THE USE OF DIFFERENT NUTRITIONAL STRATEGIES AND MATHEMATICAL MODELS TO IMPROVE PRODUCTION EFFICIENCY, PROFITABILITY, AND CARCASS QUALITY OF FEEDLOT CATTLE

A Dissertation

by

JUDSON TADEU DE VASCONCELOS

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

DOCTOR OF PHILOSOPHY

December 2006

Major Subject: Animal Science

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ABSTRACT

The Use of Different Nutritional Strategies and Mathematical Models to Improve
Production Efficiency, Profitability, and Carcass Quality of Feedlot Cattle. (December 2006)
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Forty eight crossbred steers (BW = 296 ± 16.7 kg) were fed four dietary treatments for 56 d: AL-LS (low starch diet fed *ad libitum* for a rate of gain of 1 kg/d), AL-HS (high starch diet fed *ad libitum*), LF-HS (a limit fed high starch diet designed to be isocaloric with AL-LS), and AL-IS (a diet fed *ad libitum* for the midpoint daily energy intake between AL-LS and AL-HS). On d 57 all steers were placed on AL-HS for finishing until d 140. Steers that consumed more total energy (AL-HS and AL-IS) throughout production achieved greater carcass fatness in the end of the 140 d period, although these responses were difficult to evaluate via real-time ultrasound measurements. No differences in insulin and glucose kinetics were observed. Data suggested that energy source may influence energy partitioning during the growing period, but these effects may be overcome by differences in energy intake. Higher marbling scores (AL-HS and AL-IS) rewarded higher grid values and greater premiums, which increased profitability. This data set was also used for a model evaluation that showed that mathematical models (CVDS and NRC) were able to explain most of the variation in individual feed requirements of group-fed growing and finishing cattle. Another data set was used for evaluation of a decision support system Cornell Net Carbohydrate and Protein System (CNCPS) as a tool to minimize nutrient excretion from fed cattle. One-hundred eight-four group-fed steers were fed a 13% crude protein (CP) diet until reaching 567 kg of BW, when their diets were either maintained at 13% or reduced to 11.5% or 10% CP. Data from the second half of the experiment were modeled to predict urinary, fecal, and total N excretion. As dietary CP decreased from 13 to 11.5%, the model indicated a total N excretion of 16%. An even greater reduction in total N excretion (26%) occurred when dietary CP was decreased from 11.5% to 10%. The overall decrease from 13 to 10% CP resulted in a reduction of total N excretion by 38%. Data suggest that decision support systems can be used to assist in balancing diets to meet environment restriction.

To my parents.

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CHAPTER I

INTRODUCTION

Marbling is the intramuscular fat (**IMF**) present between muscle fiber bundles within muscles. This trait enhances meat palatability and confers a higher economic value to carcasses with higher amounts of IMF (Harper and Pethick, 2004).

Nutritional strategies might impact beef cattle carcass characteristics by increasing IMF accretion if applied during growth. Glucose provides 50 to 75% of the acetyl units for lipogenesis of IMF, but only 1 to 10% of the acetyl units for lipogenesis in subcutaneous fat (**SCF**). Acetate provides 70 to 80% of the acetyl units for lipogenesis in SCF, but only 10 to 25% of the acetate units in IMF (Smith and Crouse, 1984). Diets containing glucogenic precursors may increase net glucose via gluconeogenesis, and therefore stimulate secretion of insulin (Sano et al., 1993). Growing animals fed glucogenic precursors might also have increased insulin sensitivity in peripheral tissues (Waterman et al., 2006), which would increase glucose uptake, and potentially increase the use of glucose carbons for IMF lipogenesis. The first objective of this dissertation was to evaluate the effects of different nutritional regimes applied to growing cattle on insulin sensitivity and IMF and SCF accretion in feedlot cattle.

Sorting systems have been developed to optimize productivity, minimize weight discounts, and increase economic returns (Perry and Fox, 1997; Guiroy et al, 2002; Tedeschi et al., 2004). In custom feedyards, effective application of sorting systems

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This dissertation follows the style and format of the Journal of Animal Science.

would require commingling of different lots of cattle, which makes the billing process difficult. The Cornell Value Discovery System (**CVDS**; Perry and Fox, 1997; Guiroy et al., 2001; Tedeschi et al., 2004) has been successfully used to allocate feed intake to individual animals when fed in groups (Tedeschi et al., 2006). The National Research Council (**NRC**) Nutritional Requirements of Beef Cattle (1996; 2000) can also be used for prediction of individual intake of cattle when performance is known, by manually adjusting DMI until model predicted ADG matches observed ADG. The second objective of this dissertation was to evaluate the precision and accuracy of CVDS and NRC models for predicting individual feed requirements of group-fed growing and finishing cattle, and individual feed requirements of feedlot cattle with different backgrounds.

Growing systems using nutritional strategies to enhance IMF development may increase carcass value and profitability (Pyatt et al., 2005b). Grid marketing evaluates and prices cattle individually and rewards higher carcass quality grade (QG) at slaughter (Ibarburu and Lawrence, 2005). The third objective of this dissertation is to evaluate the effects of feeding growing diets designed to increase IMF deposition, QG, and carcass value on beef cattle production profitability.

Concentrated animal feeding operations (**CAFO**) concentrate N, P, and trace minerals (e.g. Cu) in small geographic areas. Environmental issues associated with feedlot cattle include nutrient pollution of ground and surface water as well as particulate pollution of air. Nutrient requirements of feedlot cattle change during the feeding period. Nonetheless, feedlot cattle are usually fed one common diet with a constant level of CP and other nutrients from about day 24 of feeding through harvest. Consequently, CP is often underfed early and overfed late in the feeding period. Feeding nutrients at concentrations that more closely match animal requirements may prevent excess excretion of nutrients in feedlots. The fourth objective of this dissertation was to evaluate the Cornell Net Carbohydrate and Protein System (CNCPS) as a tool to assist in formulating diets for feedlot cattle to minimize environmental pollution.

CHAPTER II

REVIEW OF LITERATURE

The use of feedstuffs by the ruminant animal

Most feedstuffs are converted to volatile fatty acids (**VFA**) in the rumen to provide most of the required energy by the ruminant animal (Barcroft et al., 1944). Different VFA are produced from different types of carbohydrates sources. Forage-based diets provide structural carbohydrates (such as cellulose) that are mainly fermented to acetate. Starch-based (nonstructural carbohydrates) diets produce a greater proportion of propionate to acetate, when compared to forage-based diets (Ørskov et al., 1991; Annison and Bryden, 1999).

In ruminants, little glucose is absorbed due to the extensive degradation of carbohydrates by microbes in the rumen (Huntington, 1997). On average, 5 to 20% of starch consumed is digested postruminally, and less than 25% of the ruminant glucose supply is the product of the starch digestion in the lower gut (Streeter et al., 1989). Ruminants consuming high-forage, low-starch diets depend on liver synthesis of glucose via gluconeogenesis to meet metabolic requirements (Huntington, 1997). Gluconeogenesis is therefore the principal route of glucose supply for glucose-utilizing tissues in ruminants, and propionate is quantitatively the most important supply of key carbon sources for gluconeogenesis (Bergman, 1990). The most important carbon sources for glucose synthesis are organic acids (mainly propionate and lactate), the carbon skeletons of deaminated amino acids, and glycerol from the breakdown of triglycerides (Huntington, 1997).

Propionate allows for glucose net production, providing from 43 to 67% of carbon used for glucose synthesis in the liver (Sano et al., 1994; Huntington, 1997). Reduced hepatic supply of propionate can potentially increase the requirement and use of other substrates for gluconeogenesis to meet tissue glucose demands (Waterman et al., 2006).

Adipose tissue growth and development

Growth is measured as the accretion of tissues such as protein, fat, and bone. The growth and development of these tissues is based on importance or priority for the animal survival. Nervous tissue develops first, and it is then followed by muscle and then fat (Owens et al., 1995). Triacylglycerols (**TG**) are stored in adipocytes as a result of nutritional caloric excess and this reserve is mobilized when caloric expenditure exceeds intake (Cornelius et al, 1994).

Adipose tissue is a term for loose connective tissue that stores energy in the form of fat, although it also cushions and insulates the body. There are two types of adipose tissue: white adipose tissue (**WAT**) and brown adipose tissue (**BAT**; Ailhaud et al., 1992). The development of WAT occurs postnatally and continues throughout life; in contrast, the development of BAT occurs before birth and disappears thereafter (Ailhaud et al., 1992). The increase in adipose cell number is the result of preadipocyte division. The number of preadipocytes decreases with age, but varies according to depots and energy intake. Preadipocytes first appear in embryonic life but the major development of adipocytes occurs shortly after birth (Cornelius et al, 1994).

