important to note if a prediction of losing one BCS over a certain amount of days was made; then –45.36 kg was input. Also during gestation, pregnancy adjustment factors were added to the preliminary predicted ADG figure based on the cowherd's stage of production on each specific sample day (NRC, 1996).

NRC 96 uses cow BWT and BCS as primary inputs to the program. Therefore, predicted BWT at the next sampling period had to be calculated from the predicted average daily gain. To predict BWT the following formula was used:

Predicted BWT = (Preliminary predicted ADG * number d between sample days) + BWT input.

When using the Fecal NIRS / NutBal animal performance prediction system, cow BCS was estimated for the subsequent sample day based on the predicted NutBal ADG from the previous sample day using the following formula:

Predicted BCS = ((NutBal ADG * number d between sample days) / 45.36) + BCS Input.

45.36 kg was used as the denominator, since it constituted the average weight required for typical beef cows to gain or lose one BCS and to also be consistent with what was done for NRC calculations.

The NutBal Pro animal performance computer program used predicted forage quality results from Fecal NIRS to estimate cow performance for each specific herd (ie. replicate) in Trial 1 and Trial 2. Cow performance measures received as output in NutBal Pro were predicted ADG and predicted BCS in 30 d. Since time between sample days was not 30 d the predicted BCS in 30 d value had to be converted to predicted BCS change per day. Predicted BCS change between sample days was calculated using the following formula:

Predicted BCS change between sample days = (((BCS predicted – BCS input) / 30 d) * number d between sample days)

Predicted BCS change was added to the BCS from the specific sample day for which the computer program was last performed. This sum was the newly calculated predicted BCS that was inputted for the next sample day by using NutBal Pro.

Calculations Used To Allow Comparisons of Cow Performance Prediction Programs

Predictions for each sample day for BCS, ADG, and BWT were calculated for NRC 96, NutBal, and NutBal Pro. The calculated values were compared among prediction systems and also to actual performance of the animals. When calculating predicted performance to compare among programs, predicted ADG played the most significant role since all predictions except NutBal Pro2 BCS required the use of ADG. Predicted ADG for NRC 96, NutBal, and NutBal Pro were calculated by first determining the number of days between two continuous sample days and then dividing the result by two. Next, the result was multiplied by the predicted ADG for the each of the previously mentioned sample days. Then the two products were added together to equal the total weight change between the two sample days of interest. This result was divided by the number of days between the two continuous sample days to equal the predicted ADG during the two continuous sample days. This predicted ADG value was reported for the latter of the two continuous sample days.

Predicted BCS and BWT were also calculated using the total weight change between the two samples days of interest. The predicted BWT input into each computer program was calculated using the following formula:

Predicted BWT = Total BWT change between 2 sample days + Input BWT.

Predicted BCS change between two sample days was computed using the following equation:

Predicted BCS change = Total BWT change between two sample days / 45.36 kg.

This BCS change was added to the program input BCS for the first of the two sample days. This sum was the predicted BCS for the latter of the two sample days of interest.

Also, since NutBal Pro predicted BCS in 30 d, a conversion was performed to convert it into predicted BCS for the next sample day. The conversion was the same as discussed in the Use of Cow Performance Prediction Programs section. Once the above calculations were concluded, all cow performance prediction systems were compared to each other and to the actual performance measures. This allowed for the determination of the system that most precisely and accurately predicted overall cow performance.

Statistical Analysis

Statistical analyses were conducted using SAS (1999). Correlation coefficients were used to evaluate the relationships between actual and predicted animal performance measures from each computer program. Also, relationships for estimates of forage CP and TDN derived from fecal and handplucked forage samples during times of the year when the cattle were not receiving supplementation were determined by correlation coefficients. Simple linear regression of wet chemistry forage analysis on Fecal NIRS was conducted for each forage quality estimate (CP and TDN) that was derived from samples taken when the cows were not receiving supplementation. Also, simple linear regression of actual and prediction program estimates over sample time was performed for each animal performance variable (BWT, ADG, and BCS) to determine the line of best fit. Quadratic regression of actual and prediction program estimates over sample time was performed for BWT to determine the line of best fit. These lines were generated by combining both replicates in each trial. Performance variables and their changes between sample times were analyzed using the Mixed Procedure (SAS, 1999) with sources of variation due to method, location, and sample time and all their interactions. Location and method were fixed and sample time was a repeated measure within location and method. Least square means for method and method*location combinations were compared using Tukey's pairwise comparison.

Several variables were created to evaluate the accuracy of each animal performance prediction program compared to actual animal performance measures. The following variables were used for ADG, BWT, and BCS:

NRCDIFF = (NRC – Actual)

ANRCDIFF = |(NRCDIFF)|

NBDIFF = (NutBal – Actual)

ANBDIFF = |(NBDIFF)|

NBPDIFF = (NutBal Pro – Actual)

ANBPDIFF = |(NBPDIFF)|

NBNRCDIFF = (NutBal – NRC)

ANBNRCDIFF = |(NBNRCDIFF)|

NBPNRCDIFF = (NutBal Pro – NRC)

ANBPNRCDIFF = |(NBPNRCDIFF)|

NBNBPDIFF = (NutBal – NutBal Pro)

ANBNBPDIFF = |(NBNBPDIFF)|

Also, the following additional variables were created for BCS comparisons only:

NBP2NRCDIFF = (NutBal Pro2 – NRC)

ANBPNRCDIFF = |(NBP2NRCDIFF)|

NBNBP2DIFF = (NutBal – NutBal Pro2)

ANBNBP2DIFF = |(NBNBP2DIFF)|

Variables created for the forage quality estimates (CP and TDN) include:

CPDIFF = (CPFEC – CPFOR)

ACPDIFF = |(CPDIFF)|

TDNDIFF = (TDNFEC – TDNFOR)

ATDNDIFF = |(TDNDIFF)|

Results

Forage Quality

Estimates of forage digestibility were not similar between fecal and handplucked forage samples; however, estimates of forage CP content were similar (Table 1). The mean CPFOR in Trial 1 and 2 were similar to the mean CPFEC values for each respective trial (P = .74; Table 2 and P = 1.00; Table 3). TDNFEC was significantly greater than TDNFOR in both Trial 1 and 2. In Trial 1, ranges for the predicted forage quality estimates were: CPFEC 9.61 to 16.62%, CPFOR 8.99 to 20.07%, TDNFEC 62.77 to 71.02, and TNDFOR 56.30 to 68.82%. While in Trial 2 ranges were: CPFEC 10.68 to 16.50%, CPFOR 9.09 to 22.08%, TDNFEC 65.64 to 72.08%, and TDNFOR 61.28 to 70.95%.

Across both trials, CPFEC and CPFOR were weakly correlated (Table 4). Estimates of TDN were moderately correlated and these estimates were moderately to strongly correlated to estimates of forage crude protein content. The correlations between CPFEC and CPFOR were .24 and .43 for Trial 1 and 2, respectively (Tables 5 and 6). The correlation for Trial 1 was not significant; however, the correlation for Trial 2 was significant. Also, R^2 values were low at .06 and .19 for Trial 1 and 2, respectively. Therefore, CPFEC explains less than 20% of the variation in CPFOR; meaning these estimates did not match each other closely. Correlations between TDNFEC and TDNFOR were drastically different at .52 and .15 for Trial 1 and 2, respectively. Only in Trial 1 was the correlation between TDNFEC and TDNFOR significant. Correlations between CPFEC and TDNFEC were .84 and .76 ($P < .0001$) for Trial 1 and 2. Also, CPFOR and TDNFOR had correlation coefficients of .32 and .76 for Trial 1 and 2. The strong correlation between CP and TDN from the same sample type is due to the contribution of CP in determining the estimates of TDN of a given feedstuff.

Figures 1 and 2 illustrate the relationship for forage CP% from handplucked forage and fecal samples in Trial 1 and 2. Crude protein percent, for Trial 1, as estimated by handplucked forage samples did not demonstrate a linear relationship ($P = .17$) with CPFEC with intercept = 8.76 ± 3.34 and slope = $.36 \pm .26$. However, CPFOR had a tendency to demonstrate a linear relationship ($P < .1$) with CPFEC with intercept = 1.91 ± 6.77 and slope = $.89 \pm .49$ in Trial 2. R^2 for the regression of CPFOR against CPFEC was low for Trial 1 and 2 at .06 and .19, respectively.

Shown in Figures 3 and 4 are the regression lines for forage TDN% from handplucked forage and fecal samples in Trial 1 and 2. In Trial 1, TDN% as determined through handplucked forage samples demonstrated a linear relationship ($P < .005$) with TDNFEC with intercept = 3.63 ± 17.41 and slope = $.90 \pm .26$. However, in Trial 2 there was no linear relationship ($P = .58$) between TDNFOR and TDNFEC. The Trial 2 TDN regression line intercept and slope were 52.41 ± 22.14 and $.18 \pm .32$. The R^2 value for TDN% was higher for Trial 1 than Trial 2 with values being .27 and .02 for each respective trial.

Table 1. Least square means, standard errors, minimum and maximum values for predicted forage quality parameters combined for Trial 1 and 2 (n=50)

Forage quality measure	Mean	Standard error	Minimum	Maximum
CPFEC, %	13.14	0.41	9.61	16.62
CPFOR, %	13.69	0.41	8.99	22.08
TDNFEC, %	67.08[a]	0.41	62.77	72.08
TDNFOR, %	64.00[b]	0.41	56.30	70.95

[a,b] Means with different superscripts differ ($P < .0001$).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Table 2. Least square means, standard errors, minimum and maximum values for predicted forage quality parameters combined for Trial 1 (n=34)

Forage quality measure	Mean	Standard error	Minimum	Maximum
CPFEC, %	12.60	0.46	9.61	16.62
CPFOR, %	13.35	0.46	8.99	20.07
TDNFEC, %	65.95[a]	0.46	62.77	71.02
TDNFOR, %	63.07[b]	0.46	56.30	68.82

[a,b]Means with different superscripts differ ($P < .001$).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Table 3. Least square means, standard errors, minimum and maximum values for predicted forage quality parameters combined for Trial 2 (n=16)

Forage quality measure	Mean	Standard error	Minimum	Maximum
CPFEC, %	13.68	0.67	10.68	16.50
CPFOR, %	14.03	0.67	9.09	22.08
TDNFEC, %	68.21[a]	0.67	65.64	72.08
TDNFOR, %	64.93[b]	0.67	61.28	70.95

[a,b]Means with different superscripts differ ($P < .05$).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Table 4. Correlation coefficients between CP and TDN predictions of forage quality using fecal and handplucked forage samples for both Trial 1 and 2 (n=50)

Variable	CPFEC	CPFOR	TDNFEC	TDNFOR
CPFEC	1.00	.31[d]	.82[a]	.59[a]
CPFOR		1.00	.17	.43[c]
TDNFEC			1.00	.49[b]
TDNFOR				1.00

[a]Values different from zero ($P < .0001$).
[b]Values different from zero ($P < .001$).
[c]Values different from zero ($P < .005$).
[d]Values different from zero ($P < .05$).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Table 5. Correlation coefficients between CP and TDN predictions of forage quality using fecal and handplucked forage samples for Trial 1 (n=34)

Variable	CPFEC	CPFOR	TDNFEC	TDNFOR
CPFEC	1.00	.24	.84[a]	.58[b]
CPFOR		1.00	.07	.32[d]
TDNFEC			1.00	.52[c]
TDNFOR				1.00

[a]Values different from zero ($P < .0001$).
[b]Values different from zero ($P < .001$).
[c]Values different from zero ($P < .005$).
[d]Values different from zero ($P < .1$).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Table 6. Correlation coefficients between CP and TDN predictions of forage quality using fecal and handplucked forage samples for Trial 2 (n=16)

Variable	CPFEC	CPFOR	TDNFEC	TDNFOR
CPFEC	1.00	.43[c]	.76[a]	.50[b]
CPFOR		1.00	.31	.76[a]
TDNFEC			1.00	.15
TDNFOR				1.00

[a]Values different from zero (P < .001).
[b]Values different from zero (P < .05).
[c]Values different from zero (P < .1).
CPFEC = CP determined from fecal sample; CPFOR = CP determined from forage sample.
TDNFEC = TDN determined from fecal sample; TDNFOR = TDN determined from forage sample.

Figure 1. Regression line and individual data points of predicted forage CP% from forage and fecal samples in Trial 1.

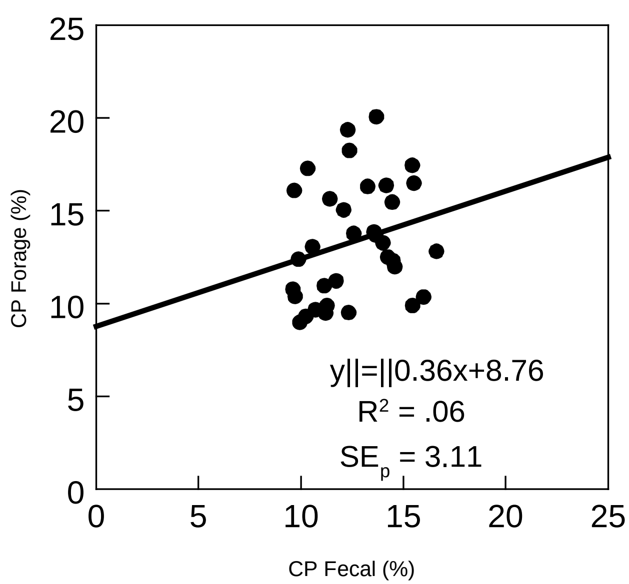


Figure 2. Regression line and individual data points of predicted forage CP% from forage and fecal samples in Trial 2.

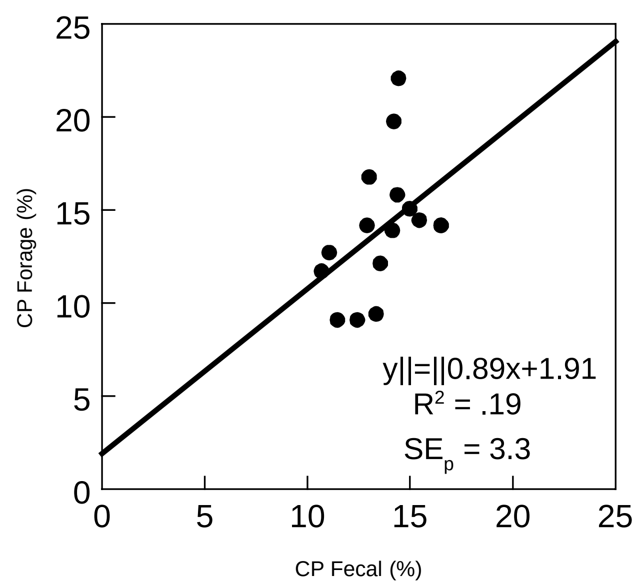


Figure 3. Regression line and individual data points of predicted forage TDN% from forage and fecal samples in Trial 1.