Adipocytes derive from multipotent mesodermal stem cells, a common precursor for myocytes, chondrocytes, and osteocytes (Cornelius et al, 1994; Lagasse et al., 2001). During embryonic life, stem cells differentiate into cell types with specialized forms and functions, losing their potential to generate other cell types (Lagasse et al., 2001). Preadipocytes mature into adipocytes during the terminal stages of differentiation.

Smith and Crouse (1984) observed that SCF has fewer cells per gram, larger cell diameter, and higher cell volume when compared to IMF. This confirmed Allen et al. (1976), who observed that IMF had smaller adipocytes and lower lipogenic rates than SCF. Adipocytes from IMF appear to be more limited in size than fat tissues from other depots; therefore their total number is more important in determining the quantity of intramuscular lipid in bovine (Allen et al., 1976).

Accretion patterns of intramuscular fat

The accretion pattern of SCF and IMF fat is still not completely understood. Marbling begins with the accumulation of TG in the adipocytes located within the bundles of the muscle fibers, but there is disagreement about when this process starts in the animal’s life.

A common assumption based on several developmental studies is that IMF is late developing (Vernon, 1981). It is generally accepted that the development order of fat depot is abdominal, intermuscular, subcutaneous and intramuscular (Pethick et al., 2004). Pethick et al. (2004) suggest that, since fat is deposited at a greater rate than are lean tissues later in life, the concentration of fat in muscle will eventually increase as the animal matures. Therefore, according to Pethick et al. (2004), the accretion of IMF is late in physiological maturation, i.e., IMF is a late-maturing depot.

The concept of accumulation of marbling relative to carcass composition and weight is also still not clear. Bruns et al. (2004) evaluated the hypothesis that marbling increase at a decreasing rate with increasing days on feed. Bruns et al. (2004) analyzed data from a 2-yr study with Angus steers slaughtered in five different groups targeted to produce hot carcass weight (**HCW**) of 204, 250, 295, 340, and 386 kg. Longissimus muscle area, marbling scores, and 12th rib IMF content increased in a linear fashion with increasing HCW. In addition, the percentage of total carcass fat increased ($P < 0.05$) in a quadratic fashion as HCW increased. The percentage of carcass protein and moisture decreased quadratically ($P < 0.05$) with increased HCW. The fractional growth (percent per day) of protein, carcass fat, and 12th rib IMF decreased with increasing HCW while SCF increased in a quadratic fashion (Bruns et al., 2004).

Bruns et al. (2004) suggested that marbling increased linearly with carcass weight across a wide spectrum of the growth curve. The line for marbling was not parallel to the line for total fatness. These data indicated that relatively early in growth, quality grade is increasing more rapidly than yield grade increases. Later in the growth curve, yield grade is increasing more rapidly than quality grade. They suggested that it is possible to alter the percent choice in a set of cattle with early management.

To support their findings, Bruns et al. (2004) evaluated older research data that have reported increases in marbling when the feeding time was extended. Data from May et al. (1992) and VanKoevering et al. (1995), for example, showed that the regression of marbling score against days on feed suggested a quadratic development until 112 (May et al., 1992) or 119 d (Van Koevering et al., 1995) before reaching a plateau. The Bruns et al. (2004) review also goes over other results (Moody et al., 1970; Butts et al., 1980; Greene et al., 1989) that also suggest a plateau in the development of marbling as time on feed increased. That is not what Bruns et al. (2004) found, but instead, they found that the IMF content of the LM increased linearly and also that scores increased when shown as a component of growth.

Bruns et al. (2004) suggested that the data from other experiments only compared marbling development to days on feed or age, but not as a component of growth. Bruns et al. (2004) also regressed their IMF data against time, and also found a quadratic response for marbling. Therefore, the results might depend on the way they are evaluated. The understanding of IMF accretion as a component of the growth makes it possible to manipulate its deposition through nutrition on growing and younger animals rather than the evaluation of its accretion based on days on feed.

Insulin

Insulin is one of the most important anabolic hormones in the body and it is critical for the control of carbohydrate, lipid, and protein metabolism (Lindmark, 2004). Insulin stimulates glucose uptake in insulin sensitive tissues (mainly skeletal muscle), inhibits glucose production in the liver, and promotes the storage of glycogen in liver and skeletal muscle. The insulin independent glucose transporter 1 (**GLUT1**) is predominantly located in the muscle cell plasma membrane, and accounts for the basal glucose supply of the myocyte.

Insulin is secreted from beta cells in the pancreas, and it acts by binding to the transmembrane insulin receptor in the target cells, activating the tyrosine kinase domain in the intracellular part of the receptor leading to phosphorylation of insulin receptor substrates (**IRS**), starting a cascade of signaling reactions in the cell leading to metabolic effects (Lindmark, 2004; Figure 2.1).

The insulin-regulated glucose transporter 4 (**GLUT4**) recycles between the cell plasma membrane (**PM**) and an intracellular tubulovesicular pool, where it is associated with cytoplasmic vesicles (**CV**; Duhlmeier et al., 2005).

In ruminants, insulin plays an important role on glucose conservation for specific, non insulin-dependent functions (i.e., cerebral tissue) at the expense of other important production parameters (e.g., growth; Waterman et al, 2006). Increased plasma insulin concentration is linked to decreased hepatic gluconeogenesis and to increased glucose use by peripheral tissues (Huntington, 1997). Blood concentrations of glucose, non-esterified fatty acids (**NEFA**), and ketone bodies decrease in response to elevated concentration of insulin (Eisemann and Huntington, 1994).

Sensitivity and resistance of tissues to insulin

Insulin sensitivity describes the ability of the peripheral tissues to respond to exogenous insulin (DeFronzo et al., 1979). A common test to assess insulin sensitivity is the intravenous glucose tolerance test (**GTT**) used in humans as well as in cattle (DeFronzo et al., 1979). A glucose load is infused i.v. and the subsequent blood insulin response is measured. Insulin resistance is related to a decreased response to

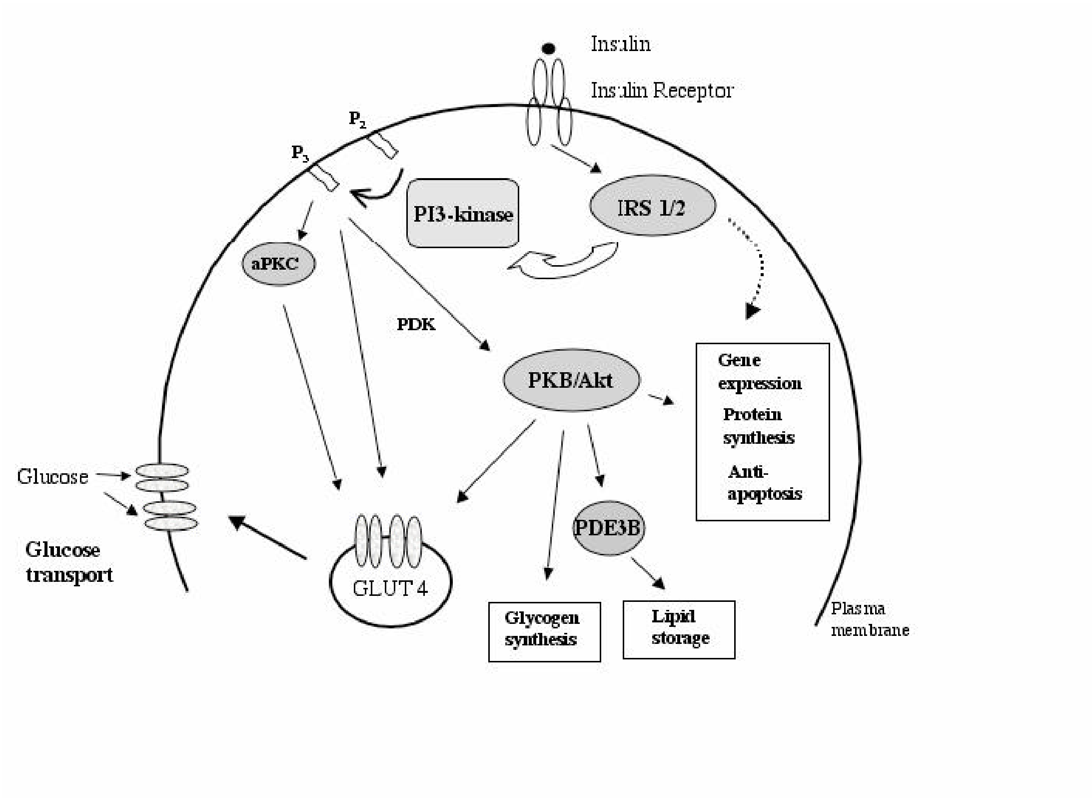

Figure 2.1. Cellular insulin signaling. GLUT 4; glucose transporter, IRS; insulin receptor substrate, PI3- kinase; phosphatidylinositol 3-kinase, aPKC; atypical protein kinase C, P2; phosphatidylinsositol- 3, 4-bisphosphate, P3; phosphatidylinositol-3, 4, 5-triphosphate, PKB; protein kinase B (Lindmark, 2003)

serum insulin by insulin-sensitive cells and it occurs primarily in muscle, adipose and liver tissues (Kahn, 1978). This resistance exists whenever normal concentration of hormone produce a less than normal response and can be a result of inefficient insulin signaling at the cell surface or consequence of a disruption of insulin signaling within the cell (Kahn, 1978).

Kahn (1978) described that insulin receptor modulation or dysfunction may contribute to both insulin insensitivity (causing decreased glucose transport into the cell) and insulin ineffectiveness (due to altered glucose metabolism inside the cell). The effectiveness of insulin on enhancing glucose use also varies with age, body composition, nutritional status, and productive state of the animal (Huntington and Richards, 2005). In dairy cattle, for example, parturition and transition from gestation to lactation are under homeorhetic control (Sano et al., 1994). During late gestation and early lactation, lowered responsiveness and sensitivity of extra hepatic tissues to insulin facilitate partitioning of nutrients toward the rapidly growing fetus and mammary tissue (Hayirli, et al., 2002).

Ketone bodies play an important role as an energy source by the peripheral metabolism, resulting from acetate loading when there is shortage of glucose (Herdt et al., 1981). Ketone bodies might inhibit glucose utilization through impaired protein kinase B activation (Tardif et al., 2001) or altered insulin signaling through IRS-1–associated PI 3-kinase (Dresner et al., 1999).

Carbons of some glucogenic precursors provide carbons for oxaloacetate production, increasing acetate oxidation. This process decreases the amount of acetate in the blood. Therefore, diets rich in glucogenic precursors could increase the supply of glucose, decrease the production of ketone bodies, and increase insulin sensitivity (Waterman et al., 2006).

Starch-rich diets produce a greater proportion of propionate providing greater levels of glucose when compared to diets with low levels of starch. The elevation in the concentration of ruminal propionate increases the supply of the main glucogenic precursor propionate, which reduces the body's requirement for alternative glucogenic precursors, and stimulates the pancreatic secretion of insulin (Sano et al., 1994). Insulin is most likely responsible for the efficient peripheral utilization of glucose and other nutrients in ruminants with a propionic acid type of rumen fermentation (Abdul-Razzaq et al., 1989). Thus, a propionic type of fermentation might be associated with an increase in IMF deposition.

Starch rich diets can induce partitioning of energetic substrate by enhancing glucose availability and uptake for and fatty acid synthesis in the IMF. For instance, Rhoades et al. (2005) observed that adipose tissue of steers fed high forage diets were insensitive to insulin, while adipose tissue from steers fed high corn diets had high insulin sensitivity.

Substrate supply to tissue from diet

In ruminants, glucose is not an important precursor for most fat tissues (Smith, 1983). Acetate and lactate are the primary carbon sources for lipogenesis; however, SCF and IMF tissues are metabolically distinct and differ in rates of development and substrates used for synthesis (Smith and Crouse, 1984). Hood and Allen (1978) found that the rate of incorporation of acetate into total fatty acids was higher in the SCF than in the IMF.

Smith and Crouse (1984) demonstrated that glucose provided 50 to 75% of the acetyl units for in vitro lipogenesis in the IMF but only 1 to 10% of the acetyl units for in vitro lipogenesis of the SCF. Acetate provided 70 to 80% of the acetyl units for lipogenesis in SCF, but only 10 to 25% of the acetyl units for lipogenesis in IMF. Therefore, it is possible that acetate is the preferred substrate for the SCF and glucose is preferred by IMF. Recent data have been supporting this premise.

Rhoades et al. (2005) fed Angus (n = 8; 210 kg) and 7/8 Wagyu (n = 8; 174 kg) steers to evaluate the effects of dietary energy source on adipose tissue metabolism. Steers were fed either grain-based or hay-based diets and gained 0.85 kg/d and 0.72 kg/d, respectively. Results showed that acetate was much more effectively utilized for fat synthesis by SCF. Data from Rhoades et al. (2005) suggested that high starch diets enhances glucose utilization, and fatty acid synthesis in IMF, while high forage fed animals had reduced glucose utilization without altering acetate incorporation in fatty acids. Overall, IMF was insulin sensitive and SCF was not.

Feeding strategies

The growing phase allows body development before the finishing phase, potentially improving marbling and quality grade by allowing the animals to reach greater maturity (Sainz et al., 1995). The sooner an animal reaches its near maximal potential for muscle and fat growth, the sooner it would begin to express marbling.

Therefore, nutritional management for fast growth throughout the animal's life will likely result in marbling at an earlier age (Pethick et al., 2004).

The substrate supply for fat synthesis based on the difference in SCF and IMF tissues metabolism may allow for the manipulation of individual fat depots (Schoonmaker et al., 2003). Nutrition strategies using different energy sources may impact beef cattle carcass characteristics when conducted during post-weaning and feedlot phases. In growing animals, the increase in sensitivity of insulin by the IMF will likely increase the amount of glucose, which is a preferred substrate for IMF synthesis.

High starch diets fed to growing animals may be beneficial on enhancing marbling deposition. Schoonmaker et al. (2003) fed 73 (170.5 kg) crossbred calves weaned at 119 d of age. Animals were fed four different feeding strategies: high-concentrate, fed *ad libitum* (ALCONC), high-concentrate fed to achieve a gain of either 1.2 kg/d (1.2CONC) or 0.8 kg/d (0.8CONC), or high-fiber, fed *ad libitum* (ALFIBER). At 218 d of age, all steers were placed on the ALCONC diet until slaughter. When steers averaged 181 and 279 d of age, serum samples were collected to determine glucose and insulin concentrations (Schoonmaker et al., 2003). The elevated insulin serum concentrations in steers consuming high-concentrate diets during the growing phase suggested an increased uptake of glucose by peripheral tissues, which might have increase use of glucose as a source of acetyl units for IMF lipogenesis. That could explain data from d 218, which showed that cattle fed ALCONC had a higher percentage of IMF when compared to other treatments; however, these IMF readings on d 218 did not translate into a difference at slaughter.

Insulin and glucose concentrations were constantly high for ALCON, which could also suggest a potential insulin resistance. This could justify why serum glucose and serum insulin concentrations at 181 d of age were lower for 0.8CONC. These data could suggest an increase in insulin sensitivity for this treatment.

The higher marbling scores for ALCONC at 218 d of age may be a result of the greater starch fermentation. Insulin at 279 d of age was different only at 3 h postfeeding, indicating that there is little residual effect of growing phase diet in the finishing phase. Overall insulin on 279d was higher for 1.2CONC, followed by 0.8CONC, ALCONC, and ALFIBER (Schoonmaker et al., 2003).

Based on these results, it is possible to conclude that starch fermentation increased blood glucose, and insulin in ALCONC and 1.2CONC. Overall data suggested that IMF accretion was affected, just not at the end of the experiment.

CHAPTER III

CHANGES IN INTRAMUSCULAR AND SUBCUTANEOUS ADIPOSE TISSUE, PERFORMANCE, INSULIN SENSITIVITY, AND CARCASS CHARACTERISTICS OF FEEDLOT CATTLE FED DIFFERENT GROWING DIETS

Overview

Forty eight crossbred steers (BW = 296 ± 16.7 kg) were individually fed to evaluate effects of different growing diets on changes on accretion of intramuscular (IMF) and subcutaneous adipose tissues (SCF), insulin sensitivity, and carcass traits. Four dietary treatments were assigned: AL-LS (a low starch diet fed *ad libitum*), AL-HS (a high starch diet fed *ad libitum*), LF-HS (a limited fed high starch diet designed to provide the same amount of energy provided by AL-LS), and AL-IS (a diet with approximately the midpoint daily energy intake between AL-LS and AL-HS). Steers received treatments until d 56, when they were all fed AL-HS until d 140. Real-time ultrasound (RTU) and BW measurements were taken at 28-d interval. Ultrasound IMF and SCF readings during the growing phase showed that HS diets increased accretion of IMF ($P = 0.01$), and that LS and IS diets resulted on lower accretion of SCF ($P < 0.01$). During the finishing period, accretion of IMF ($P = 0.13$) and SCF ($P = 0.81$) were similar among treatments. This similarity diluted differences in overall (d 0 to 140) accretion of IMF ($P = 0.28$) and SCF ($P = 0.52$), such that final RTU measures of IMF and SCF were similar ($P > 0.36$) among treatments. However, carcass marbling scores were higher for AL-HS and AL-IS groups ($P = 0.02$), and fat thickness tended to be higher for AL-HS and AL-IS groups (*P* = 0.08). High starch diets increased growing phase accretion of IMF and SCF. Steers that consumed more total energy (AL-HS and AL-IS) throughout production achieved greater carcass fatness, although these responses were difficult to evaluate via RTU measurements. Three glucose tolerance test (GTT) were conducted on d 0, 27 and 56 of the growing period. Insulin sensitivity was assessed by the incremental area under the curve (AUC) and the area over the curve (AOC) as indicators of insulin release and glucose uptake, respectively. No differences in insulin sensitivity were observed at any GTT (*P* > 0.05). Data suggested that energy source may influence energy partitioning during the growing period, but these effects may be overcome by differences in energy intake.