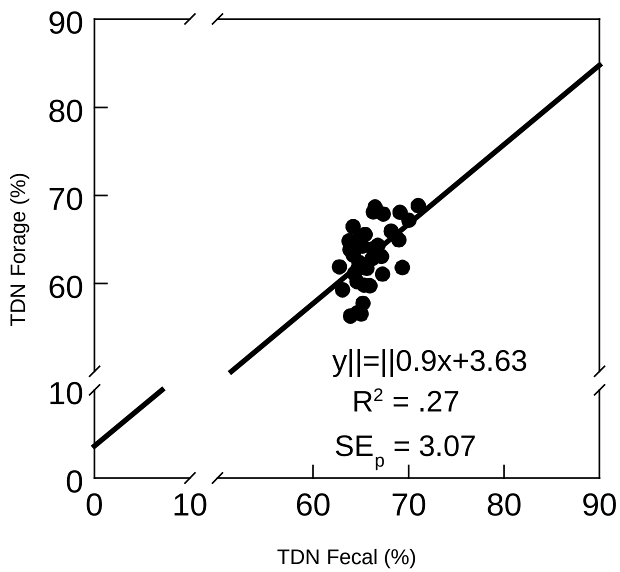
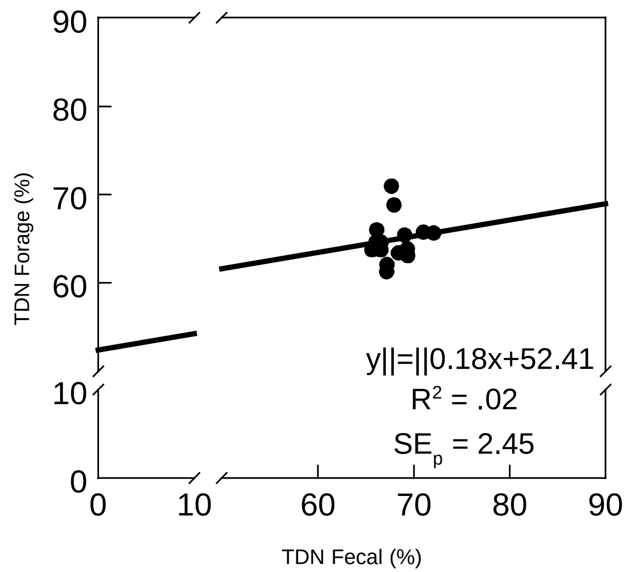


Figure 4. Regression line and individual data points of predicted forage TDN% from forage and fecal samples in Trial 2.



Bodyweight

Overall, NRC was a more accurate predictor of BWT and BWTCHG than other prediction programs used. In comparison to Actual mean BWT for Trial 1, NRC, NutBal, and NutBal Pro overpredicted mean BWT by .92%, 9.75%, and 9.16%, respectively (Tables 7 and 8). In Trial 2, compared to Actual mean BWT, NRC underpredicted mean BWT by 3.25%. In contrast, NutBal and NutBal Pro overpredicted mean BWT by 45.16% and 40.08%, respectively, for Trial 2.

Actual and NRC predicted mean BWTCHG were similar ($P = .51$ and $P = 1.00$ for Trial 1 and 2, respectively; Table 9 and 10). In Trial 1 and 2, NutBal and NutBal Pro predicted mean BWTCHG were greater ($P < .0001$) than both Actual and NRC predicted mean BWTCHG. However, NutBal and NutBal Pro predicted mean BWTCHG were similar ($P = .91$ and $P = .62$ for Trial 1 and 2, respectively). In Trial 1, Actual and predicted BWTCHG ranges were: Actual BWTCHG -50.58 to 52.93 kg, NRC predicted BWTCHG -8.86 to 27.54 kg, NutBal predicted BWTCHG 23.64 to 85.08 kg, and NutBal Pro predicted BWTCHG 18.51 to 71.35 kg. Actual and predicted BWTCHG ranges in Trial 2 were: Actual BWTCHG -25.58 to 56.70 kg, NRC predicted BWTCHG -32.57 to 39.37 kg, NutBal predicted BWTCHG 31.62 to 83.51 kg, and NutBal Pro predicted BWTCHG 23.27 to 76.57 kg.

The relationship between actual BWT and a BWT prediction was strongest between actual BWT and NRC predicted BWT with correlation coefficients of .82 and .64, for Trials 1 and 2, respectively (Tables 11 and 12). The relationship among Actual BWT and both NutBal and NutBal Pro predicted BWT was weaker with correlation coefficients of .48 and .60 respectively for Trial 1 and .42 and .39 for Trial 2. In Trial 1 and 2, NutBal predicted BWT and NutBal Pro predicted BWT were detected to be highly correlated as evidenced by correlation coefficients of .97 and 1.00, respectively.

Based on mean BWTCHG NRCDIFF, Actual mean BWTCHG and NRC predicted mean BWTCHG by weigh period were similar for each trial. In contrast, mean BWTCHG NBDIFF, NBPDIFF, NBNRCDIFF, and NBPNRCDIFF were all different ($P < .001$); meaning NutBal and NutBal Pro predicted mean BWTCHG were significantly different from Actual and NRC predicted mean BWTCHG for Trial 1 and 2. Mean BWTCHG NBNBPDIFF was also different ($P < .01$) in Trial 2, however; no significant difference was detected between NutBal and NutBal Pro predicted mean BWTCHG in Trial 1. Means and standard errors along with significance levels for predicted mean BWTCHG's compared to Actual mean BWTCHG and/or other predicted mean BWTCHG's by weigh period for Trial 1 and 2 are reported in Tables 13 and 14.

In order to determine the accuracy and precision with which each animal performance prediction program predicted BWT, absolute BWTCHG means and standard deviations for consecutive weigh periods were calculated and analyzed (Tables 15 and 16). By comparing the absolute differences in BWTCHG's strictly, the magnitude to which each animal performance prediction program over or underpredicts BWT was taken into account. In Trial 1 and 2, using the absolute means, all prediction program predicted mean BWTCHG's (mean ADG ANRCDIFF, ANBDIFF, ANBPDIFF, ANBNRCDIFF, ANBPNRCIFF, and ANBNBPDIFF) were different ($P < .001$), not only from actual mean BWTCHG but also from prediction program estimated mean BWTCHG's when they were compared against one another.

In Trial 1 and 2, NRC predicted BWT regression lines stayed in closest proximity to Actual BWT regression lines (Figures 5 and 6). NutBal and NutBal Pro predicted BWT regression lines appear to follow a similar trend but increased more quickly than either the Actual or NRC predicted BWT regression lines. This quicker increase is due to greater slopes for NutBal and NutBal Pro predicted BWT regression lines. In Trial 2, the difference between NutBal or NutBal Pro predicted BWT regression lines and Actual or NRC predicted BWT regression lines is greater than in Trial 1 because of the continuous method used for cow BWT prediction. Using the continuous method, overprediction of BWT was additive and, therefore, predicted BWT estimates increased very quickly for both NutBal and NutBal Pro. There was a significant quadratic and linear relationship for actual and predicted BWT regression lines over sample time except for the NutBal and NutBal Pro regression lines in Trial 1. There was only a significant linear relationship for NutBal and NutBal Pro over sample time in Trial 1. Presented in Tables 17 and 18 are the intercept, intercept SE, linear regression coefficient, linear regression coefficient SE slope, quadratic regression coefficient, quadratic regression coefficient SE, and R^2 for each of the Actual and predicted BWT regression lines.

Table 7. Means, standard errors, minimum and maximum values for actual and predicted cow bodyweight (BWT) for Trial 1 (n=22)

Cow BWT estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	693.09	9.20	607.36	755.68
NRC	699.44	8.39	611.90	752.51
NutBal	760.67	14.22	638.20	909.45
NutBal Pro	756.59	11.98	641.83	880.42

NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 8. Means, standard errors, minimum and maximum values for actual and predicted cow bodyweight (BWT) for Trial 2 (n=18)

Cow BWT estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	571.53	4.69	533.88	620.06
NRC	552.93	9.05	500.77	620.51
NutBal	829.62	35.82	597.83	1049.16
NutBal Pro	800.59	31.91	596.93	992.46

NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 9. Means, standard errors, minimum and maximum values for actual and predicted cow bodyweight change (BWTCHG) for Trial 1 (n=22)

Cow BWTCHG estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	3.85[a]	5.36	-50.58	52.93
NRC	8.58[a]	2.46	-8.86	27.54
NutBal	47.63[b]	3.76	23.64	85.08
NutBal Pro	45.42[b]	3.23	18.51	71.35

[a,b]Means with different superscripts differ ($P < .0001$).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 10. Means, standard errors, minimum and maximum values for actual and predicted cow bodyweight change (BWTCHG) for Trial 2 (n=18)

Cow BWTCHG estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	4.98[a]	5.47	-25.58	56.70
NRC	5.66[a]	5.21	-32.57	39.37
NutBal	52.10[b]	3.93	31.62	83.51
NutBal Pro	45.96[b]	3.69	23.27	76.57

[a,b]Means with different superscripts differ (P < .0001).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 11. Correlation coefficients between actual and predicted cow bodyweight (BWT) using animal performance prediction computer programs for Trial 1 (n=22)

Cow BWT estimator	Actual	NRC	NutBal	NutBal Pro
Actual	1.00	.82[a]	.48[c]	.60[b]
NRC		1.00	.82[a]	.89[a]
NutBal			1.00	.97[a]
NutBal Pro				1.00

[a]Values different from zero (P < .0001).
[b]Values different from zero (P < .01).
[c]Values different from zero (P < .05).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 12. Correlation coefficients between actual and predicted cow bodyweight (BWT) using animal performance prediction computer programs for Trial 2 (n=18)

Cow BWT estimator	Actual	NRC	NutBal	NutBal Pro
Actual	1.00	.64[b]	.42[c]	.39
NRC		1.00	.65[b]	.64[b]
NutBal			1.00	1.00[a]
NutBal Pro				1.00

[a]Values different from zero (P < .0001).
[b]Values different from zero (P < .01).
[c]Values different from zero (P < .1).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 13. Means, standard deviations, and significance levels for bodyweight changes (BWTCHG) from weigh period to weigh period compared to Actual BWT changes for Trial 1 (n=22)

BWTCHG comparison	Mean (kg)	Standard error (kg)	Significance level
NRCDIFF	4.73	3.94	NS
NBDIFF	43.78	5.68	**
NBPDIFF	41.58	4.35	**
NBNRCDIFF	39.05	4.41	**
NBPNRCDIFF	36.85	3.15	**
NBNBPDIFF	2.21	2.44	NS

NS – Mean values similar to zero.
**Mean values different from zero ($P < .001$).
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBPDIFF = (NutBal Pro – Actual); NBNRCDIFF = (NutBal – NRC);
NBPNRCDIFF = (NutBal Pro – NRC); NBNBPDIFF = (NutBal – NutBal Pro).

Table 14. Means, standard errors, and significance levels for bodyweight changes (BWTCHG) from weigh period to weigh period compared to Actual BWT changes for Trial 2 (n=18)

BWTCHG comparison	Mean (kg)	Standard error (kg)	Significance level
NRCDIFF	0.68	6.07	NS
NBDIFF	47.12	6.89	**
NBPDIFF	40.99	7.43	**
NBNRCDIFF	46.44	6.24	**
NBPNRCDIFF	40.30	6.30	**
NBNBPDIFF	6.14	1.79	*

NS – Mean values similar to zero.
*Mean values different from zero (P < .01).
**Mean values different from zero (P < .001).
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBPDIFF = (NutBal Pro – Actual); NBNRCDIFF = (NutBal – NRC);
NBPNRCDIFF = (NutBal Pro – NRC); NBNBPDIFF = (NutBal – NutBal Pro).

Table 15. Absolute means, standard errors, and significance levels for bodyweight changes (BWTCHG) from weigh period to weigh period compared to Actual BWT changes for Trial 1 (n=22).

Absolute BWTCHG comparison	Mean (kg)	Standard error (kg)	Significance level
ANRCDIFF	14.83	2.48	**
ANBDIFF	44.81	5.29	**
ANBPDIFF	41.65	4.31	**
ANBNRCDIFF	39.05	4.41	**
ANBPNRCDIFF	36.85	3.15	**
ANBNBPDIFF	9.60	1.33	**

**Mean values different from zero (P < .001).
ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|;
ANBPDIFF = |(NutBal Pro – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|;
ANBPNRCDIFF = |(NutBal Pro – NRC)|; ANBNBPDIFF = |(NutBal – NutBal Pro)|.

Table 16. Absolute means, standard errors, and significance levels for bodyweight changes (BWTCHG) from weigh period to weigh period compared to Actual BWT changes for Trial 2 (n=18)

Absolute BWTCHG comparison	Mean (kg)	Standard error (kg)	Significance level
ANRCDIFF	20.42	3.52	**
ANBDIFF	49.57	5.79	**
ANBPDIFF	44.96	5.92	**
ANBNRCDIFF	46.44	6.24	**
ANBPNRCDIFF	40.30	6.30	**
ANBNBPDIFF	7.73	1.38	**

**Mean values different from zero (P< .001).
ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|;
ANBPDIFF = |(NutBal Pro – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|;
ANBPNRCDIFF = |(NutBal Pro – NRC)|; ANBNBPDIFF = |(NutBal – NutBal Pro)|.

Table 17. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, quadratic regression coefficient, quadratic regression coefficient SE, and R^2 values for Actual, NRC, NutBal, and NutBal Pro BWT (kg) regression lines for Trial 1 that are plotted in Figure 5

Cow BWT estimator	Intercept (kg)	Intercept SE (kg)	Linear regression coefficient	Linear regression coefficient SE*	Quadratic regression coefficient*	Quadratic regression coefficient SE*	R^2
Actual	587.15	22.42	45.38	8.59	-3.62	0.70	.60
NRC	605.77	22.07	31.53	8.45	-2.07	0.68	.53
NutBal	642.00	33.14	26.03	12.69	-0.82	1.03	.63
NutBal Pro	655.40	33.11	26.29	12.68	-1.23	1.03	.48

* Slope and Slope SE are expressed in kg / sample time.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 18. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, quadratic regression coefficient, quadratic regression coefficient SE, and R^2 values for Actual, NRC, NutBal, and NutBal Pro BWT (kg) regression lines for Trial 1 that are plotted in Figure 6

Cow BWT estimator	Intercept (kg)	Intercept SE (kg)	Linear regression coefficient	Linear regression coefficient SE*	Quadratic regression coefficient*	Quadratic regression coefficient SE*	R^2
Actual	585.27	14.32	-13.05	6.58	1.63	0.64	.43
NRC	581.91	11.92	-32.67	5.47	4.24	0.54	.90
NutBal	517.59	12.45	71.92	5.72	-1.51	0.56	.99
NutBal Pro	517.70	12.93	66.90	5.93	-1.63	0.58	.99

* Slope and Slope SE are expressed in kg / sample time.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Figure 5. Regression lines and individual data points of cow BWT (kg) regressed on sample time for Actual, NRC, NutBal, and NutBal Pro in Trial 1.