Introduction

Marbling is the commercial meat trait based on the intramuscular adipose tissue (**IMF**) between muscle fiber bundles within muscles, and its amount influences economic value of carcasses (Harper and Pethick, 2004).

It is generally accepted that the development order of fat depots is abdominal, intermuscular, subcutaneous and intramuscular (Pethick et al., 2004). On the contrary, Bruns et al. (2004) have shown that the development of the IMF is not late-maturing, but starts early in the animal's life.

Growing animals fed high starch diets have higher production of ruminal propionate, a glucose precursor. This increase in glucose stimulates the secretion of insulin, which might be a key component in triggering IMF development in growing cattle (Bines and Hart, 1984; Schoonmaker et al., 2003). Increased insulin concentrations may increase uptake of glucose by peripheral tissues in growing steers. Glucose provides 50 to 75% of the acetyl units for lipogenesis of IMF and only 1 to 10% for the subcutaneous fat (**SCF**). Acetate provides 70 to 80% of the acetyl units for lipogenesis in the SCF, but only 10 to 25% in the IMF (Smith and Crouse, 1984).

Gluconeogenesis is the principal route of glucose supply for glucose-utilizing tissues in ruminants, and propionate is quantitatively the most important supply of key carbon sources for gluconeogenesis (Huntington, 1997). Steers in high forage-based growing systems, however, have higher production of acetate in the rumen. Ketone bodies are also used as an energy source by the peripheral metabolism, resulting from acetate loading when there is shortage of glucose (Huntington, 1997), and they might inhibit glucose utilization through impaired protein kinase B activation (Tardif et al., 2001) or altered insulin signaling (Dresner et al., 1999), increasing insulin resistance.

The objectives of this study were to evaluate the effects of growing diets with different source and amount of dietary energy on IMF and SCF deposition, insulin sensitivity, performance, and carcass characteristics of feedlot cattle.

Material and methods

This study was conducted at the Texas Agricultural Experiment Station/USDA-ARS Conservation and Production Laboratory, Bushland, TX. Care, handling, and sampling of steers were approved by the Cooperative, Research, Education, and Extension Triangle Animal Care and Use Committee.

Forty eight crossbred steers were purchased from a commercial order buyer and utilized for a summer grazing trial during the summer and fall of 2004 at the Bush

Research Farm, Bushland, TX. In the winter of 2004 these steers were transported to the Texas Agricultural Experiment Station/USDA-ARS Experimental Feedlot in Bushland, weighed (BW = 296.0 ± 16.7 kg) and trained to consume their daily feed from individual feeders (American Calan, Northwood, NH) for a 2-wk period, while fed a high roughage diet. Steers were implanted with Synovex-S (20 mg of estradiol benzoate and 200 mg of progesterone; Fort Dodge Animal Health, Overland Park, KS), and assigned to one of six pens and four different dietary treatments in a completely randomized design.

During 56 d steers, received one of the following dietary treatments: **AL-LS** (a low starch diet fed *ad libitum*), **AL-HS** (a high starch diet fed *ad libitum*), **LF-HS** (a limit fed high concentrate diet with the same amount of energy provided by treatment 1), and **AL-IS** (a diet with approximately the midpoint daily energy intake between AL-LS and AL-HS). Diets compositions are shown in Table 3.1. High starch treatments (AL-HS and LF-HS) contained approximately 80% corn and 7% roughage (DMB). The AL-LS dietary treatment consisted of a high roughage. The AL-LS diets contained approximately 50% wheat middlings and 36% cottonseed hulls during the first 28 d. The amount of wheat middlings was then decreased to 25% in the following 28 d because of an unexpected excess in the CP concentration of this feedstuff. The percentage of cottonseed hulls in the diet was then increased to approximately 60%. The IS dietary treatment was a diet containing approximately half of the amount of corn and forage present on HS and LS, respectively. Diets also contained molasses, tallow, and a supplement containing minerals (calcium, phosphorus, sodium, magnesium, potassium,

Table 3.1. Composition and analyzed nutrient content of diets fed during growing (56 d) and finishing (84 d) period of beef steers.

Item	Dietary treatments (d0-d27) [a]			
	AL-LS	AL-HS [c]	LF-HS	AL-IS
Ingredient [b]				
Corn Grain, Steam Flaked, %	0.0	79.2	79.2	38.0
Cottonseed, Hulls, %	36.0	7.0	7.0	30.0
Fat/Steep/Molasses blend	3.0	3.0	3.0	3.0
Mineral and vitamins premix [d], %	11.0	10.0	10.0	10.0
Wheat, Middlings, %	50.0	0.0	0.0	19.0
Chemical composition				
CP,%	26.95	12.85	12.85	17.30
NEm, Mcal/kg	1.86	2.03	2.03	1.86
NEg, Mcal/kg	1.22	1.39	1.39	1.24
Ca, %	2.11	0.79	0.79	1.19
P, %	0.87	0.30	0.30	0.47
	Dietary treatments (d27-d56)			
Corn Grain, Steam Flaked, %	0.0	79.2	79.2	38.0
Cottonseed, Hulls, %	61.0	7.0	7.0	40.0
Fat/Steep/Molasses blend, %	3.0	3.0	3.0	3.0
Mineral and vitamins premix [d], %	11.0	10.0	10.0	10.0
Wheat, Middlings, %	25.0	0.0	0.0	9.0
Chemical composition				
CP,%	22.40	12.45	12.45	13.07
NEm, Mcal/kg	1.75	2.06	2.06	1.83
NEg, Mcal/kg	1.13	1.39	1.39	1.19
Ca, %	1.37	0.66	0.66	0.72
P, %	0.87	0.39	0.39	0.38

[a] AL-LS (a low starch diet fed *ad libitum*), AL-HS (a high starch diet fed *ad libitum*), LF-HS (a limited fed high starch diet designed to provide the same amount of energy provided by AL-LS), and AL-IS (a diet with approximately the midpoint daily energy intake between AL-LS and AL-HS).

[b] DM basis.

[c] This diet was fed *ad libitum* to all treatments during finishing (84d).

[d] Composed of 5.44% Ca, 0.20% P, 4.43% NaCl, 0.51% Mg, 3.94% K, 0.29% S, 1.83% Na, 827 ppm Mn, 1286 ppm Zn, 633 ppm Fe, 135 ppm Cu, 0.17 ppm Se, 2.68 ppm Co, 13.64 ppm I, 18,651 IU of Vit. A/kg and 110 IU of Vit. E/kg. All diets contained monensin (30 mg/kg) and tylosin (11 mg/kg).

sulfur, manganese, zinc, cupper, selenium, cobalt, iodine, and iron), Vitamin A, Vitamin E, monensin, and tylosin.

On d 57 all animals (BW = 400.6 ± 31.9 kg) were placed on the same high-concentrate diet (the same diet from treatment AL-HS) for finishing until all steers reached approximately 1 cm of back fat (d 140). During the 140-d period, steers were weighed and ultrasonically scanned between the 12th and 13th ribs at approximately 28-d interval. Real time ultrasound (**RTU**) measurement of IMF and SCF were obtained using a real-time linear array ultrasound instrument (SSD-500V; Aloka Co., Wallingford, CT). The differences between subsequent RTU readings on individual animals were used for calculation of accretion (the difference of readings between a period of time) of IMF and SCF during the 140 d period.

Steers were individually fed once daily at 0800. Feed refusals were collected and weighed at 7-d intervals. Feed samples were analyzed by a commercial laboratory (Dairy One Forage Lab, Ithaca, NY) for the following items: DM, CP (Kjeldahl; AOAC, 1990); ADF and NDF (Ankom 200 Fiber Analyzer; Ankom Co., Fairport, NY); and Ca, P, Mg, K, Na, Fe, Zn, Cu, Mn, and Mo (Iris ICP atomic emission spectrophotometer; Thermo Jarrell Ash Corp., Franklin, MA). Steers were harvested on d 140 (BW = 569.3 ± 36.2 kg) at a local commercial packing plant. One animal from AL-LS died during the experiment. Carcass characteristics were determined by the West Texas A&M University Cattlemen's Carcass Data Service.

Glucose tolerance test

On d 0 (beginning of the growing period), 28, and 56 (end of the growing period), a glucose tolerance test (**GTT**) was conducted with half (n = 24) of the steers in the experiment. In all GTT, steers were initially fitted with an indwelling jugular cannula. On each GTT, the 24 steers were randomly sorted in three groups during the day, with one group being placed in the working area at a time for sample collection. After cannula insertion, an initial blood sample was collected to provide insulin and glucose baseline values for each animal. Steers were then infused with 0.5 mL/kg BW of a 50% dextrose solution within 2 min. Blood samples were withdrawn via cannula at 0, 2.5, 5, 10, 15, 25, 35, 45, and 55 min post-infusion, and were collected in potassium oxalate/sodium fluoride tubes, placed on ice for 2 h, and then centrifuged at 1500 X g for 20 min. Serum was decanted and stored at -20°C until analyses for glucose and for insulin were conducted.

Insulin was measured by an independent lab using Diagnostic Products Corp. (Los Angeles, CA; D.M. Hallford, NMSU) and glucose was measured in our laboratory with a slightly modified version of a commercially kit (Stanbio Laboratories; San Antonio, TX).

Glucose disappearance rate was calculated by the regression of logarithmically transformed glucose concentrations over time. The slope parameter of this regression model represents the fractional disappearance rate of glucose [k, mol/ (L min)]. The glucose plasma half-life (T1/2, min) was calculated by dividing 0.693 into k. The incremental area under the curve (**AUC**) for insulin and the area over the curve (**AOC**) for glucose were measured as indicators of total insulin release and glucose uptake. Areas under the curve of glucose and insulin were determined using trapezoidal summation method modified from Kaneko (1989).

Statistical analyses

Data were analyzed as a completely randomized design using the Mixed Procedure of SAS (SAS Institute, Cary, NC). Each steer was considered an experimental unit. For the production part of the study, response variables were ADG, DM intake, G:F, accretion of IMF and SCF, and carcass characteristics with treatment as the fixed effect in the model and steer (treatment) as the error term. For each treatment, the least square means (LS Means) were computed and pairwise comparisons were conducted only if the F-test was significant at $P < 0.05$.

To further explore our data set, we used orthogonal contrasts to compare LF to all other treatments, although pairwise comparisons were also conducted. Linear and quadratic contrasts were applied across increasing starch content of the diets within AL treatments. Responses from the glucoses tolerance tests were modeled using PROC MIXED procedures of SAS for repeated measures. Treatment, GTT (d 0, 28, or 56) and their interaction were included as fixed effects, with measurements repeated on GTT. Steer was included as a subject effect to estimate within animal covariance parameters for repeated measures with an auto-regressive structure (lag = 1), and steer was also included as a random effect to determine among animal effects according to Littell et al. (1998). Results were considered significant if $P < 0.05$ and tendencies if $P > 0.05$ and $P < 0.10$.

Results and discussion

From d 0 to d 56, the amount of energy and protein fed in AL-LS and AL-IS deviated from formulated values. The reason for these differences in diet composition is likely because of the higher than expected CP concentration of the wheat middlings. Although the amount of wheat middlings in the LS experimental diet was reduced from d 27 to d 56 (50 to 25%, DM basis), the chemical composition still did not match formulated values, offering more than required CP.

The “growing phase” or “growing period” for beef cattle is the period between weaning and finishing in a feedlot (Sainz et al., 1995). Growing diets are used in the beef cattle industry to allow animal BW development before entering the finishing period, so that cattle are harvested at desirable carcass weights (Sainz et al., 1995). In the present study, steers were initially placed in growing diets for 56 d, and then all animals were placed on the same high concentrate diet until harvest. Treatments AL-LS and LF-HS were designed to provide the same amount of energy from different sources. The AL-HS diet was formulate to provide a target ADG in accordance to the standard of the industry growing systems, and the AL-IS diet, an intermediate diet, was formulated to provide data to evaluate and compare results of the other treatments.

Overall performance data from the growing period are presented in Table 3.2. Target gains were exceeded during the growing phase possibly because of the unexpected composition of the experimental diets. Steers fed AL-HS and AL-IS had higher ($P < 0.01$) ADG than AL-LS and LF-HS during the growing period. Possibly because of the problem on composition of experimental diets, steers on AL-LS and AL-IS gained more than previously programmed.

Increasing starch concentration increased ADG quadratically across AL treatments (*P* = 0.04; Table 3.2). By design, LF resulted in reduced DMI (*P* < 0.01) during the growing phase. Increasing starch content of the diets resulted in a quadratic DMI response (*P* < 0.01). Increasing starch resulted in a linear increase in G:F (*P* = 0.02). During d 57-140, LF steers had ADG similar to AL treatments (*P* = 0.9; Table 3.2). No compensatory gain was observed during the feedlot phase, which contradicts data showing effects of nutrient restriction on subsequent performance of beef cattle (Carstens et al., 1991). However, response variations are expected due to differences in the duration and severity of the restriction, and in the genetic potential of the cattle (Carstens et al., 1991; Sainz et al., 1995). During the finishing period, increased starch levels resulted in a quadratic ADG response in AL treatments (*P* = 0.06). Intake was lower for previously LF steers (*P* = 0.04) but was not different among AL treatments (*P* > 0.5). Steers previously fed LF treatment had increased G:F (*P* = 0.04), possibly due to the lower intake, likely because they were lighter. Increasing starch in growing treatments resulted in a linear decrease in G:F during finishing (*P* = 0.02). Across the 140-d trial, LF reduced ADG (*P* < 0.01), and reduced DMI (*P* < 0.01), but tended to improve G:F (*P* = 0.07), while minimum separations were observed among AL treatments. The RTU readings for IMF and SCF are presented on Figures 3.1 and 3.2. The scale used for IMF data analyze was the one provide by the RTU instrument, which is in accordance to the USDA grades for marbling score (300 = slight, 400 = small; 500 = modest). Readings for SCF were given in millimeters.

Table 3.2. Effect of growing systems with different amount and source of energy on performance of growing steers.

	Treatment					P-value [a]			
Item	AL-LS	AL-HS	LF-HS	AL-IS	*SEM*	*TRT*	*LF vs. AL*	*AL LINEAR*	*AL QUAD.*
Growing period									
d 0 wt, kg	296.7	296.3	296.3	296.1	5.05	0.99	-	-	-
d 27 wt, kg	343.0^{b}	349.8^{b}	320.9^{c}	356.0^{b}	7.80	< 0.001	-	-	-
d 56 wt, kg	391.8^{c}	417.2^{b}	371.8^{c}	421.0^{b}	10.6	< 0.001	-	-	-
ADG, kg	1.86^{c}	2.32^{b}	1.51^{c}	2.40^{b}	0.11	<0.01	<.0001	0.01	0.04
Intake, kg	10.0^{b}	10.2^{b}	6.5^{d}	11.6^{c}	0.28	<.0001	<.0001	0.70	<0.01
G:F	0.185^{c}	0.228^{b}	0.232^{b}	0.208^{b}	0.39	0.04	0.13	0.01	0.47
Finishing period									
ADG, kg	1.88^{b}	1.70^{b}	1.75^{c}	1.63^{b}	0.07	0.90	0.92	0.08	0.06
Intake, kg	11.2	11.6	10.3	11.2	0.40	0.17	0.04	0.54	0.56
G:F	0.177^{b}	0.156^{c}	0.179^{b}	0.155^{c}	0.18	0.01	0.04	0.02	0.17
d 140 wt, kg	572.6^{b}	583.6^{b}	540.1^{c}	581.5^{b}	13.6	< 0.01	-	-	-
Overall									
ADG, kg	1.87^{b}	1.95^{b}	1.65^{c}	1.94^{b}	0.14	<0.05	<.0001	0.38	0.71
Intake, kg	10.6^{b}	10.9^{b}	8.4^{c}	11.4^{b}	0.32	<.0001	<.0001	0.56	0.28
G:F	0.180	0.183	0.196	0.177	0.75	0.28	0.07	0.66	0.61

[a] Contrasts: LF vs. AL = LF diet vs. all *Ad libitum* treatments; AL LINEAR = test of linearity among Ad libitum treatments; AL QUAD. = test of quadratic effect on Ad libitum treatments.

[b, c, d] Within a row, means without a common superscript letter differ, $P < 0.05$.