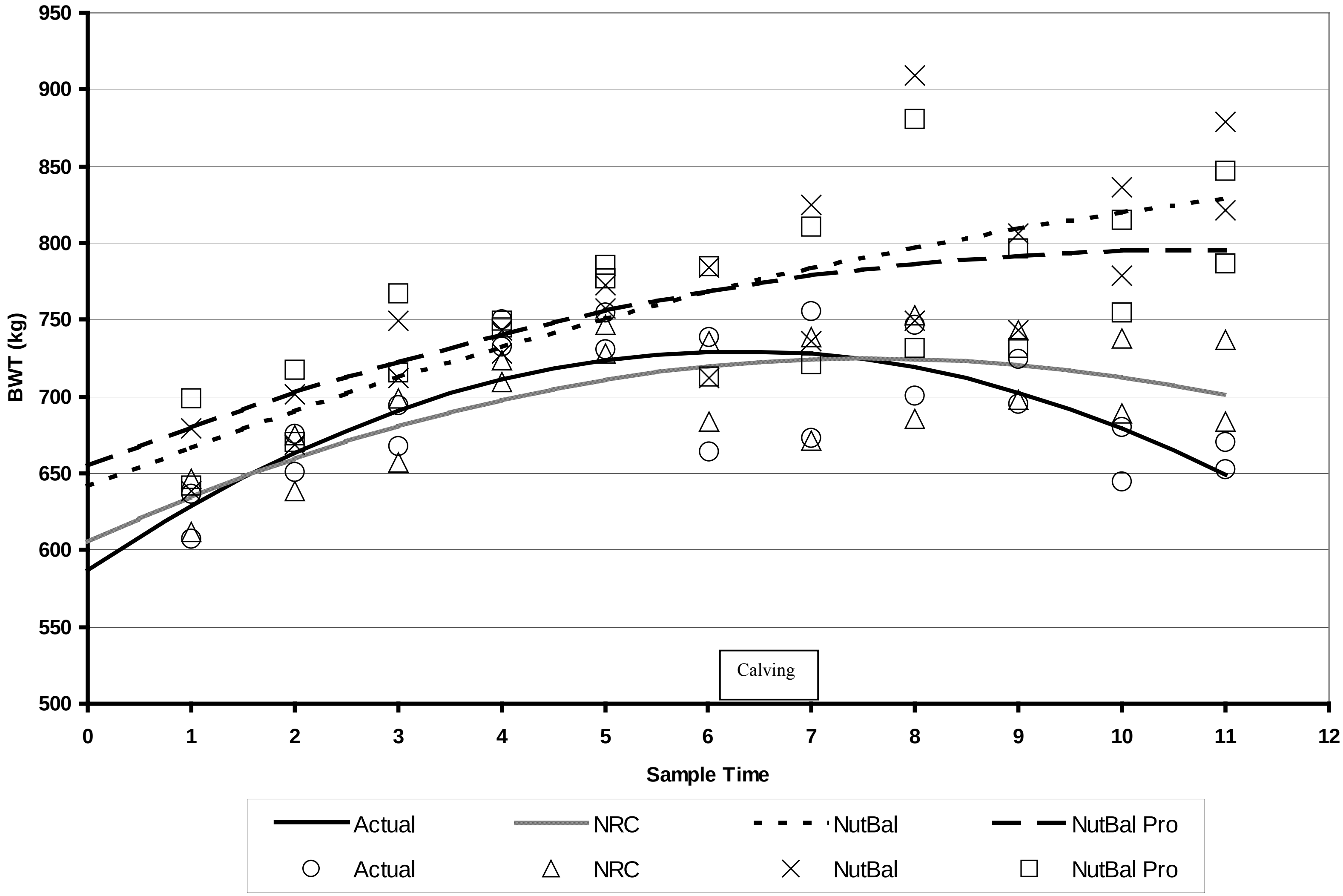
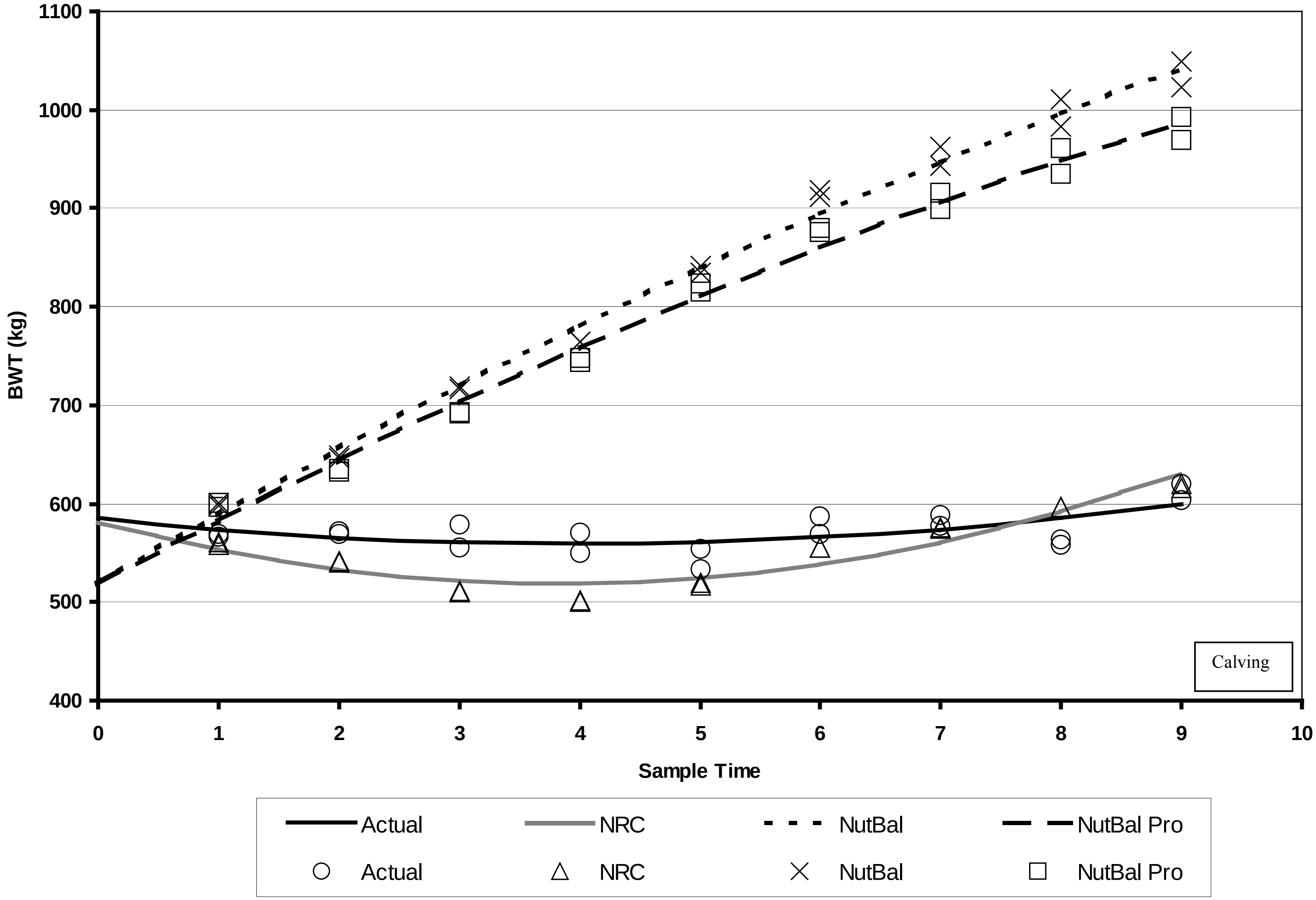


Figure 6. Regression lines and individual data points of cow BWT (kg) regressed on sample time for Actual, NRC, NutBal, and NutBal Pro in Trial 2.



Average Daily Gain

Estimates of ADG paralleled BWT and BWTCHG with NRC predictions more closely agreeing with actual observations (Tables 19 and 20). Actual mean ADG and NRC predicted mean ADG were similar ($P = .51$ and $P = 1.00$ in Trial 1 and 2, respectively). Actual and NRC predicted mean ADG were each different ($P < .0001$) from NutBal predicted and NutBal Pro predicted mean ADG in each trial. However, NutBal and NutBal Pro predicted mean ADG were found to be similar ($P = .94$ and $P = .84$ for Trial 1 and 2, respectively). In Trial 1, ranges for actual and predicted ADG (kg/d) were: Actual ADG -1.81 to 1.89 kg/d, NRC predicted ADG -.32 to .98 kg/d, NutBal predicted ADG .84 to 3.04, and NutBal Pro predicted ADG .66 to 2.55 kg/d. In Trial 2, ranges for actual and predicted ADG (kg/d) were: Actual ADG -.64 to 1.49 kg/d, NRC predicted ADG -.88 to .96 kg/d, NutBal predicted ADG .99 to 2.04 kg/d, and NutBal Pro predicted ADG .83 to 2.20 kg/d.

The strongest relationship for ADG was between NutBal predicted ADG and NutBal Pro predicted ADG as evidenced by correlation coefficients of .77 and .85, in Trial 1 and 2, respectively (Tables 21 and 22). Only in Trial 1 was a relatively strong relationship detected between Actual ADG and NRC predicted ADG, based on a correlation coefficient of .73. The relationship between Actual ADG and both NutBal and NutBal Pro predicted ADG was weaker with correlation coefficients of .27 and .56 for Trial 1 and -.26 and -.47 in Trial 2. The negative correlation coefficients found in Trial 2 are evidence that when the cattle actually lost weight, both NutBal and NutBal Pro predicted an increase in cow BWT.

Differences in predicted mean ADG for consecutive weigh periods compared to Actual or other predicted mean ADG for Trial 1 and 2, respectively, are presented in Tables 23 and 24. In both trials, no significant difference was detected for mean ADG NRCDIFF indicating that on average Actual ADG and NRC predicted ADG were similar. Mean ADG NBDIFF, NBPDIFF, NBNRCDIFF, and NBPNRCDIFF were each different ($P < .001$), meaning Actual and NRC predicted mean ADG were significantly different from NutBal and NutBal Pro predicted mean ADG in both Trial 1 and 2. In Trial 2, a detectable difference ($P < .01$) was found for mean ADG NBNBPDIFF; however, no significant difference was found between NutBal and NutBal Pro predicted mean ADG in Trial 1.

Similar to BWTCHG, absolute differences in predicted mean ADG from Actual or other predicted mean ADG were compared (Tables 25 and 26). Based on mean ADG ANRCDIFF, Actual and NRC predicted mean ADG were similar for Trial 2; however, they were found to be different ($P < .001$) for Trial 1. In Trial 1 and 2, mean ADG ANBDIFF, ANBPDIFF, ANBNRCDIFF, ANBPNRCDIFF, and ANBNBPDIFF were ($P < .001$), indicating that each prediction program mean ADG differed from Actual mean ADG and other prediction program predicted mean ADG.

Illustrated in Figures 7 and 8 are regression lines and individual data points of ADG for Actual, NRC, NutBal, and NutBal Pro in Trial 1 and 2. Shown in Tables 27 and 28 are the intercept, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, and NutBal Pro predicted ADG regression lines. In Trial 1 and 2, NutBal and NutBal Pro each consistently overpredicted

ADG; thus their regression lines are each found above both Actual and NRC predicted ADG regression lines.

Table 19. Means, standard errors, minimum and maximum values for actual and predicted cow average daily gain (ADG) for Trial 1 (n=22)

Cow ADG estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	0.14[a]	0.19	-1.81	1.89
NRC	0.31[a]	0.09	-0.32	.98
NutBal	1.68[b]	0.14	0.84	3.04
NutBal Pro	1.61[b]	0.12	0.66	2.55

[a,b]Means with different superscripts differ (P < .0001).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 20. Means, standard errors, minimum and maximum values for actual and predicted cow average daily gain (ADG) for Trial 2 (n=18)

Cow ADG estimator	Mean (kg)	Standard error (kg)	Minimum (kg)	Maximum (kg)
Actual	0.13[a]	0.14	-0.64	1.49
NRC	0.15[a]	0.15	-0.88	0.96
NutBal	1.56[b]	0.09	0.99	2.04
NutBal Pro	1.39[b]	0.10	0.83	2.20

[a,b]Means with different superscripts differ ($P < .0001$).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 21. Correlation coefficients between actual and predicted cow average daily gain (ADG) using animal performance prediction computer programs for Trial 1 (n=22)

Cow ADG estimator	Actual	NRC	NutBal	NutBal Pro
Actual	1.00	.73[a]	.27	.56[b]
NRC		1.00	.07	.42[c]
NutBal			1.00	.77[a]
NutBal Pro				1.00

[a]Values different from zero ($P < .0001$).
[b]Values different from zero ($P < .01$).
[c]Values different from zero ($P < .1$).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 22. Correlation coefficients between actual and predicted cow average daily gain (ADG) using animal performance prediction computer programs for Trial 2 (n=18)

Cow ADG estimator	Actual	NRC	NutBal	NutBal Pro
Actual	1.00	.36	-.26	-.47[b]
NRC		1.00	-.11	-.20
NutBal			1.00	.85[a]
NutBal Pro				1.00

[a]Values different from zero (P < .0001).
[b]Values different from zero (P < .1).
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 23. Means, standard errors, and significance levels for average daily gain changes (ADGCHG) from weigh period to weigh period compared to Actual ADG changes for Trial 1 (n=22)

ADGCHG comparison	Mean (kg)	Standard error (kg)	Significance level
NRCDIFF	0.20	0.15	NS
NBDIFF	1.43	0.19	**
NBPDIFF	1.38	0.15	**
NBNRCDIFF	1.23	0.17	**
NBPNRCDIFF	1.18	0.14	**
NBNBPDIFF	0.05	0.08	NS

NS – Mean values similar to zero.
**Mean values different from zero (P < .001).
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBPDIFF = (NutBal Pro – Actual); NBNRCDIFF = (NutBal – NRC);
NBPNRCDIFF = (NutBal Pro – NRC); NBNBPDIFF = (NutBal – NutBal Pro).

Table 24. Means, standard errors, and significance levels for average daily gain changes (ADGCHG) from weigh period to weigh period compared to Actual ADG changes for Trial 2 (n=18)

ADGCHG Comparison	Mean (kg)	Standard Error (kg)	Significance Level
NRCDIFF	0.01	0.17	NS
NBDIFF	1.43	0.19	**
NBPDIFF	1.26	0.21	**
NBNRCDIFF	1.42	0.18	**
NBPNRCDIFF	1.25	0.20	**
NBNBPDIFF	0.17	0.05	*

NS – Mean values similar to zero.
*Mean values different from zero ($P < .01$).
**Mean values different from zero ($P < .001$).
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBPDIFF = (NutBal Pro – Actual); NBNRCDIFF = (NutBal – NRC);
NBPNRCDIFF = (NutBal Pro – NRC); NBNBPDIFF = (NutBal – NutBal Pro).

Table 25. Absolute means, standard errors, and significance levels for average daily gain changes (ADGCHG) from weigh period to weigh period compared to Actual ADG changes for Trial 1 (n=22)

Absolute ADGCHG comparison	Mean (kg)	Standard error (kg)	Significance level
ANRCDIFF	0.55	0.10	**
ANBDIFF	1.47	0.17	**
ANBPDIFF	1.40	0.14	**
ANBNRCDIFF	1.28	0.15	**
ANBPNRCDIFF	1.24	0.12	**
ANBNBPDIFF	0.31	0.05	**

**Mean values different from zero ($P < .001$).
ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|;
ANBPDIFF = |(NutBal Pro – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|;
ANBPNRCDIFF = |(NutBal Pro – NRC)|; ANBNBPDIFF = |(NutBal – NutBal Pro)|.

Table 26. Absolute means, standard errors, and significance levels for average daily gain changes (ADGCHG) from weigh period to weigh period compared to Actual ADG changes for Trial 2 (n=18)

Absolute ADGCHG comparison	Mean (kg)	Standard error (kg)	Significance level
ANRCDIFF	0.59	0.09	NS
ANBDIFF	1.50	0.16	**
ANBPDIFF	1.37	0.17	**
ANBNRCDIFF	1.42	0.18	**
ANBPNRCDIFF	1.25	0.20	**
ANBNBPDIFF	0.24	0.04	**

**Mean values different from zero ($P < .001$).
ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|;
ANBPDIFF = |(NutBal Pro – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|;
ANBPNRCDIFF = |(NutBal Pro – NRC)|; ANBNBPDIFF = |(NutBal – NutBal Pro)|.

Table 27. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, and NutBal Pro ADG (kg/d) regression lines for Trial 1 that are plotted in Figure 7

Cow BWT estimator	Intercept (kg/d)	Intercept SE (kg/d)	Linear regression coefficient*	Linear regression coefficient SE*	R^2
Actual	.97	.36	-.14	.05	.25
NRC	.76	.15	-.07	.02	.36
NutBal	1.51	.30	.03	.04	.02
NutBal Pro	1.61	.22	-.04	.04	.07

* Slope and Slope SE are expressed in (kg/d) / sample time.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Table 28. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, and NutBal Pro ADG (kg/d) regression lines for Trial 1 that are plotted in Figure 8

Cow BWT estimator	Intercept (kg/d)	Intercept SE (kg/d)	Linear regression coefficient*	Linear regression coefficient SE*	R^2
Actual	-.28	.30	.08	.05	.13
NRC	-.80	.21	.19	.04	.62
NutBal	1.74	.20	-.03	.03	.06
NutBal Pro	2.04	.25	-.07	.04	.16

* Slope and Slope SE are expressed in (kg/d) / sample time.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

Figure 7. Regression lines and individual data points of ADG (kg/d) regressed on sample time for Actual, NRC, NutBal, and NutBal Pro in Trial 1.