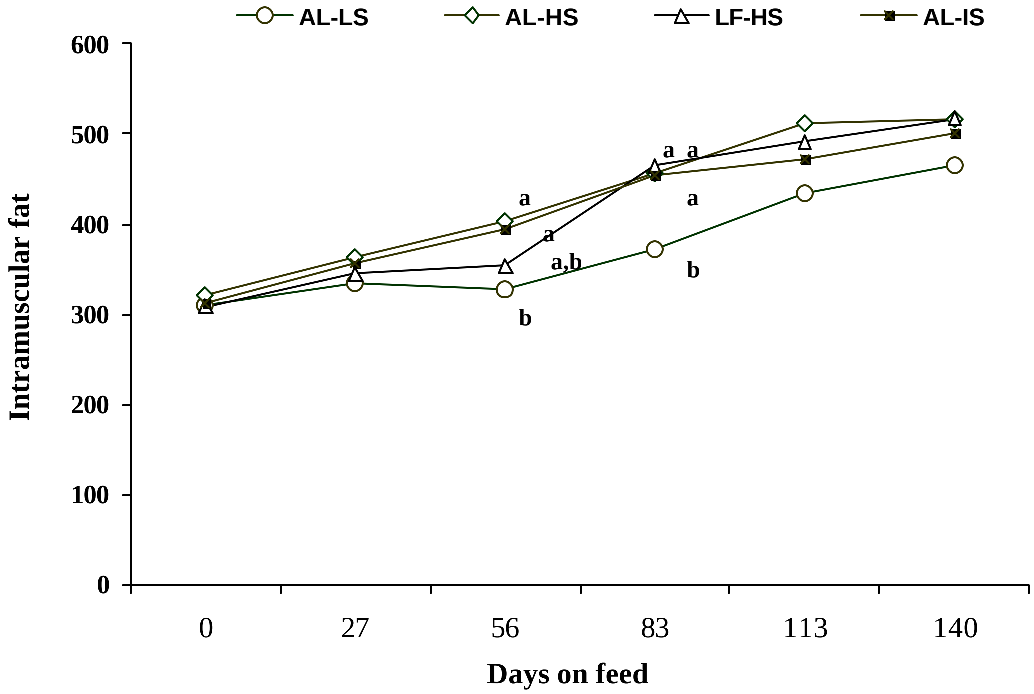

Figure 3.1. Intramuscular fat (IMF) RTU readings of steers fed in 4 different growing systems (approximately 28-d intervals). Steers fed the LF-HS and AL-LS diets had lower IMF readings on d56 (*P* = 0.03). The readings were lower for steers fed the low starch diet (AL-LS) on d83 (*P* = 0.04). Numerical but no statistical differences were observed on d140 (*P* > 0.05).

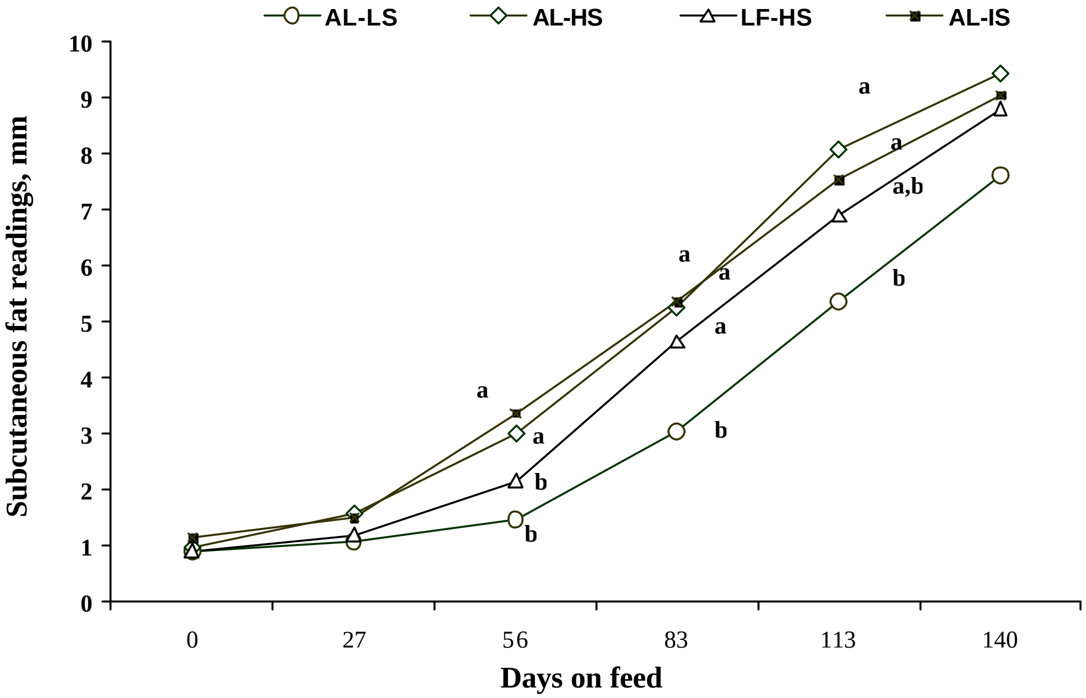

Figure 3.2 Subcutaneous fat (SCF) RTU readings of steers fed in 4 different growing systems (approximately 28-d intervals). Steers fed the LF-HS and AL-LS diets had lower SCF readings on d56 (*P* < 0.0001) and also on d113 (*P* = 0.03). Numerical but not statistical differences were observed on d140 (*P* > 0.05).

Readings of IMF were lower for LF-HS and AL-LS at the end of the growing phase (d 56; *P* = 0.03). The RTU readings were also lower for steers previously fed AL-LS diet on d83 (*P* = 0.04), and were numerically lower through d 140 (*P* > 0.05; Figure 3.1).

For steers fed the LF-HS and AL-LS diets, the SCF readings were lower on d 56 (*P* < 0.01). No differences (*P* > 0.05) for SCF were observed on d 140. Diets containing high amounts of starch resulted in higher IMF readings during the latter part of the growing period (*P* < 0.01; Table 3.3). On d83, steers previously fed AL-LS sill had less SCF, while the fed LF-HS were similar to AL-HS and AL-IS. On d113, SCF was lowest in AL-LS, intermediate in LF-HS, and highest in AL-IS and AL-HS Animals fed the AL-HS or AL-IS had accretion of IMF almost 5 times higher than animals fed low starch diets. Lower energy levels resulted on lower accretion of SCF (*P* < 0.01).

Data presented in Table 3.4 show the accretion of IMF and SCF during the finishing period. The accretion of IMF (*P* = 0.13) and SCF (*P* = 0.81) during finishing were similar among treatments. This similarity diluted differences in overall (d 0 to 140) rates of IMF (*P* = 0.28) and SCF (*P* = 0.52) accretion, such that final RTU readings of IMF and SCF were similar (*P* > 0.36) among treatments. However, carcass marbling scores were higher for HS diets (*P* = 0.02; Table 3.5).

Fat thickness tended to be higher for AL-HS, LF-HS, and AL-IS groups (*P* = 0.08). Steers that were limit fed during the growing period were not able to reach the same BW of animals from other treatments, and were approximately 6% lighter (*P* =

0.01) at harvest. Likewise, LF-HS fed steers had lighter (P = 0.01) HCW. Steers fed the AL-HS diet had the numerically higher yield grade (P = 0.03). No differences were observed in dressing percent (P = 0.64), longissimus area (P = 0.25); and percentage of kidney, pelvic and heart fat (P = 0.42).

Higher starch diets increased growing phase accretion of IMF and SCF regardless of level of energy consumption. Steers that consumed more energy throughout production achieved greater carcass fatness, although these responses were difficult to evaluate using interim ultrasound measurements. No differences were observed on d 140, but differences on IMF and SCF were observed on the carcass data when compared to the last RTU reading. Ultrasound technology is a useful tool to estimate carcass characteristics on the live animal. However, the visual image interpretation of the technician is subjective, which may influence the values (Brethour, 1994).

During the growing phase, animals fed AL-HS and AL-IS consumed higher amounts of starch when compared to AL-LS and LF-HS. Starch-rich diets produce a greater proportion of propionate, providing greater levels of glucose when compared to diets with low levels of starch (Ørskov et al., 1991; Annison and Bryden, 1999). Increased supply of propionate reduces the body's requirement for alternative glucogenic precursors, and might stimulate the pancreatic secretion of insulin (Bines and Hart, 1984; Sano et al., 1993). Trenkle (1970) observed a 50-60% increase in insulin concentration concomitant with the propionate increase from grain versus a hay diet.

Table 3.3. Effect of growing systems with different amount and source of energy on fat deposition of growing steers.

Item	Treatment					
	AL-LS	AL-HS	LF-HS	AL-IS	SEM	*P*-value[a]
Growing period (d0 - d27)						
Intramuscular fat readings (d27)	3.35	3.64	3.45	3.56	0.16	0.62
Subcutaneous fat readings (d27)	1.07	1.59	1.20	1.51	0.18	0.17
Change in IMF readings (dif. d0/d27)	0.26	0.43	0.36	0.44	0.10	0.62
Change in SCF readings (dif. d0/d27)	0.17	0.64	0.29	0.37	0.23	0.51
Growing period (d27 - d56)						
Intramuscular fat readings (d56)	3.27^{c}	4.04^{b}	$3.54^{c,d}$	$3.95^{c,d}$	0.20	0.03
Subcutaneous fat readings (d56)	1.48^{c}	3.03^{b}	2.17^{c}	3.39^{b}	0.28	< 0.01
Change in IMF readings (dif. d0/d56)	0.18^{c}	0.83^{b}	$0.46^{b,c}$	0.82^{b}	0.15	0.01
Change in IMF readings (dif. d27/d56)	-0.08	0.40	0.10	0.39	0.13	0.03
Change in SCF readings (dif. d0/d56)	0.57^{c}	2.08^{b}	1.26^{c}	2.25^{b}	0.32	< 0.01
Change in SCF readings (dif. d27/d56)	0.41	1.44	0.97	1.88	0.27	< 0.01

[a] Probability value for the *F*-test for an overall treatment effect.

[b, c, d] Within a row, means without a common superscript letter differ, $P < 0.05$.

Table 3.4. Effect of growing systems with different amount and source of energy on fat deposition of feedlot steers.

Item	Treatment					
	AL-LS	AL-HS	LF-HS	AL-IS	SEM	*P*-value[a]
Finishing period (d57 - d83)[b]						
Intramuscular fat readings (d83)	3.72^c	4.56^b	4.65^b	4.55^b	0.23	0.04
Subcutaneous fat readings (d83)	3.03^c	5.25^b	4.66^b	5.37^b	0.46	< 0.01
Change in IMF readings (d0/d83)	0.62^c	1.34^b	1.56^b	1.42^b	0.22	0.02
Change in SCF readings (d0/d83)	2.12^c	4.30^b	3.75^b	4.23^b	0.49	0.01
Finishing period (d84 - d113)						
Intramuscular fat readings (d113)	4.33	5.13	4.91	4.72	0.23	0.11
Subcutaneous fat readings (d113)	5.37^c	8.09^b	$6.91^{b,c}$	7.54^b	0.64	0.03
Change in IMF readings (d0/d113)	1.24	1.91	1.82	1.59	0.20	0.14
Change in SCF readings (d0/d113)	4.47^c	7.14^b	$6.00^{b,c}$	6.40^b	0.65	0.05
Finishing period (d114 - 140d)						
Intramuscular fat readings (d140)	4.66	5.16	5.17	5.00	0.22	0.36
Subcutaneous fat readings (d140)	7.63	9.45	8.82	9.06	0.82	0.46
Entire finishing period						
Change in IMF readings (dif. d56/140)	1.39	1.11	1.63	1.05	0.19	0.13
Change in SCF readings (dif. d56/140)	6.15	6.43	6.65	5.68	0.75	0.81
Entire experiment						
Change in IMF readings (d0/d140)	1.56	1.95	2.08	1.87	0.19	0.28
Change in SCF readings (d0/d140)	6.72	8.50	7.91	7.92	0.83	0.52

[a] Probability value for the *F*-test for an overall treatment effect.

[b] d57 is d0 of the feedlot phase

Table 3.5. Effects of growing systems with different amount and source of energy on carcass characteristics of feedlot steers.

Item	Treatment					
	AL-LS	AL-HS	LF-HS	AL-IS	SEM	*P*-value[a]
Live weight, kg	550[b]	560[b]	518[c]	558[b]	9.05	0.01
Hot carcass weight, kg	351[b]	357[b]	326[c]	353[b]	6.33	0.01
Dressing %	63.74	63.77	62.84	63.27	0.60	0.64
Marbling score [d]	452.7[c]	538.3[b]	490.8[b,c]	524.2[b]	19.60	0.02
Fat thickness, cm	0.90[c]	1.26[b]	0.96[b,c]	1.06[b]	0.10	0.08
Longissimus area, cm^2	91.03	88.39	87.53	94.41	2.58	0.25
Kidney, pelvic, heart fat, %	1.59	1.75	1.63	1.58	0.08	0.42
Yield Grade	2.14[c]	2.71[b]	2.16[c]	2.14[c]	0.15	0.03

[a] Probability value for the *F*-test for an overall treatment effect.

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

[d] Marbling score: 300 = slight, 400 = small; 500 = modest.

Evans et al. (1975) and Jenny and Polan (1975) also observed elevated plasma glucose and insulin in cows fed a high-concentrate diet compared to cows fed a low-concentrate diet.

Insulin might be a key component in triggering IMF development in growing cattle (Schoonmaker et al., 2003). To determine whether glucose and insulin dynamics were altered by the different growing diets in the present experiment, three GTT were conducted to assess the insulin sensitivity of the steers in this study. Under a propionic acid type of rumen fermentation, insulin is most likely responsible for the efficient peripheral utilization of glucose and other nutrients in ruminants (Abdul-Razzaq et al., 1989; Lindmark, 2004). Smith and Crouse (1984) showed that IMF adipocytes prefer glucose/lactate carbons while SCF adipose tissue uses mainly acetate as a source of acetyl units for lipogenesis (Smith & Crouse 1984). Likewise, Rhoades et al. (2005) observed that high starch diets enhanced glucose availability and uptake, and IMF fatty acid synthesis while high forage fed animals have reduced glucose availability without changes on acetate incorporation in fatty acids. Therefore, we expected that growing animals fed AL-HS and AL-IS would be able to use glucose as a major source of acetyl units for lipogenesis.

Glucose disposal and tissue responsiveness to insulin were calculated with plasma insulin and glucose concentration. Insulin sensitivity describes the ability of the peripheral tissues to respond to exogenous insulin (Sternbauer, 2005). The GTT is a common test to assess insulin sensitivity also used in humans (Sternbauer, 2005). Insulin resistance is related to a decreased response to serum insulin by insulin-sensitive cells and it occurs primarily in muscle, adipose and liver tissues (Treiber et al., 2005). This resistance exists whenever normal concentration of hormone produce a less than normal response and can be a result of inefficient insulin signaling at the cell surface or consequence of a disruption of insulin signaling within the cell (Kronfeld et al., 2005).

A ratio of AOC (glucose) by AUC (insulin; **AOC_g/AUC_i**) was calculated as a way to verify units of glucose utilized per unit of insulin secreted. In the present study, no differences were observed in the AOC_g/AUC_i ratio of animals in the first GTT (*P* = 0.85; Table 3.6), as expected since animals were under the same nutritional conditions before the start of the trial. Data from the second and third GTT also did not show treatment differences in glucose and insulin kinetics, as it would be expected.

On the second GTT (d 27), no differences were observed in baseline glucose (*P* = 0.17), peak glucose (*P* = 0.85), glucose peak time (*P* = 0.89), glucose half-life (*P* = 0.29), glucose AOC (*P* = 0.64), baseline insulin (*P* = 0.92), peak insulin (*P* = 0.86), insulin peak time (*P* = 0.86), insulin half-life (*P* = 0.36), and insulin AUC (*P* = 0.77). The lack of differences in glucose and insulin kinetics suggests that there was no effect of the diets on insulin sensitivity; however, some variation was observed in the data set among individual animals, which could not be accounted for. No differences were observed in the AOC_g/AUC_i ratio on GTT 2 (*P* = 0.37). Likewise, no differences were observed on glucose and insulin kinetics on the third GTT (d 56). Baseline glucose (*P* = 0.30), peak glucose (*P* = 0.60), glucose peak time (*P* = 0.90), glucose half-life (*P* = 0.34), glucose AOC (*P* = 0.55), baseline insulin (*P* = 0.32), peak insulin (*P* = 0.62), insulin peak time (*P* = 0.26), insulin half-life (*P* = 0.46), insulin AUC (*P* = 0.83), and AOC_g/AUC_i ratio (*P* = 0.47) were not statistically different.

When comparing all treatments on repeated measures (GTT as the time effect), no differences were observed on glucose uptake (AOC_g/AUC_i) among GTT (*P* = 0.75). Likewise, no interactions between treatments and GTT were observed (*P* = 0.36; data not shown).

On d 27, numeric results suggest that there was a reduction in insulin sensitivity for animals fed AL-HS. This is indicated by the numerically greater glucose T1/2 and the lowest AOC_g/AUC_i ratio.

By d 56 also glucose T1/2 was numerically lower for AL-LS, AL-HS and LF-HS when compared to GTT2; however, the AOC_g/AUC_i ratio declined for all treatments except AL_LS. These data are consistent with the lower accretion of fat in AL-LS, suggesting that insulin sensitivity may have been altered by adiposity as much as by diet. Similarly, McCann and Reimers (1989) observed reduced insulin sensitivity in heifers with increased body fat.

Although these results were not statistically different, the dynamics of glucose and insulin changes after the feeding period on different diets agree with data from Schoonmaker et al. (2003). In similar diets, Schoonmaker et al. (2003) also observed increased levels of glucose and increased levels of insulin for a diet similar to LF-HS.

It would be expected that the adaptation to a high-glycemic diet of steers on HS treatments would result on decreased insulin resistance. Insulin resistance is a normal response to a decrease on energy availability or increased energy demand (Brand-Miller

Table 3.6. Effects of different growing systems on glucose and insulin kinetics of beef cattle.