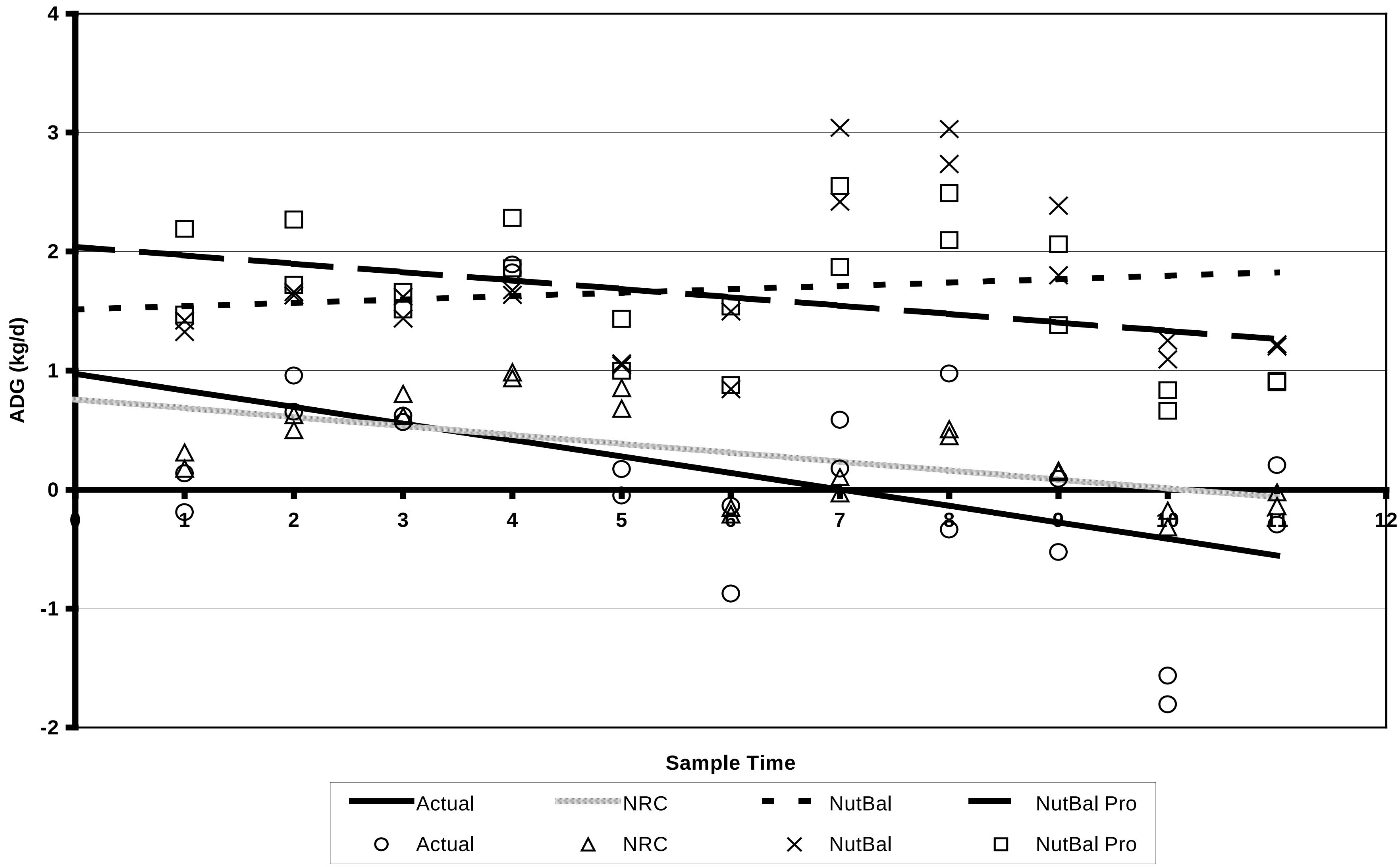
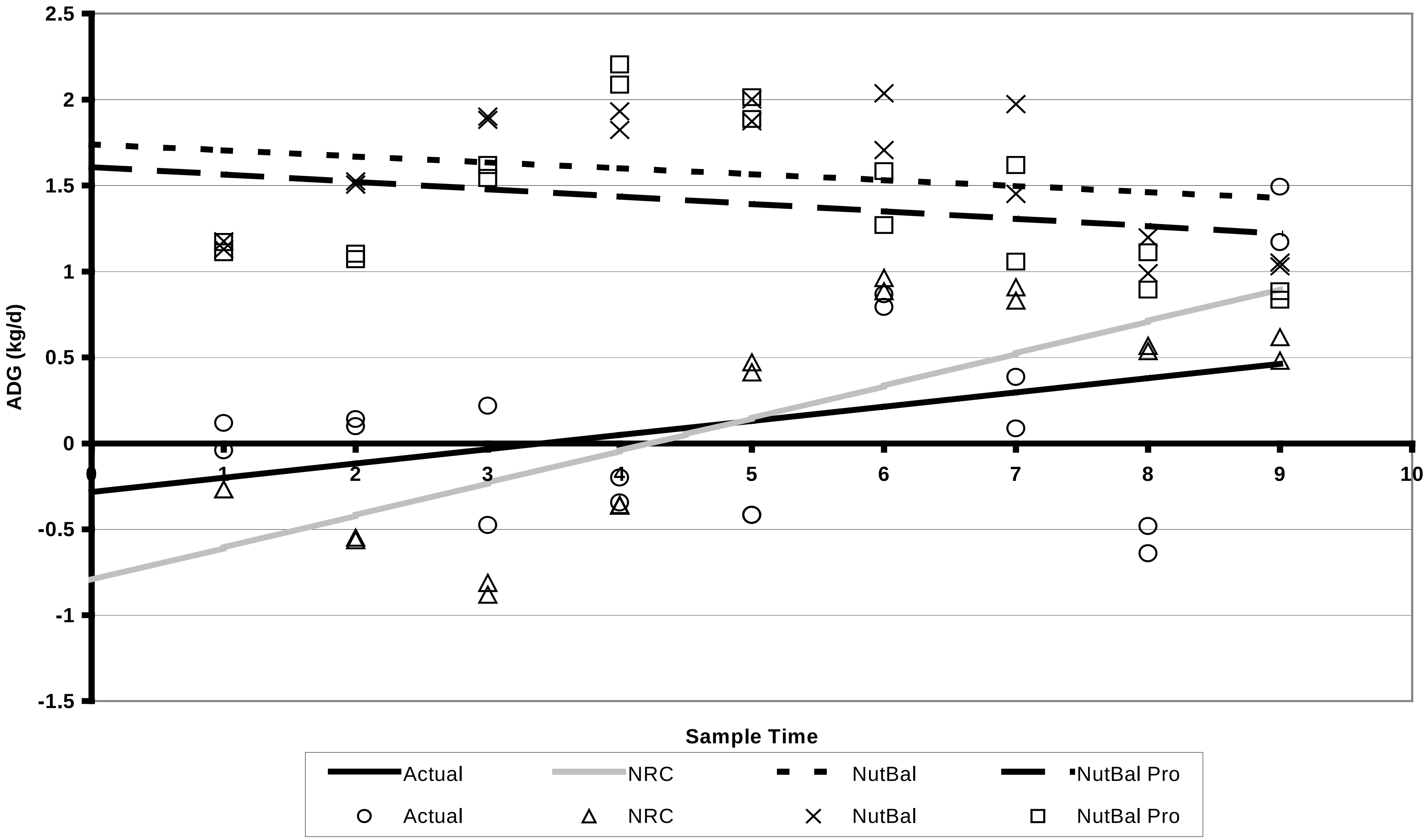


Figure 8. Regression lines and individual data points of ADG (kg/d) regressed on sample time for Actual, NRC, NutBal, and NutBal Pro in Trial 2.



Body Condition Score

In both trials, BCS predicted by NRC more closely approximated Actual BCS compared to NutBal programs (Tables 29 and 30). In Trial 1, ranges for Actual BCS and predicted BCS were: Actual BCS 5.2 to 6.9, NRC predicted BCS 5.7 to 7.5, NutBal predicted BCS 6.3 to 9.8, NutBal Pro1 predicted BCS 6.3 to 9.1, and NutBal Pro2 predicted BCS 6.2 to 8.5. In Trial 2, ranges for Actual BCS and predicted BCS were: Actual BCS 5.1 to 6.1, NRC predicted BCS 3.8 to 6.5, NutBal predicted BCS 6.0 to 15.9, NutBal Pro1 predicted BCS 6.0 to 14.7, and NutBal Pro2 predicted BCS 6.1 to 12.4.

In Trial 2, BCSs were not taken on 1/18/00; therefore, two sample times had to be eliminated for proper statistical analysis to occur in order to compare mean BCSCHG (Table 32). As evidenced through the means prior to removing the two sample days, Actual and NRC predicted mean BCSCHG appeared to be similar. However, once the two days were removed Actual and NRC predicted BCSCHG tended to be different ($P < .1$) from each other. NRC and Actual predicted mean BCSCHG were similar ($P = .30$) in Trial 1. In Trial 1 and 2, NutBal, NutBal Pro1, and NutBal Pro2 predicted mean BCSCHG were different ($P < .0001$) from Actual and NRC predicted mean BCSCHG. NutBal Pro1 and NutBal predicted mean BCSCHG were similar ($P = .98$ and $P = .57$ for Trial 1 and 2, respectively). NutBal and NutBal Pro2 estimates of BCSCHG were similar ($P = .31$) in Trial 1; although in Trial 2, they were different ($P < .005$). NutBal Pro1 and NutBal Pro2 predicted mean BCSCHG were similar ($P = .11$) in Trial 1; while in Trial 2 they were different ($P < .05$).

NRC tended to be the most accurate predictor of BCSCHG over the entire experimental period (Tables 31 and 32). The relationships among NutBal, NutBal Pro1, and NutBal Pro2 predicted BCS were strongest in each trial, with correlation coefficients between any combination of these variables ranging from .88 to 1.00 (Tables 33 and 34). In Trial 1, the correlation between Actual BCS and a prediction program BCS was strongest between Actual BCS and NRC predicted BCS as evidenced by a correlation coefficient of .72. Also, in Trial 1 the relationships among Actual BCS and NutBal, NutBal Pro1, and NutBal Pro2 predicted BCS were weaker ranging from .39 to .52. In Trial 2, relationships between Actual BCS and all prediction program BCSs were similar based on their correlation coefficients which ranged from .61 to .65.

Consecutive BCSCHG was examined to compare the ability of prediction programs to estimate BCS from one weigh period to the next (Tables 35 and 36). Means and standard deviations along with significance levels for predicted mean BCSCHG compared to Actual mean BCSCHG and other predicted mean BCSCHG between consecutive weigh periods for Trial 1 and 2 are reported in Tables 32 and 33, respectively. For Trial 1 and 2, no significant difference was found for BCSCHG NRCDIFF, which is evidence that Actual and NRC mean ADGCHG were similar within each trial. In Trial 1 and 2, there were significant differences detected for BCSCHG NBDIFF, NBP1DIFF, NBP2DIFF, NBNRCDIFF, NBP1NRCDIFF, and NBP2NRCDIFF; meaning NutBal, NutBal Pro1, and NutBal Pro2 predicted mean BCSCHG were declared different when compared to Actual and NRC predicted mean BCSCHG. However, in Trial 1, no detectable difference was found between NutBal, NutBal Pro1, and NutBal Pro2 predicted mean BCSCHG. Nonetheless, in Trial 2, NutBal, NutBal Pro1, and NutBal Pro2 predicted mean BCSCHG were significantly different from each other.

Absolute means and standard deviations for predicted mean BCSCHG compared to the Actual or other predicted mean BCSCHG were compared in Tables 37 and 38 for Trial 1 and 2, respectively. In Trial 1 and 2, according to absolute means estimated mean BCSCHG for each prediction program was found to be significantly different from both Actual mean BCSCHG and other prediction program's estimated mean BCSCHG. Although these values were found to be significantly different from zero; numerically NRC appeared to be a fairly reliable and accurate predictor of BCSCHG with means of .30 and .41 for Trial 1 and 2, respectively. Those BCSCHG values are undetectable to the human eye; however, each of the other programs mispredicted BCSCHG by .78 to .94 and .68 to .97 BCS. These values approach mispredicting cow BCS by one BCS using the 1-9 BCS system; which is a very noticeable change.

Depicted in Figures 9 and 10 are regression lines and individual data points of BCS for Actual, NRC, NutBal, NutBal Pro1 and NutBal Pro2 in Trial 1 and 2. Tables 39 and 40 show the intercept, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, NutBal Pro1, and NutBal Pro2 predicted BCS regression lines. The slopes associated with NutBal, NutBal Pro1, and Nutbal Pro2 predicted BCS were numerically larger resulting in regression lines that increase more quickly when compared to Actual and NRC predicted BCS regression lines for both Trial 1 and 2.

Table 29. Means, standard errors, minimum and maximum values for actual and predicted cow body condition score† (BCS) for Trial 1 (n=22)

Cow BCS estimator	Mean	Standard error	Minimum	Maximum
Actual	6.09	0.09	5.2	6.9
NRC	6.29	0.09	5.7	7.5
NutBal	7.63	0.20	6.3	9.8
NutBal Pro1[1]	7.55	0.15	6.3	9.1
NutBal Pro2[2]	7.32	0.14	6.2	8.5

† Nine point scale with 1 = emaciated and 9 = obese.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.
[1] Predicted BCS calculated from predicted ADG using NutBal Pro.
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 30. Means, standard errors, minimum and maximum values for actual and predicted cow body condition score† (BCS) for Trial 2 (n=18)

Cow BCS estimator	Mean	Standard error	Minimum	Maximum
Actual	5.64	0.09	5.1	6.1
NRC	5.04	0.20	3.8	6.5
NutBal	11.14	0.79	6.0	15.9
NutBal Pro1[1]	10.50	0.70	6.0	14.7
NutBal Pro2[2]	9.28	0.54	6.1	12.4

† Nine point scale with 1 = emaciated and 9 = obese.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.
[1] Predicted BCS calculated from predicted ADG using NutBal Pro.
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 31. Means, standard errors, minimum and maximum values for actual and predicted cow body condition score† change (BCSCHG) for Trial 1 (n=22)

Cow BCS estimator	Mean	Standard error	Minimum	Maximum
Actual	.07[a]	0.08	-.67	.55
NRC	.20[a]	0.06	-.20	.65
NutBal	.97[b]	0.09	-.01	1.88
NutBal Pro1[1]	1.01[b]	0.07	.41	1.57
NutBal Pro2[2]	.84[b]	0.06	.27	1.32

[a,b]Means with different superscripts differ ($P < .0001$).

† Nine point scale with 1 = emaciated and 9 = obese.

NRC = National Research Council, Nutritional Requirements of Beef Council 1996.

NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.

NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.

[1] Predicted BCS calculated from predicted ADG using NutBal Pro.

[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 32. Means, standard errors, minimum and maximum values for actual and predicted cow body condition score[†] change per weigh period (BCSCHG) for Trial 2 (n=14)

Cow BCS estimator	Mean	Standard error	Minimum	Maximum
Actual	.14[a]	0.10	-.48	.67
NRC	.32[b]	0.10	-.20	.87
NutBal	1.11[c]	0.10	.70	1.84
NutBal Pro1[1]	1.01[c]	0.10	.52	1.69
NutBal Pro2[2]	.82[d]	0.11	.39	1.85

[a,b]Means with different superscripts differ ($P < .1$).
[a,c; a,d; b,c; b,d] Means with different superscripts differ ($P < .0001$).
[c,d]Means with different superscripts differ ($P < .05$).
[†] Nine point scale with 1 = emaciated and 9 = obese.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.
[1] Predicted BCS calculated from predicted ADG using NutBal Pro.
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 33. Correlation coefficients between actual and predicted cow body condition score† (BCS) using animal performance prediction computer programs for Trial 1 (n=22)

Cow BCS estimator	Actual	NRC	NutBal	NutBal Pro1	NutBal Pro2
Actual	1.00	.72[b]	.39[e]	.47[d]	.52[d]
NRC		1.00	.27	.51[d]	.61[c]
NutBal			1.00	.92[a]	.88[a]
NutBal Pro1				1.00	.97[a]
NutBal Pro2					1.00

[a]Values different from zero (P < .0001).
[b]Values different from zero (P < .001).
[c]Values different from zero (P < .01).
[d]Values different from zero (P < .05).
[e]Values different from zero (P < .1).
† Nine point scale with 1 = emaciated and 9 = obese.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.
[1] Predicted BCS calculated from predicted ADG using NutBal Pro.
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 34. Correlation coefficients between actual and predicted cow body condition score† (BCS) using animal performance prediction computer programs for Trial 2 (n=18)

Cow BCS estimator	Actual	NRC	NutBal	NutBal Pro1	NutBal Pro2
Actual	1.00	.65[b]	.61[c]	.61[c]	.62[c]
NRC		1.00	.65[b]	.64[b]	.66[b]
NutBal			1.00	1.00[a]	.99[a]
NutBal Pro1				1.00	1.00[a]
NutBal Pro2					1.00

[a]Values different from zero (P < .0001).
[b]Values different from zero (P < .01).
[c]Values different from zero (P < .05).
† Nine point scale with 1 = emaciated and 9 = obese.
NRC = National Research Council, Nutritional Requirements of Beef Council 1996.
NutBal = Nutritional Balance Analyzer Version 1.18, Texas A&M University.
NutBal Pro = Nutritional Balance Analyzer Version 1.0, Texas A&M University.
[1] Predicted BCS calculated from predicted ADG using NutBal Pro.
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro.

Table 35. Means, standard deviations, and significance levels for body condition score† changes (BCSCHG) from weigh period to weigh period compared to Actual BCS changes for Trial 1 (n=22)

BCSCHG comparison	Mean	Standard error	Significance level
NRCDIFF	.13	0.07	NS
NBDIFF	.90	0.10	**
NBP1DIFF	.94	0.08	**
NBP2DIFF	.78	0.08	**
NBNRCDIFF	.77	0.10	**
NBP1NRCDIFF	.81	0.07	**
NBP2NRCDIFF	.65	0.06	**
NBNBP1DIFF	-.04	0.09	NS
NBNBP2DIFF	.13	0.09	NS

NS – Mean values similar to zero.
**Mean values different from zero ($P < .001$).
† Nine point scale with 1 = emaciated and 9 = obese.
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBP1DIFF = (NutBal Pro1 – Actual); NBP2DIFF = (NutBal Pro2 – Actual);
NBNRCDIFF = (NutBal – NRC); NBP1NRCDIFF = (NutBal Pro1 – NRC);
NBP2NRCDIFF = (NutBal Pro2 – NRC); NBNBP1DIFF = (NutBal – NutBal Pro1);
NBNBP2DIFF = (NutBal – NutBal Pro2).

Table 36. Means, standard errors, and significance levels for body condition score[†] changes (BCSCHG) from weigh period to weigh period compared to Actual BCS changes for Trial 2 (n=18)

BCSCHG comparison	Mean	Standard error	Significance level
NRCDIFF	.18	0.13	NS
NBDIFF	.97	0.13	**
NBP1DIFF	.87	0.13	**
NBP2DIFF	.68	0.16	*
NBNRCDIFF	1.02	0.14	**
NBP1NRCDIFF	.89	0.14	**
NBP2NRCDIFF	.64	0.14	**
NBNBP1DIFF	.14	0.04	*
NBNBP2DIFF	.38	0.08	**

NS – Mean values similar to zero.
*Mean values different from zero ($P < .01$).
**Mean values different from zero ($P < .001$).
[†] Nine point scale with 1 = emaciated and 9 = obese.
NRCDIFF = (NRC – Actual); NBDIFF = (NutBal – Actual);
NBP1DIFF = (NutBal Pro1 – Actual); NBP2DIFF = (NutBal Pro2 – Actual);
NBNRCDIFF = (NutBal – NRC); NBP1NRCDIFF = (NutBal Pro1 – NRC);
NBP2NRCDIFF = (NutBal Pro2 – NRC); NBNBP1DIFF = (NutBal – NutBal Pro1);
NBNBP2DIFF = (NutBal – NutBal Pro2).

Table 37. Absolute means, standard errors, and significance levels for body condition score† changes (BCSCHG) from weigh period to weigh period compared to Actual BCS changes for Trial 1 (n=22)

Absolute BCSCHG comparison	Mean	Standard error	Significance level
ANRCDIFF	.30	0.05	**
ANBDIFF	.93	0.09	**
ANBP1DIFF	.94	0.08	**
ANBP2DIFF	.78	0.08	**
ANBNRCDIFF	.80	0.09	**
ANBP1NRCDIFF	.81	0.07	**
ANBP2NRCDIFF	.65	0.06	**
ANBNBP1DIFF	.27	0.07	**
ANBNBP2DIFF	.33	0.07	**

**Mean values different from zero ($P < .001$).

† Nine point scale with 1 = emaciated and 9 = obese.

ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|; ANBP1DIFF = |(NutBal Pro1 – Actual)|; ANBP2DIFF = |(NutBal Pro2 – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|; ANBP1NRCDIFF = |(NutBal Pro1 – NRC)|; ANBP2NRCDIFF = |(NutBal Pro2 – NRC)|; ANBNBP1DIFF = |(NutBal – NutBal Pro1)|; ANBNBP2DIFF = |(NutBal – NutBal Pro2)|.

Table 38. Absolute means, standard errors, and significance levels for body condition score† changes (BCSCHG) from weigh period to weigh period compared to Actual BCS changes for Trial 2 (n=18)

Absolute BCSCHG comparison	Mean	Standard error	Significance level
ANRCDIFF	.41	0.08	**
ANBDIFF	.97	0.13	**
ANBP1DIFF	.87	0.13	**
ANBP2DIFF	.68	0.16	*
ANBNRCDIFF	1.02	0.14	**
ANBP1NRCDIFF	.89	0.14	**
ANBP2NRCDIFF	.67	0.13	**
ANBNBP1DIFF	.17	0.03	**
ANBNBP2DIFF	.42	0.07	**

*Mean values different from zero (P < .01).
**Mean values different from zero (P < .001).
† Nine point scale with 1 = emaciated and 9 = obese.
ANRCDIFF = |(NRC – Actual)|; ANBDIFF = |(NutBal – Actual)|; ANBP1DIFF = |(NutBal Pro1 – Actual)|; ANBP2DIFF = |(NutBal Pro2 – Actual)|; ANBNRCDIFF = |(NutBal – NRC)|; ANBP1NRCDIFF = |(NutBal Pro1 – NRC)|; ANBP2NRCDIFF = |(NutBal Pro2 – NRC)|; ANBNBP1DIFF = |(NutBal – NutBal Pro1)|; ANBNBP2DIFF = |(NutBal – NutBal Pro2)|.

Table 39. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, NutBal Pro1 and NutBal Pro2 BCS† regression lines for Trial 1 that are plotted in Figure 9

Cow BWT estimator	Intercept	Intercept SE	Linear regression coefficient	Linear regression coefficient SE	R^2
Actual	5.88	.19	.04	.03	.08
NRC	6.31	.20	-.002	.03	.00
NutBal	6.39	.30	.21	.04	.53
NutBal Pro1	6.92	.29	.10	.04	.23
NutBal Pro2	6.70	.26	.10	.04	.26

† Nine point scale with 1 = emaciated and 9 = obese.
[1] NutBal Pro1 calculated BCS using NutBal Pro predicted ADG and then determines BCS as 45.36 kg bodyweight / BCS change.
[2] NutBal Pro2 are BCS calculated using NutBal Pro predicted BCS.

Table 40. Intercepts, intercept SE, linear regression coefficient, linear regression coefficient SE, and R^2 values for Actual, NRC, NutBal, NutBal Pro1 and NutBal Pro2 BCS† regression lines for Trial 1 that are plotted in Figure 10

Cow BWT estimator	Intercept	Intercept SE	Linear regression coefficient	Linear regression coefficient SE	R^2
Actual	5.21	.17	.08	.03	.36
NRC	3.97	.33	.21	.06	.45
NutBal	4.87	.18	1.25	.03	.99
NutBal Pro1	4.92	.19	1.11	.03	.99
NutBal Pro2	5.00	.20	.86	.04	.97

† Nine point scale with 1 = emaciated and 9 = obese.
[1] NutBal Pro1 calculated BCS using NutBal Pro predicted ADG and then determines BCS as 45.36 kg bodyweight / BCS change.
[2] NutBal Pro2 are BCS calculated using NutBal Pro predicted BCS.

Figure 9. Regression lines and individual data points of cow BCS regressed on sample time for Actual, NRC, NutBal, NutBal Pro1, and NutBal Pro2 in Trial 1.

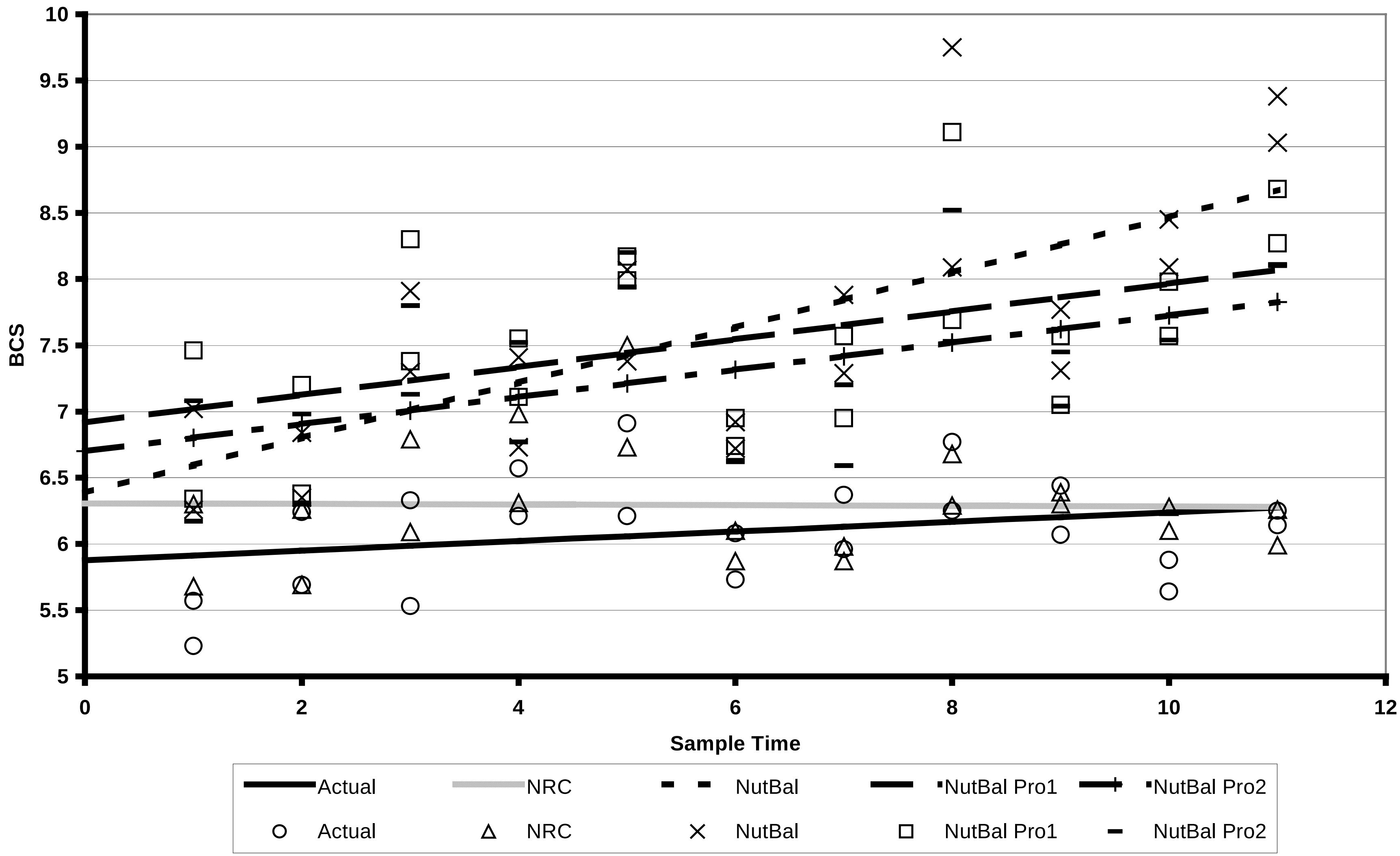
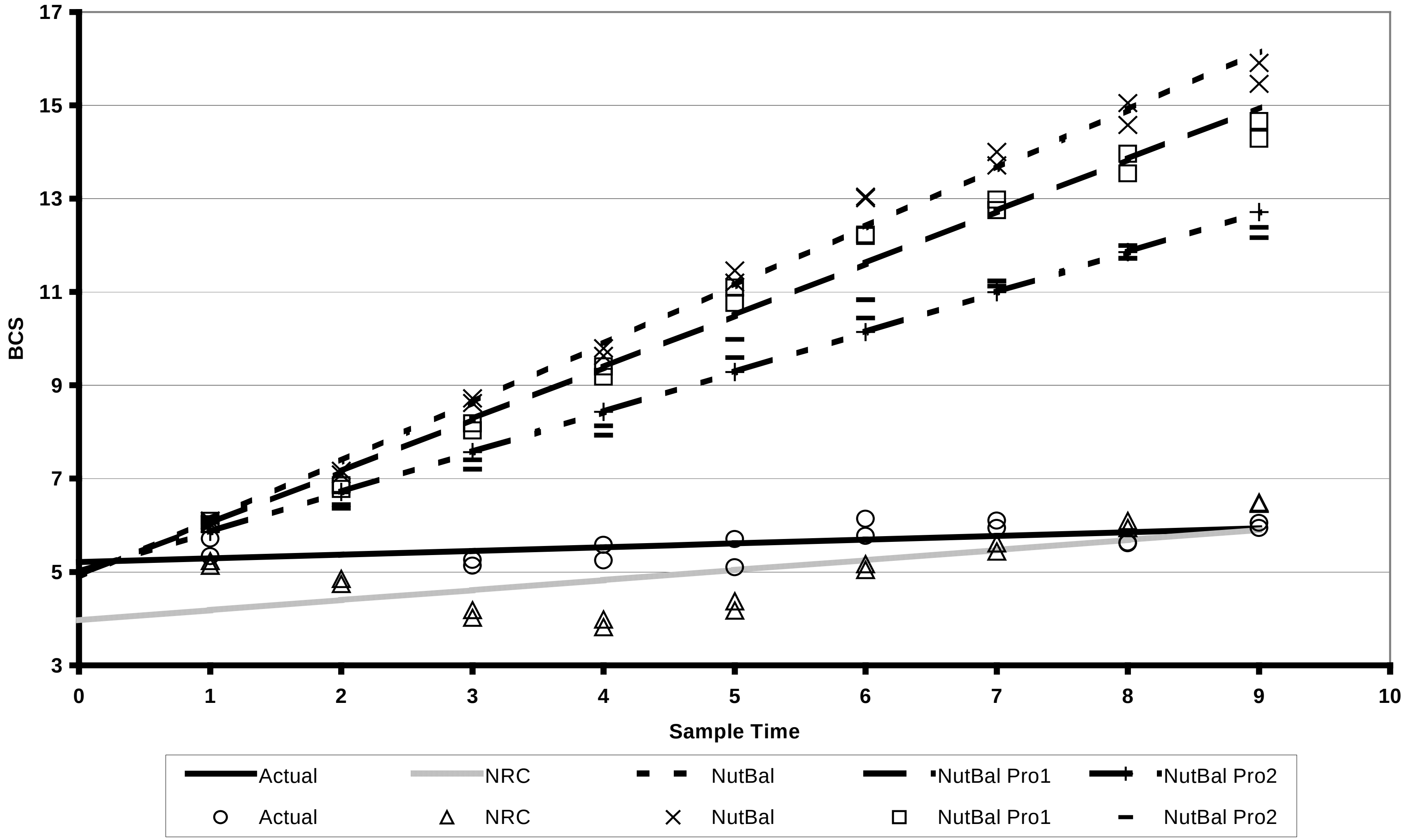


Figure 10. Regression lines and individual data points of cow BCS regressed on sample time for Actual, NRC, NutBal, NutBal Pro1 and NutBal Pro2 in Trial 2.



Discussion

In the present trials, Fecal NIRS was concluded to be a relatively inaccurate method to predict forage digestibility and crude protein content compared to standardized wet chemistry analysis. Also, when compared to actual measures of animal performance NRC using wet chemistry analysis results from handplucked forage samples provided the most accurate and realistic predictions. NutBal and NutBal Pro both consistently overpredicted animal performance using Fecal NIRS estimates of forage quality.

Digestible organic matter and TDN are easily convertible measures used to describe the digestibility and energy content of livestock feedstuffs. In Trial 1, a linear relationship existed between TDNFOR and TDNFEC (TDNFOR = .90*TDNFEC + 3.63). The intercept was not significantly different from zero and the slope was similar in magnitude to one. In general, this meant for every one percent increase in TDNFEC there was a one percent increase in TDNFOR. In contrast, the linear coefficient was not significant in Trial 2; no linear trend was observed between TDNFOR and TDNFEC (TDNFOR = .18*TDNFEC + 52.41). The slope was found to be not significantly different from zero. Andrae et al. (2000), reported a linear relationship ($P < .01$) between collected forage samples and NIRS predicted DOM (Forage DOM = 1.01*NIRS DOM). In their study, the slope was close to one indicating that the Fecal DOM estimate more precisely agreed with the wet chemistry analysis results from handplucked forage samples. In addition, Lalman et al. (2001) reported a linear relationship between grazed forage samples and fecal samples collected from the same animal (Forage DOM = 1.30*(Fecal NIRS predicted DOM%) – 22.51). Using this equation a reference forage

DOM value of 47.8% would correspond to a Fecal NIRS DOM value of 54.1% (Lalman et al., 2001). Using our formula for Trial 1 a reference forage TDN value of 50.7% would correspond to a Fecal NIRS TDN value of 52.3%.

The standard error of prediction or calibration is used as a measure of precision to evaluate the ability with which equations and models predict forage quality. The standard error of prediction for Fecal NIRS predicted DOM was 3.07% and 2.45% for Trial 1 and 2, respectively. Both of these standard error of predictions were higher than 1.95% which was reported for a study conducted using Hereford and Angus based stocker cattle grazing different varieties of tall fescue (Andrae et al., 2000). However, the value reported by Andrae and coworkers was similar to the standard error of prediction for the overall NIRS data set (1.66%). In fact, this standard error of calibration for the NIRS data set validation was nearly equivalent to the laboratory standard error of 1.68% (Lyons and Stuth, 1992). Since the samples collected for the validation set were from the same cows grazing the same pastures used in the development of the calibration set, one would expect a low standard error of calibration. Also, standard error of calibration for *in vitro* DM digestibility using NIR predicted and laboratory reference values was .033 in a grazed pasture 427 sample calibration set and .022 in a 196 fecal sample set (CSIRO, 1998).

Possible explanations for the higher standard error of predictions in Trial 1 and 2 could be associated with pasture size and available forage composition. The lower standard error of prediction or calibration was found in cases where cattle were grazing smaller paddocks and/or monoculture forage pastures (Lyons and Stuth, 1992; Andrae et al., 2000). In each of these cases, the animal's chance of being more selective grazers increases as the pasture becomes larger in size or more heterogeneous in nature. Trial 1 and 2 pastures were a minimum of 10.1 ha in size, and although they were predominantly tall fescue based; they also contained some legumes as well as other types of grasses. This makes it more difficult to accurately predict forage quality from handplucked forage samples. Also, the difference in the standard error of prediction between Trial 1 and 2 could be partially due to a difference in the pastures soil type.

The R^2 values reported for digestibility were evaluated to determine the amount of variation that the Fecal NIRS digestibility estimate explains in the reference digestibility estimate. Lyons et al. (1995) reported R^2 values of .69 and .80. The lower R^2 value was reported for grazing cattle where digestibility estimates were calculated using fecal samples and forage samples; however, the higher R^2 value was reported for a data set that included the above mentioned samples from the grazing cattle along with samples collected from other trials where fecal samples and extrusa samples were collected. R^2 values of .80 and .97 were reported for *in vitro* DM digestibility for cattle grazing a wide range of pasture species including various legumes and grasses and pen fed animals, respectively (CSIRO, 1998). However, both of these values were higher than .27 and .02 that were computed for Trial 1 and 2. These low R^2 values were evidence of a relatively small relationship between Fecal NIRS and wet chemistry analysis estimates of forage TDN%. These low R^2 values could be partially due to most of the calibration and validation sets used to formulate the Fecal NIRS prediction equations included forages common to the Western rangelands (Lyons and Stuth, 1992). For the most part, these forages were lower quality than the high quality cool season forage grazed in both Trial 1 and 2. Also extrusa samples collected from esophageal fistulated animals were found to be higher quality than handplucked forage samples (Weir and Torell, 1959; Van Dyne and Torell, 1964; Coleman and Barth, 1973). This indicated that cattle are selective grazers; thus the extrusa sample contained exactly what the animal consumed. Therefore, one would expect R^2 values between extrusa and fecal samples to be higher than handplucked and fecal samples since both the extrusa and fecal sample allow forage estimates to be derived from what the animal actually consumed. A slightly higher R^2 value to those found for Trial 1 and 2 was reported in a trial using cattle grazing native tall grass prairie and bermudagrass pasture where grazed forage and fecal samples were taken from the same animals (Lalman, 2001). Also, Leite and Stuth (1995) reported an R^2 value of .92 for DOM% using extrusa and fecal samples collected from adult Spanish goats grazing various vegetation types.

Correlation coefficients describing the relationship between TDN% predicted from handplucked forage samples and fecal samples varied from .52 for Trial 1 to .15 in Trial 2. In Trial 1, TDNFEC and TDNFOR were moderately correlated yet the correlation coefficient was lower than the value (r = .82) reported in another study conducted on cattle grazing tall fescue (Andrae et al., 2000). However, virtually no relationship was detected (r = .15) in Trial 2. Lalman et al. (2001) evaluated the accuracy with which Fecal NIRS predicted forage DOM by classifying predictions for DOM that were within 5%, 5-10%, or > 10% of DOM predicted from handplucked forage samples as accurate, marginal, or inaccurate. They classified 18.5%, 24.2%, and 57.1% of their fecal DOM values as accurate, marginal, and inaccurate, respectively. Using this classification system to evaluate the use of Fecal NIRS to predict DOM, mean TDNFEC would be designated accurate in Trial 1 and marginal for Trial 2. In actuality, this assessment is of minimal value because although the mean TDNFEC value was accurate in Trial 1 and marginal in Trial 2, it is possible that the majority of the TDNFEC values for Trial 1 could be marginal or inaccurate.

In Trial 1 and 2, TDNFEC was greater than TDNFOR. Lalman et al. (2001) found similar results using cattle grazing bermudagrass pastures. In contrast, Lalman et al. (2001) also reported that DOM% predicted using NIRS and wet chemistry analysis from fecal and grazed forage samples of cattle grazing native tall grass prairie was similar. Andrae et al. (2000) also reported that DOM estimates using Fecal NIRS were precise and concluded that NIRS was an accurate management and research tool for predicting DOM of cattle grazing various varieties of tall fescue. In contrast, based on the results from Trial 1 and Trial 2, one would discourage the use of Fecal NIRS as a research and management tool. As long as, TDNFOR estimates were accurate this would be a correct assumption. If Fecal NIRS can become a better predictor of forage quality of heterogeneous pastures that are composed mostly of cool season forages common in the Eastern United States, then it should be reconsidered as an effective and accurate way to determine forage quality.

In Trial 1, no linear relationship existed between CP predicted from handplucked forage samples and fecal samples (Trial 1: CPFOR = .36*CPFEC + 8.76). However, in Trial 2, a tendency for a linear relationship existed between CP predicted from handplucked forage samples and fecal samples (Trial 2: CPFOR = .89*CPFEC + 1.91). In Trial 2, the intercept was not significantly different from zero and the slope was relatively close to one. This meant an approximate one to one relationship existed between CPFOR and CPFEC in Trial 2, therefore a one unit change in CPFOR meant an approximate one unit change in CPFEC. Lalman et al. (2001) reported reference CP% from grazed forage samples = .77*(Fecal NIRS predicted CP%) + 2.06. The slope of this regression line was different (P = .01) from zero and the intercept differed ($P < .05$) from zero.

Standard error of predictions for Fecal NIRS CP in Trial 1 and 2 were 3.11% and 3.32%, respectively. These values were higher than the 2.66% reported by Andrae et al. (2000) on fescue pastures. However, Lyons and Stuth (1992) reported a smaller value of .89 for the overall NIRS data set. CSIRO (1998) reported standard error of calibration values of .087 and .133 for pen fed and grazing cattle, respectively. Therefore, the relationship between NIR predicted dietary N and laboratory reference values for the pen-fed cattle was better than for the grazing cattle. This was due to the greater accuracy of the laboratory reference values for the pen-fed diets. Due to animal selectivity, representative diet samples from pen fed animals were more obtainable than grazing animals (Coleman and Barth, 1973). Lower standard error of prediction or calibration were typically reported in scenarios where extrusa samples from esophageal fistulated animals were compared to fecal samples. By using extrusa samples instead of handplucked forage samples to compare to fecal samples; variation resulting from animal selectivity is eliminated since both samples are from what the animal actually consumed. Also, in some instances the same sample sets that were used for the development of prediction equations were also used in the calibration sets (Lyons and Stuth, 1992); therefore the standard error of calibration should be low.

The overall NIRS data set R^2 value for CP was .92 (Lyons and Stuth, 1992). According to this R^2 value, Fecal NIRS CP explained 92% of the variation in the laboratory reference CP. Similar R^2 values of .94 and .99 for Nitrogen % were reported for pen-fed and grazing cattle, respectively (CSIRO, 1998). In contrast, low R^2 values of .06 and .19 were calculated for Trial 1 and 2, respectively which both used cattle grazing fescue based pastures. Therefore, CPFEC explained less than 20% of the variation in CPFOR, meaning CPFEC and CPFOR values in both Trial 1 and 2 did not match one another very closely. These low values could be a result of the handplucked forage sample not being a representative sample of what the cattle consumed. In a study conducted using esophageal fistulated animals grazing high quality cool season pastures, Coleman and Barth (1973) reported the animals selected plant parts high in CP. Another viable explanation is that Fecal NIRS overpredicted forage CP content and was an inaccurate predictor of forage quality in Trial 1 and 2.

Correlation coefficients describing the relationship between CP% predicted from handplucked forage samples and fecal samples were similar for Trial 1 and 2. Correlation coefficients were .24 and .43 for Trail 1 and 2, respectively. These values were relatively similar to the correlation coefficient of .39 that was reported by Andrae et al. (2000). These correlation coefficients provide evidence that there is only a weak to moderate relationship between Fecal NIRS predicted CP% and CP% predicted using wet chemistry analysis on Handplucked Forage samples. Lalman et al. (2001) stated that 12.2, 22.9, and 64.9% of Fecal NIR CP values were accurate, marginal, and inaccurate predictions of "actual" diet CP level. In order for the Fecal NIR CP value to be deemed accurate, marginal, or inaccurate Fecal NIR CP values had to be within ±5, ±5 – 10, or > 10% of the laboratory reference value which in this case were generated using grazed forage samples and wet chemistry analysis. Using this classification system on the mean

CP values reported in Trial 1 and 2; CPFEC was found to be a marginal predictor in Trial 1 and an accurate predictor in Trial 2 of forage CP. In contrast, CPFEC would have been declared an accurate predictor of forage CP in Trial 2. However, both of these classifications were done strictly based on means; therefore, one should not assume that all nor the majority of the samples would be classified as accurate and marginal respective trial.

In Trial 1 and 2, forage CP values were determined from fecal and handplucked forage samples by Fecal NIRS and wet chemistry analysis, respectively. In Trial 1 and 2 CPFOR and CPFEC values were not significantly different in each respective trial; meaning wet chemistry analysis and Fecal NIRS both could be considered as poor or as viable ways to accurately and precisely determine forage CP%. Fecal NIRS did not recognize as much differentiation in CP content of the forage. CPFEC values tended to not exceed 17% CP while CPFOR values approached 25% CP. Lalman et al., (2001), found Fecal NIRS tended to overpredict (P = .1) CP% of native tall grass and underestimate CP% of bermudagrass. Andrae et al. (2000) conducted a trial on Hereford- and Angus-based stocker cattle grazing different varieties of tall fescue and suggested that Fecal NIRS overpredicted forage CP content. Therefore, according to various CP data, precision must be increased for crude protein predictions from fecal samples to be more useful (Andrae et al., 2000; Lalman et al., 2001).

Limited research has been conducted comparing the Handplucked Forage / NRC96, Fecal NIRS / NutBal, and the Fecal NIRS / NutBal Pro systems of predicting animal performance. Block et al. (2001) reported both Level 1 and Level 2 of the NRC96 model underpredicted performance of backgrounding and finishing cattle. The backgrounding cattle ADG was underpredicted ($P < .05$) using the NRC96 model as it predicted ADG values that were 52% and 86% of the actual ADG for the two backgrounding cattle trials. Also, ADG for the finishing cattle were underpredicted with predicted values being 95% and 91% of the actual ADG in each of the finishing trials using the NRC96 program. Although, Trial 1 and 2 were conducted using mature beef cows, similar results were found concerning predicted performance estimates. In both Trial 1 and 2 NRC96 underpredicted ADG, BWT, and BCS for a significant time period except for BCS in Trial 1. However, NutBal and NutBal Pro consistently overpredicted cow performance. Overall, when evaluating a one year production cycle, NRC96 estimates of cow performance including ADG, BWT, and BCS typically were not significantly different from actual performance. All performance results should be similar across performance parameters as they were all related to one another.

Of the three performance measures evaluated, accurate BCS predictions are the least laborious to obtain and they are also of most biological importance because of the strong relationship between BCS and reproduction. Also, due to this strong relationship BCS then has a significant impact on number of calves that can be produced, therefore correctly monitoring and predicting changes in cow BCS is very important to the cattle producer. Cow BCS has been shown to affect days to estrus, pregnancy rates, and calving difficulty. Richards et al. (1986) reported that cows calving at a BCS ≥ 5 required less days to return to estrus after calving and had higher pregnancy rates. Similarly, Herd and Sprott (1986) reported cows that calve at a BCS ≥ 5 had higher pregnancy rates and calving intervals less than 365 d. Maintaining cow BCS at ≥ 5 using the 1 – 9 BCS system will enable cow reproductive performance to be optimized.

According to findings in Trial 1 and 2, NRC predicted BCSCHG was not significantly different from Actual BCSCHG. In this scenario, NRC was identified as an accurate predictor and useful management tool for cow BCS. Also, NutBal and NutBal Pro both overpredicted BCSCHG each sample time by ¾ to 1 BCS and were declared not useful as management tools; however, they predicted BCSCHG per sample time within ¼ of a BCS of one another. Their predicted estimates were very similar as would be expected since their BCS prediction equations are very similar as NutBal Pro is a modified version of NutBal.

Using cow bodyweight to measure cow performance is more valid as a research tool than as a management tool since in the industry cows generally are weighed only 2 – 3 times annually, at weaning and prior to calving. However, cow bodyweight is directly related to cow BCS; therefore, in most situations as a cow gains or loses weight, they are also gaining or losing body condition. Also, if inaccurate estimates of cow bodyweight are predicted through the use of animal performance prediction programs then they do not correctly predict the nutritional requirements of the cow. In most instances where cow bodyweight is overpredicted, the programs overpredict the nutritional requirements of the defined group of animals and predict that the cows have higher intake levels than in actuality or suggest the animals receive supplementation. The inverse of these is also true. Over supplementation would cause an unnecessary increase in feed costs; inturn decreasing the producers profit potential. Based on the results from Trial 1 and 2 NRC was declared a satisfactory predictor of animal bodyweight; however, NutBal and NutBal Pro consistently overpredicted cow bodyweight.

In the case where cow bodyweight is inaccurately predicted, cow reproduction and milk production may be affected. When cow nutritional requirements are underpredicted, then the cow has less dietary energy available for gain and lactation which results in a reduction in energy reserves (BCS). This reduction in energy reserves causes decreased milk production and losses in body condition, which leads to lighter calves at weaning and lower pregnancy rates (Herd and Sprott, 1986; Roche et al., 1992; Wright et al., 1992).

Average daily gain was calculated and evaluated as a way to monitor changes in cow bodyweight over time. For example, in Trial 1 and 2, ADG was calculated between sample days which was approximately every 28 d. This would allow for sudden changes in cow bodyweight to be noticed which would allow the producer to make appropriate decisions concerning supplementation, pasture management, and herd health in time to eliminate detrimental effects on the cow herd. Average daily gain is directly related to bodyweight and is a more common management tool used to evaluate the performance of stocker, backgrounding, and finishing cattle. However, in terms of evaluating the performance prediction programs, it would allow one to determine where the misprediction of performance occurred. In addition, by evaluating ADG by periods, bias introduced by a miscalculation of animal performance or forage quality at one period could be reduced when evaluating subsequent periods. Because of its close relationship to bodyweight, NRC was the most accurate predictor of ADG. NutBal and NutBal Pro overpredicted ADG by relatively unrealistic values for mature beef cows. The incorrect predictions made by these programs were due to problems with the program's predictions of animal performance over the entire time of the study and not during a specific month or season.

In both Trial 1 and 2, results were very similar across performance prediction programs. However, it is important to note that the magnitude of difference was less for the overall average cow bodyweight and cow BCS in Trial 1 compared to Trial 2. This was because in Trial 1 actual bodyweight and BCS were input into the programs for numerous sample days because of cows moving in and out of the groups; while on the other sample days where no cows moved in or out of the groups a continuous method of prediction was used. This continuous method of prediction was used in Trial 2 for all sample days, except sample day one, because no cows changed groups for the entire study. This explains why the overprediction of NutBal and NutBal Pro was magnified in Trial 2 with mean overestimates of cow bodyweight and BCS of ≥ 220 kg and 3.5 BCS. In an effort to eliminate some of the cumulative error collected through the use of the continuous method, the change and absolute change of the different measures of cow performance were evaluated. This allowed the performance prediction programs to be evaluated more accurately and fairly.

Various research protocols that evaluated the accuracy and precision with which NIRS predicted forage quality proposed the idea of also evaluating NutBal's ability to predict animal performance; however, minimal results have been reported. Mattox et al. (2000) reported NutBal overpredicted ADG of mature Brahman influenced cows when estimates of forage quality from fecal samples were used. However, NutBal underpredicted or slightly overpredicted cow performance when estimates of diet quality from the forage samples were input. NutBal and NutBal Pro both overpredicted cow performance by significant amounts in both Trial 1 and 2. This overprediction was most likely due to the combination of the overprediction of forage quality by Fecal NIRS that was input in the prediction programs and to problems with the performance prediction programs themselves. Lalman et al. (2001) reported that a 6.3% Fecal NIRS DOM% overprediction using NRC96 resulted in a difference of .54 kg/d or a difference of .92 BCS over a 60 d period using 498.95 kg mid gestation Angus × Hereford crossbred cows. NutBal and NutBal Pro each predicted unrealistic ADG values of approximately 3 kg/d which could be partially due to improper predicted intake values of over 100 kg/d. Voluntary DMI values estimated by NRC96 were greater than actual DMI in a trial conducted on pen fed backgrounded steers; however, actual DMI had been restricted in the trial to limit ADG (Block et al., 2001). DMI predicted for steers and heifers using NRC96 were reported accurate.

Dry matter intake by NRC, NutBal, and NutBal Pro was calculated based on many factors. Mature cattle DMI for NRC is dependent on body composition, sex, age, physiological state, frame size, available forage quantity and various environmental conditions (NRC, 1996). It is calculated in NRC using an equation that includes the animal's NE_m intake and standard bodyweight (bodyweight at a BCS 5). The NutBal programs predict animal intake based on the animal's predicted fecal output and the indigestible fraction of the diet. Predicted fecal output is calculated by first correcting the animal's bodyweight for amount of fat; then the numerical factors are multiplied by this fat corrected bodyweight. Different factors are used based on the animal's physiological state, breedtype, mud / coat factor, diet crude protein level, amount of standing forage, and ambient temperature. The indigestible fraction of the diet is calculated by subtracting the TDN% (in decimal) from one. Then animal intake is calculated by dividing predicted fecal output by the indigestible fraction of the diet (Nutritional Balance Analyzer, 1994).

When evaluating these animal performance prediction programs as possible management tools, the user friendliness, amount of time, and number of inputs required are important issues to address concerning the programs since no difference existed between the length of time to obtain estimates of forage quality from the fecal and forage samples. NRC and NutBal require the least time and inputs and are the easiest to use for the average computer literate individual. NutBal Pro requires the most computer knowledge. It requires approximately three times the amount of inputs used in NRC and NutBal and thus requires more time to complete. However, for the person with above average computer skills and a greater interest in monitoring their cow performance and forage quality over time NutBal Pro offers some special features. NutBal Pro printouts can easily be converted to Microsoft Word files, as well as graphs, which can easily made to show changes in forage quality and cow performance over time. Also, while running different cases through the computer programs, both NutBal and NutBal Pro were noticed to lack the ability to predict young and mature cow bodyweight based on input cow BCS. In addition, correct 2 and 3 year old cow frame sizes were unable to be input to formulate these animal's breedtype since predicted cow bodyweight would be incorrect therefore larger than actual frame sizes were input in order for the program to assume correct bodyweights.

NutBal and NutBal Pro animal performance predictions followed similar trends and the updated version, NutBal Pro, did not overpredict to quite the numerical magnitude that Nutbal did. However, they were still inferior to NRC. More updated versions of NutBal with a main focus on the developing of animal breedtypes and predicted DMI will hopefully make NutBal a beneficial management tool for producers with non Brahman influenced cattle grazing cool season type forages.

Conclusions

Accurate and precise estimates of actual cattle diet crude protein and digestibility can enable the progressive and technologically advanced cattle producer of the 21^{st} century to predict cattle performance for their defined production system using cattle performance prediction programs. It is believed that wet chemistry analysis conducted on the feedstuffs consumed by the animal can provide estimates of "actual" diet quality. Fecal NIRS provides relatively accurate estimates of diet quality in situations where diet:fecal pairs were collected from esophageal fistulated animals. However, Fecal NIRS has provided minimal accuracy or precision for predicting the diet quality of cattle grazing monoculture high quality, cool season pastures found in the Eastern United States.

Actual cow performance can most accurately be predicted using the Handplucked Forage / NRC96 system. NRC96 estimates of cow performance more closely followed the trend and were closer in the magnitude of change of actual cow performance. On average, the Handplucked Forage / NRC96 system predicted cow bodyweight within 2-3% of their bodyweight. The Fecal NIRS / NutBal and Fecal NIRS / NutBal Pro systems steadily overpredicted cow performance by large amounts. Overall, the Handplucked Forage / NRC96 system is the most adapted cow performance prediction system for mature British and British crossbred cows grazing predominantly cool season grass pastures.

Summary

Having the ability to accurately and precisely predict diet quality and cattle performance are of great significance to cattle producers. These two characteristics are interrelated, because in order to correctly predict cattle performance the producer must have a way to attain accurate estimates of the diet quality. This will allow producers to feed his/her cattle to gain, lose, or maintain bodyweight or BCS as he/she desires.

Both Trial 1 and 2 were conducted on extensively well managed beef cattle farms in Virginia. Also, due to the research trails being conducted additional measures were taken in order to allow each cow performance prediction program the best chance to precisely predict cow performance. At both locations cows were maintained in good body condition by having continued access to high quality forage that was made possible by the interseeding of legumes and fertilization of the pastures. Also, cattle were rotationally grazed and supplemented with corn silage or concentrates at the respective managers request. Cow and calf weights, BCS, climatic data, available forage per acre, and milk production were recorded. Also, at each location, calves were weaned at approximately 7 – 8 mo and then the cows were rebred by artificial insemination to keep the calving window relatively narrow. Although numerous inputs were required for the performance prediction programs this research was conducted in as practical manner as possible in order for it to be applicable to the average cattle producer.

Looking back on these research trials if they were to be re-performed some possible changes could occur. In Trial 1, it would have been more ideal for the original cow base from the beginning of the trial to be maintained for the duration of the trial.

Then the performance prediction programs could have been evaluated for their ability to predict performance of 2 and 3 year old cows. Also, in Trial 2 cows should have been rotated pastures between weigh days instead of on actual weigh days. In both trials, supplementation as suggested by the respective performance prediction programs would have enabled the evaluation of the program's ability to predict cow performance when they were supplemented. For both trials, if cow DMI would have been monitored and changed to realistic values during times when the performance prediction programs overestimated animal DMI, predicted performance estimates may have been closer to actual animal performance. Also, by milking the cows at various times during their lactation period would have allowed for more accurate estimates of cow milk production, which is required as an input for the programs. Also, duplicates on all the forage and fecal samples would have eliminated possible error that may have existed in the estimates of forage crude protein content and digestibility.

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Table 1. Previous 30 d average ambient daily high temperatures, ambient daily low temperatures, windspeed, and relative humidity for Trial 1 (Blacksburg, VA)

Date	Daily High (ºF)	Daily Low (ºF)	Relative Humidity	Windspeed (mph)
08/13/99	90	65	67	6
08/30/99	87	65	66	5
09/08/99	86	63	65	8
09/22/99	79	58	62	6
10/04/99	76	55	61	6
10/18/99	71	50	57	5
11/03/99	66	44	51	6
11/18/99	64	40	47	8
12/01/99	63	42	47	6
12/18/99	59	38	44	6
12/29/99	51	32	37	8
01/16/00	51	31	36	8
01/26/00	47	28	32	11
02/15/00	41	25	28	9
02/23/00	46	28	31	7
03/10/00	62	38	43	7
03/22/00	63	39	44	7
04/10/00	63	40	44	9
04/19/00	65	43	47	6
05/09/00	69	48	52	7
05/17/00	74	50	55	8
05/31/00	80	55	59	7
06/14/00	80	58	61	6
06/30/00	83	63	66	6
07/12/00	85	66	68	6
08/04/00	81	65	67	6
08/16/00	82	64	67	6
Average	69.04 ± 13.85	47.89 ± 13.25	52.00 ± 12.53	6.89 ± 1.37

Table 2. Previous 30 d average ambient daily high temperatures, ambient daily low temperatures, windspeed, and relative humidity for Trial 2 (Buckingham Courthouse, VA)

Date	Daily High (ºF)	Daily Low (ºF)	Relative Humidity	Windspeed (mph)
11/19/99	65	37	45	5
12/17/99	58	34	43	4
01/18/00	50	28	35	6
02/24/00	45	24	31	5
03/20/00	63	35	43	6
04/27/00	65	42	48	7
06/07/00	78	54	61	5
06/29/00	82	61	66	5
08/08/00	81	63	68	4
09/15/00	80	61	66	4
12/06/00	50	29	36	5
Average	65.18 ± 13.57	42.55 ± 14.60	49.27 ± 13.64	5.09 ± 0.94

Table 3. Number of days mature cows have been in either the gestating or lactating stage of their production cycle for Trial 1

Date	Number of d gestating	Number of d lactating
08/13/99	120	0
08/30/99	137	0
09/08/99	145	0
09/22/99	159	0
10/04/99	171	0
10/18/99	185	0
11/03/99	200	0
11/18/99	215	0
12/01/99	228	0
12/18/99	245	0
12/29/99	256	0
01/16/00	273	0
01/26/00	283	1
02/15/00	0	20
02/23/00	0	28
03/10/00	0	45
03/22/00	0	57
04/10/00	1	75
04/19/00	10	84
05/09/00	30	104
05/17/00	38	112
05/31/00	52	126
06/14/00	66	140
06/30/00	82	156
07/12/00	94	168
08/04/00	116	190
08/16/00	128	202

Table 4. Number of days mature cows have been in either the gestating or lactating stage of their production cycle for Trial 2

Date	Number of d Gestating	Number of d Lactating
11/19/99	0	30
12/17/99	0	58
01/18/00	1	90
02/24/00	38	127
03/20/00	63	152
04/27/00	101	190
06/07/00	142	221
06/29/00	164	0
08/08/00	204	0
09/15/00	242	0
12/06/00	0	50

Table 5. Comparisons of forage crude protein (CP) and total digestible nutrients percentage estimates using fecal and forage samples for pastures grazed by Kentland 1 cows in Trial 1

Date	CP (Fecal)	CP (Forage)	TDN (Fecal)	TDN (Forage)
08/13/99	10.57	13.06	63.09	59.28
08/30/99	15.52	16.49	69.36	61.80
09/08/99	13.26	16.31	64.72	61.67
09/22/99	15.44	17.45	66.51	68.66
10/04/99	14.17	16.37	65.63	61.71
10/18/99	12.37	18.25	64.20	66.45
11/03/99	16.62	12.81	71.02	68.82
11/18/99	14.59	11.98	68.19	65.92
12/01/99	15.45	9.89	69.11	68.08
12/18/99	10.71	9.67	64.22	63.22
12/29/99	9.95	8.99	63.92	56.30
01/16/00	10.24	9.30	65.04	56.53
03/10/00	13.07	16.74	67.41	68.81
03/22/00	12.67	16.49	67.60	64.77
04/10/00	15.12	22.21	72.22	70.47
04/19/00	14.36	21.14	71.01	71.54
05/09/00	14.62	22.77	71.49	69.12
05/17/00	15.61	16.95	69.32	67.34
05/31/00	11.66	20.15	66.34	66.28
06/14/00	11.72	11.22	66.19	62.80
06/30/00	9.61	10.77	64.34	61.12
07/12/00	9.88	12.39	64.60	60.22
08/04/00	13.69	20.07	66.32	68.11
08/16/00	14.01	13.27	67.17	63.06
Average	13.12 ± 2.14	15.20 ± 4.25	67.04 ± 2.66	64.67 ± 4.28

Table 6. Comparisons of forage crude protein (CP) and total digestible nutrients percentage estimates using fecal and forage samples for pastures grazed by Kentland 2 cows in Trial 1

Date	CP (Fecal)	CP (Forage)	TDN (Fecal)	TDN (Forage)
08/13/99	10.33	17.28	64.80	62.38
08/30/99	13.65	13.69	65.96	59.74
09/08/99	14.46	15.46	67.29	61.04
09/22/99	13.57	13.86	65.18	64.21
10/04/99	12.58	13.78	65.34	59.81
10/18/99	11.41	15.64	63.88	63.83
11/03/99	14.24	12.50	67.36	67.87
11/18/99	14.50	12.30	70.04	67.17
12/01/99	15.99	10.35	68.99	64.93
12/18/99	11.28	9.89	63.77	64.81
12/29/99	11.21	9.48	64.66	56.66
01/16/00	11.14	10.96	65.24	57.74
03/10/00	13.97	17.66	72.09	67.42
03/22/00	13.82	13.83	71.19	63.75
04/10/00	16.25	24.43	74.90	72.62
04/19/00	15.57	20.00	72.63	72.45
05/09/00	16.76	21.89	73.90	70.65
05/17/00	14.52	18.17	70.82	69.86
05/31/00	14.33	17.00	72.22	66.67
06/14/00	12.33	9.51	65.47	65.55
06/30/00	9.72	10.39	62.77	61.88
07/12/00	9.68	16.09	64.71	64.92
08/04/00	12.09	15.05	66.80	64.31
08/16/00	12.29	19.36	66.30	63.94
Average	13.15 ± 2.03	14.94 ± 4.03	67.76 ± 3.57	64.76 ± 4.19

Table 7. Comparisons of forage crude protein (CP) and total digestible nutrients percentage estimates using fecal and forage samples for pastures grazed by Buckingham 1 cows in Trial 1

Date	CP (Fecal)	CP (Forage)	TDN (Fecal)	TDN (Forage)
11/19/99	16.50	14.17	71.01	65.75
12/17/99	13.34	9.41	66.60	64.61
01/18/00	13.60	7.74	68.71	55.38
02/24/00	10.40	7.83	65.99	55.45
03/20/00	13.19	11.52	69.38	60.94
04/27/00	14.20	19.76	67.95	68.82
06/07/00	14.97	15.07	72.08	65.66
06/29/00	14.37	15.82	69.35	63.86
08/08/00	11.06	12.71	67.21	62.08
09/15/00	14.13	13.90	69.05	65.42
12/06/00	12.42	9.09	66.59	63.75
Average	13.47 ± 1.72	12.46 ± 3.76	68.54 ± 1.91	62.88 ± 4.22

Table 8. Comparisons of forage crude protein (CP) and total digestible nutrients percentage estimates using fecal and forage samples for pastures grazed by Buckingham 2 cows in Trial 1

Date	CP (Fecal)	CP (Forage)	TDN (Fecal)	TDN (Forage)
11/19/99	16.50	14.17	71.01	65.75
12/17/99	13.54	12.13	66.09	64.63
01/18/00	13.39	8.92	69.34	56.25
02/24/00	9.65	10.57	65.50	57.46
03/20/00	14.15	9.40	71.11	57.61
04/27/00	14.43	22.08	67.69	70.95
06/07/00	12.90	14.17	68.41	63.39
06/29/00	13.00	16.77	66.15	66.01
08/08/00	10.68	11.71	67.18	61.28
09/15/00	15.44	14.45	69.39	63.09
12/06/00	11.45	9.09	65.64	63.75
Average	13.19 ± 2.02	13.04 ± 3.93	67.96 ± 2.06	62.74 ± 4.37

Table 9. Calf weights for calves whose dams were designated in either Kentland 1 or Kentland 2 for Trial 1

Date	Calf Age (d)	Average Kentland 1 calf weights (kg)	Average Kentland 2 calf weights (kg)
01/26/00	1	38.56	38.56
02/23/00	28	63.96	69.17
03/22/00	57	89.31	99.74
04/19/00	84	114.53	119.02
05/17/00	112	151.73	158.89
06/14/00	140	170.51	179.89
07/12/00	168	191.87	200.53
08/16/00	202	236.64	239.13

Table 10. Calf weights for calves whose dams were designated in either Buckingham 1 or Buckingham 2 for Trial 2

Date	Calf Age (d)	Average Buckingham 1 calf weights (kg)	Average Buckingham 2 calf weights (kg)
11/19/99	30	55.79	58.69
12/17/99	58	75.43	81.06
01/18/00	90	122.64	120.68
02/24/00	127	177.22	166.42
03/20/00	152	211.60	205.07
04/27/00	190	259.50	251.61
06/07/00	221	312.21	313.66

Table 11. Average forage height and average total forage yield for Kentland 1 pastures grazed in Trial 1

Date	Average forage height (in.)	Average total forage yield per ha
08/13/99	8.40	2520.00
08/30/99	8.30	2490.00
09/08/99	8.30	2490.00
09/22/99	7.20	2160.00
10/04/99	5.10	1530.00
10/18/99	2.85	855.00
11/03/99	7.17	2151.00
11/18/99	4.39	1317.00
12/01/99	4.00	1200.00
12/18/99	4.38	1314.00
12/29/99	6.31	1893.00
01/16/00	3.80	1140.00
01/26/00		
02/15/00		
02/23/00		
03/10/00	2.18	599.50
03/22/00	1.50	412.50
04/10/00	3.00	900.00
04/19/00	3.67	1101.00
05/09/00	5.11	1533.00
05/17/00	3.90	1170.00
05/31/00	3.20	960.00
06/14/00	30.60	9180.00
06/30/00	8.39	2517.00
07/12/00	10.20	3060.00
08/04/00	1.94	581.00
08/16/00	12.09	3627.00

Table 12. Average forage height and average total forage yield for Kentland 2 pastures grazed in Trial 1

Date	Average forage height (in.)	Average Total Forage Yield per Acre
08/13/99	8.40	2520.00
08/30/99	8.30	2490.00
09/08/99	8.30	2490.00
09/22/99	8.00	2400.00
10/04/99	6.80	2040.00
10/18/99	3.31	993.00
11/03/99	6.39	1917.00
11/18/99	4.44	1332.00
12/01/99	5.50	1650.00
12/18/99	6.21	1863.00
12/29/99	7.21	2163.00
01/16/00	6.50	1950.00
01/26/00		
02/15/00		
02/23/00		
03/10/00	3.00	825.00
03/22/00	3.07	844.25
04/10/00	4.32	1296.00
04/19/00	4.48	1344.00
05/09/00	4.86	1458.00
05/17/00	6.20	1860.00
05/31/00	5.10	1530.00
06/14/00	20.96	6288.00
06/30/00	13.50	4050.00
07/12/00	9.50	2850.00
08/04/00	2.05	615.00
08/16/00	12.64	3792.00

Table 13. Average forage height and average total forage yield for Buckingham 1 pastures grazed in Trial 2

Date	Average forage height (in.)	Average Total Forage Yield per Acre
11/19/99	3.53	1059.00
12/17/99	9.29	3019.25
01/18/00	8.15	2445.00
02/24/00	5.47	1641.00
03/20/00	5.78	1734.00
04/27/00	19.00	6175.00
06/07/00	14.30	4290.00
06/29/00	19.70	5910.00
08/08/00	5.87	2348.50
09/15/00	11.00	3300.00
12/06/00	15.20	4560.00

Table 14. Average forage height and average total forage yield for Buckingham 2 pastures grazed in Trial 2

Date	Average forage height (in.)	Average Total Forage Yield per Acre
11/19/99	3.53	1059.00
12/17/99	9.87	3207.75
01/18/00	7.62	2286.00
02/24/00	4.03	1209.00
03/20/00	4.32	1296.00
04/27/00	24.29	7894.25
06/07/00	12.30	3690.00
06/29/00	19.70	5910.00
08/08/00	9.50	3800.00
09/15/00	10.93	3279.00
12/06/00	15.20	4560.00

Table 15. Actual average daily gain (kg/d) compared to predictions from NRC, NutBal, and NutBal Pro for Kentland 1 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro
08/13/99-09/08/99	-0.19	0.18	1.42	2.19
09/08/99-10/04/99	0.65	0.63	1.63	2.27
10/04/99-11/03/99	0.62	0.80	1.62	1.66
11/03/99-12/01/99	1.89	0.93	1.64	1.86
12/01/99-12/29/99	0.17	0.85	1.06	1.00
02/23/00-03/22/00	-0.88	-0.15	0.84	0.88
03/22/00-04/19/00	0.18	0.10	2.42	1.87
04/19/00-05/17/00	0.98	0.45	2.74	2.10
05/17/00-06/14/00	0.09	0.16	1.80	1.38
06/14/00-07/12/00	-1.81	-0.32	1.25	0.83
07/12/00-08/16/00	0.20	-0.14	1.22	0.91

Table 16. Actual average daily gain (kg/d) compared to predictions from NRC, NutBal, and NutBal Pro for Kentland 2 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro
08/13/99-09/08/99	0.14	0.31	1.32	1.47
09/08/99-10/04/99	0.96	0.50	1.66	1.72
10/04/99-11/03/99	0.57	0.62	1.44	1.51
11/03/99-12/01/99	1.82	0.98	1.67	2.28
12/01/99-12/29/99	-0.05	0.68	1.04	1.43
02/23/00-03/22/00	-0.14	-0.21	1.50	1.54
03/22/00-04/19/00	0.59	-0.03	3.04	2.55
04/19/00-05/17/00	-0.34	0.51	3.03	2.49
05/17/00-06/14/00	-0.53	0.15	2.39	2.06
06/14/00-07/12/00	-1.56	-0.18	1.09	0.66
07/12/00-08/16/00	-0.29	-0.02	1.20	0.90

Table 17. Actual average daily gain (kg/d) compared to predictions from NRC, NutBal, and NutBal Pro for Buckingham 1 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro
11/19/99-12/17/99	-0.04	-0.27	1.17	1.17
12/17/99-01/18/00	0.14	-0.56	1.51	1.07
01/18/00-02/24/00	0.22	-0.88	1.88	1.54
02/24/00-03/20/00	-0.34	-0.36	1.82	2.09
03/20/00-04/27/00	-0.42	0.42	1.87	1.89
04/27/00-06/07/00	0.79	0.96	2.04	1.58
06/07/00-06/29/00	0.09	0.83	1.97	1.62
06/29/00-08/08/00	-0.64	0.57	1.20	1.11
08/08/00-09/15/00	1.49	0.62	1.03	0.83

Table 18. Actual average daily gain (kg/d) compared to predictions from NRC, NutBal, and NutBal Pro for Buckingham 2 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro
11/19/99-12/17/99	0.12	-0.27	1.13	1.11
12/17/99-01/18/00	0.10	-0.55	1.52	1.10
01/18/00-02/24/00	-0.48	-0.81	1.90	1.62
02/24/00-03/20/00	-0.20	-0.36	1.93	2.20
03/20/00-04/27/00	-0.42	0.47	2.00	2.01
04/27/00-06/07/00	0.86	0.88	1.71	1.27
06/07/00-06/29/00	0.39	0.91	1.45	1.06
06/29/00-08/08/00	-0.48	0.54	0.99	0.90
08/08/00-09/15/00	1.17	0.48	1.05	0.88

Table 19. Actual Body Condition Score* compared to predictions from NRC, NutBal, and NutBal Pro for Kentland 1 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro[1]	NutBal Pro[2]
09/08/99	5.57	6.30	7.02	7.46	7.08
10/04/99	6.24	6.26	6.84	7.20	6.98
11/03/99	6.33	6.79	7.91	8.30	7.80
12/01/99	6.57	6.98	7.41	7.55	7.52
12/29/99	6.91	7.50	8.07	8.17	8.20
03/22/00	5.73	6.10	6.72	6.74	6.62
04/19/00	6.37	5.87	7.29	6.95	6.59
05/17/00	6.77	6.68	8.09	7.69	7.53
06/14/00	6.07	6.30	7.31	7.05	7.04
07/12/00	5.64	6.10	8.09	7.57	7.54
08/16/00	6.14	5.99	9.03	8.27	8.10

* Nine point scale with 1 = emaciated and 9 = obese
[1] Predicted BCS calculated from predicted ADG using NutBal Pro
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro

Table 20. Actual Body Condition Score* compared to predictions from NRC, NutBal, and NutBal Pro for Kentland 2 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro[1]	NutBal Pro[2]
09/08/99	5.23	5.68	6.26	6.34	6.17
10/04/99	5.69	5.69	6.35	6.38	6.30
11/03/99	5.53	6.09	7.30	7.38	7.13
12/01/99	6.21	6.31	6.73	7.11	6.77
12/29/99	6.21	6.73	7.38	7.99	7.94
03/22/00	6.08	5.87	6.92	6.95	6.63
04/19/00	5.96	5.98	7.88	7.57	7.20
05/17/00	6.25	6.29	9.75	9.11	8.52
06/14/00	6.44	6.39	7.77	7.57	7.45
07/12/00	5.88	6.28	8.45	7.98	7.72
08/16/00	6.25	6.26	9.38	8.68	8.11

* Nine point scale with 1 = emaciated and 9 = obese
[1] Predicted BCS calculated from predicted ADG using NutBal Pro
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro

Table 21. Actual Body Condition Score* compared to predictions from NRC, NutBal, and NutBal Pro for Buckingham 1 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro[1]	NutBal Pro[2]
12/17/99	5.34	5.13	6.03	6.02	6.06
01/18/00		4.74	7.09	6.78	6.36
02/24/00	5.26	4.02	8.62	8.03	7.20
03/20/00	5.25	3.82	9.63	9.18	7.93
04/27/00	5.70	4.17	11.20	10.76	9.59
06/07/00	6.14	5.04	13.04	12.20	10.44
06/29/00	5.94	5.44	14.00	12.98	11.12
08/08/00	5.61	5.94	15.05	13.96	11.99
09/15/00	5.94	6.46	15.91	14.66	12.38

* Nine point scale with 1 = emaciated and 9 = obese
[1] Predicted BCS calculated from predicted ADG using NutBal Pro
[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro

Table 22. Actual Body Condition Score* compared to predictions from NRC, NutBal, and NutBal Pro for Buckingham 2 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro[1]	NutBal Pro[2]
12/17/99	5.71	5.23	6.10	6.09	6.15
01/18/00		4.85	7.17	6.86	6.44
02/24/00	5.13	4.18	8.72	8.18	7.40
03/20/00	5.58	3.98	9.79	9.40	8.13
04/27/00	5.10	4.37	11.46	11.09	9.98
06/07/00	5.77	5.17	13.01	12.23	10.83
06/29/00	6.10	5.61	13.71	12.75	11.23
08/08/00	5.63	6.09	14.58	13.54	11.72
09/15/00	6.05	6.49	15.46	14.28	12.16

* Nine point scale with 1 = emaciated and 9 = obese

[1] Predicted BCS calculated from predicted ADG using NutBal Pro

[2] Predicted BCS calculated from predicted BCS in 30 d using NutBal Pro

Table 23. Actual mean cow bodyweight (kg) and predictions from NRC, NutBal, and NutBal Pro for Kentland 1 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro
09/08/99	637.03	646.55	678.98	698.99
10/04/99	675.54	674.81	701.07	717.49
11/03/99	694.22	698.94	749.65	767.25
12/01/99	750.15	723.34	743.03	749.29
12/29/99	754.96	747.16	772.79	777.28
03/22/00	663.83	683.97	711.96	712.87
04/19/00	673.18	671.14	735.91	720.58
05/17/00	700.48	685.79	749.79	731.87
06/14/00	695.63	697.49	743.53	731.69
07/12/00	645.05	688.64	778.55	754.96
08/16/00	652.22	683.65	821.27	786.89

Table 24. Actual mean cow bodyweight (kg) and predictions from NRC, NutBal, and NutBal Pro for Kentland 2 cows in Trial 1

Date	Actual	NRC	NutBal	NutBal Pro
09/08/99	607.13	611.76	638.11	641.88
10/04/99	650.63	638.70	668.91	670.41
11/03/99	667.64	657.16	712.00	715.72
12/01/99	732.55	709.06	728.42	745.34
12/29/99	731.15	728.11	757.59	785.49
03/22/00	738.40	736.36	784.13	785.26
04/19/00	755.73	738.40	824.45	810.71
05/17/00	746.34	752.65	909.23	880.42
06/14/00	724.34	743.17	805.94	796.78
07/12/00	680.57	738.22	836.56	815.29
08/16/00	670.18	737.41	878.61	846.95

Table 25. Actual mean cow bodyweight (kg) and predictions from NRC, NutBal, and NutBal Pro for Buckingham 1 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro
12/17/99	566.63	560.23	600.60	600.51
01/18/00	569.80	542.22	648.82	634.71
02/24/00	579.19	509.66	718.40	691.73
03/20/00	570.57	500.72	764.03	743.89
04/27/00	554.70	516.51	835.20	815.56
06/07/00	587.18	555.88	918.71	880.51
06/29/00	589.03	574.16	962.11	916.17
08/08/00	563.45	596.88	1010.06	960.57
09/15/00	620.15	620.29	1049.11	992.28

Table 26. Actual mean cow bodyweight (kg) and predictions from NRC, NutBal, and NutBal Pro for Buckingham 2 cows in Trial 2

Date	Actual	NRC	NutBal	NutBal Pro
12/17/99	569.26	558.42	597.61	597.11
01/18/00	572.43	540.82	646.28	632.35
02/24/00	554.79	510.74	716.68	692.32
03/20/00	549.84	501.63	764.98	747.43
04/27/00	534.06	519.50	841.01	823.95
06/07/00	569.49	555.74	910.99	876.02
06/29/00	577.97	575.70	942.97	899.29
08/08/00	558.74	597.06	982.44	935.13
09/15/00	603.14	615.25	1022.35	968.74

Vita

Donald Shane Horsley, son of Donald H. and Diane F. Horsley, was born January 3, 1977 in Norfolk, VA. He graduated form Floyd E. Kellam High School in Virginia Beach, VA in June, 1995. He attended Virginia Polytechnic Institute and State University and received a Bachelor of Science in Animal and Poultry Sciences, with a minor in Agricultural and Applied Economics in May, 1999. In July of 1999, he entered a Master of Science program in Animal and Poultry Sciences (Beef Cattle Nutrition / Management) at Virginia Polytechnic Institute and State University.

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