Item	Treatment					
	AL-LS	AL-HS	LF-HS	AL-IS	SEM	*P*-value[a]
Glucose tolerance test (d0)						
Baseline glucose, mg/100 mL	68.9	79.5	91.1	89.0	5.8	0.60
Peak glucose, mg/100 mL	197.0	210.3	212.2	203.7	6.21	0.85
Glucose peak time, min	1.38	0.83	1.75	1.08	0.46	0.89
Glucose half-life, min	64.3	71.9	144.77	111.89	16.08	0.29
Glucose area, mg/100 mL	2,402	3,801	3,480	2,909	385	0.64
Baseline insulin, ng/mL	0.70	0.70	1.18	0.69	0.30	0.92
Peak insulin, ng/mL	7.78	6.10	4.04	6.34	1.40	0.86
Insulin peak time, min	6.12	10.00	8.75	4.97	2.76	0.86
Insulin half-life, min	72.63	44.94	43.40	37.41	6.5	0.36
Insulin area, (ng/mL) min	187.3	182.8	101.6	1512.0	31.7	0.77
Ratio AOC_g/AUC_i	13.9	23.3	23.7	18.2	4.15	0.85
Glucose tolerance test (d27)						
Baseline glucose, mg/100 mL	92.1	116.6	87.1	109.6	5.2	0.17
Peak glucose, mg/100 mL	220.3	182.7	209.6	194.1	5.2	0.10
Glucose peak time, min	2.45	0.02	1.00	1.67	0.40	0.20
Glucose half-life, min	108.1	136.3	104.2	96.3	13.77	0.74
Glucose area, mg/100 mL	3,328	1,953	3,631	2,911	330	0.32
Baseline insulin, ng/mL	0.92	1.68	2.17	0.88	0.30	0.19
Peak insulin, ng/mL	5.31	8.38	13.24	6.45	1.25	0.15
Insulin peak time, min	19.18	14.94	6.00	5.83	2.27	0.13
Insulin half-life, min	36.3	38.5	20.7	32.8	5.6	0.68
Insulin area, (ng/mL) min	133.0	133.1	235.5	114.3	29.5	0.45
Ratio AOC_g/AUC_i	34.4	19.1	32.6	34.4	3.4	0.37
Glucose tolerance test (d56)						
Baseline glucose, mg/100 mL	80.6	85.1	105.3	78.1	5.4	0.30
Peak glucose, mg/100 mL	197.3	176.1	190.4	185.3	5.2	0.60
Glucose peak time, min	0.55	0.63	1.00	1.25	0.40	0.90
Glucose half-life, min	61.5	57.5	60.8	115.4	13.72	0.34
Glucose area, mg/100 mL	4,059	2,674	3,417	3,072	333	0.55
Baseline insulin, ng/mL	1.79	1.54	2.65	1.54	0.24	0.32
Peak insulin, ng/mL	7.76	8.14	11.61	7.55	1.24	0.62
Insulin peak time, min	15.21	1.64	6.50	9.17	2.28	0.26
Insulin half-life, min	48.21	30.46	27.07	45.53	5.58	0.46
Insulin area, (ng/mL) min	155.7	191.0	229.4	169.4	29.1	0.83
Ratio AOC_g/AUC_i	31.5	14.8	20.0	22.7	3.4	0.47

[a] Probability value for the *F*-test for an overall treatment effect.

and Colagiuri, 1999). Young animals require energy for growth and steers fed AL-LS were possibly using acetate as source of energy. Changes on IMF and ADG were higher for AL-HS during the growing period (*P* = 0.03 and *P* = 0.11, respectively). Even though AL-HS AOC_g/AUC_i on d 56 (14.8) was not significantly different from the other treatments, that may be because of the difference in BW. The IMF readings suggested that there was a change in body composition; however glucose and insulin differences might have been diluted by differences in BW among treatments.

Several factors might have been responsible for the lack of response in terms of insulin and glucose dynamics after the 56-d period. Propionate is quantitatively the most important supply of key carbon sources for gluconeogenesis (Huntington, 1997), but the amount of glucose supplied by amino acids (**AA**) may vary with their supply to the liver and metabolic demand (Reynolds et al., 1994). These can also increase glucose concentrations which might stimulate the pancreatic secretion of insulin (Sano et al., 1993). Erickson et al. (1985) observed that wheat middlings are a good source of energy and amino acids. According to Sunvold et al. (1991), wheat middlings contain moderate amounts of CP (17 to 21%CP) and moderately high amounts of rapidly degradable fiber (40% NDF, 14.4% digested/h).

Not enough data are available concerning the ways in which wheat middlings can affect digestion, digesta flow, or fermentation characteristics of cattle consuming forage. In the present study, the wheat middlings had high percentage of CP. Lopez et al. (2001) fed different levels of protein (12, 14, 16 or 18% CP) to growing heifers and found that insulin concentrations were greatest for heifers fed 16% protein and while glucose concentrations were greatest in heifers consuming 18% protein diets. Therefore, high CP levels, like the observed in our LS diet, can lead to an increase in blood insulin and glucose concentration.

High fiber diets may shift the acetate:propionate ratio, reducing the substrates for gluconeogenesis (Waterman et al., 2006). Reduced supply of propionate might increase the requirement of other substrates for gluconeogenesis to meet tissue glucose demands, and increase the insulin resistance as a mechanism to conserve glucose for non-insulin dependent functions (Waterman et al., 2006). Under the experimental conditions of the present study, animals from AL-LS might have had enough substrates for gluconeogenesis from the CP fed, which might have kept insulin sensitivity stable.

Therefore the development of insulin resistance due to ketone body accumulation that occurs in animals fed high fiber diets might not have occurred. Possibly, with no increase in ketone bodies, there was not an inhibition on glucose utilization through the selective expression of glucose transporters (Tardif et al., 2001) or altered insulin signaling (Dresner et al., 1999).

It might be also possible that 56 d might have not been the adequate number of days on the growing diets to verify the changes in glucose and insulin dynamics. Schoonmaker et al. (2003) did find elevated concentrations of insulin approximately 50% higher for a high concentrate diet when compared to diets similar to AL-LS and AL-IS at 181 d of age after being fed for 62 d. These responses may vary with age, body composition, nutritional status, and productive state of the animal (Huntington and Richards, 2005).

With the factors discussed above, it cannot be determined if increased accretion of IMF for steers consuming a high-concentrate diet was a result of increased liver conversion of propionate, and consequent increase in metabolizable energy available. Likewise it cannot be determined if the lack of differences is related to the use of glucogenic amino acids (from the excessive amounts of CP fed) as an alternative to the low availability of starch for the AL-LS treatment. Marbling scores were 452.73 and 490.83 for AL-LS and LF-HS respectively and 524.17 and 538.33 for AL-IS and AL-HS, respectively. These numbers show a significant (*P* = 0.02) increase in this economic trait related to carcass quality, and this might result in economic advantage to the producer. However, it is not possible to conclude if that response is totally related to an increased insulin sensitivity based on the GTT data. The similarity in sensitivity to insulin for all treatments observed in the present study imply that high CP diets (>20%CP) might spare other glucose precursors, such as glycerol and lactate, when low starch diets are fed.

Implications

Energy source may influence energy partitioning during the growing period, but these effects may have been overcome by differences in energy and protein intake.

Data from this experiment suggest that it is possible to manipulate marbling accretion; however, these mechanisms are still not clear and were not elucidated by this experiment.

CHAPTER IV

EVALUATION OF TWO MATHEMATICAL MODELS TO PREDICT INDIVIDUAL FEED REQUIREMENTS OF FEEDLOT CATTLE

Overview

A data set of group fed growing and finishing steers with individual bunk access was used to evaluate predictions of DM requirements by the Cornell Value Discovery System (CVDS) and NRC (2000) models. Forty eight crossbred steers (BW = 296 ± 16.7 kg) were assigned to one of six pens and fed one of four growing diets with different energy concentration for 56 d: AL-LS, a low energy diet fed *ad libitum* for a rate of gain of approximately 1 kg/d; AL-HS, a high starch diet fed *ad libitum* for a rate of gain of approximately 1.6 kg/d; LF-HS, a limit fed high starch diet with energy for a rate of gain of approximately 1 kg/d; and AL-IS, a diet fed *ad libitum* with approximately the midpoint daily energy intake between AL-LS and AL-HS. On d 57, all steers (BW = 400.6 ± 31.9 kg) were placed on a high concentrate diet (AL-HS) for 84 d, until d 140. The CVDS model was able to account for 61% of the variation in the observed DMI (oDMI) of steers during the growing period with no mean bias (MB; $P > 0.1$), and for 71% of the variation in oDMI during finishing, with an average overprediction of 4.09 % (MB of -0.48 kg/d). The NRC model was able to explain 59% of the variation in oDMI adjusted for known performance during the growing period with no bias ($P > 0.1$) and 57% of the variation in oDMI during the finishing period, with an average underprediction of 4.40 % (MB of 0.47 kg/d). The R^2 for the regression equation comparing both models was 0.88. Both models were able to explain most of the variation in individual oDMI during the finishing rather than during the growing period. Overall, results suggested that the CVDS model was slightly better on predicting DMI for individual animals, although differences were marginal. In addition, data showed that predictions of DMI of finishing cattle were affected by cattle from different backgrounds. Although data suggested that models can be successfully used for individual feed allocation of group fed cattle, these predictions may differ for cattle fed different growing diets and on different levels of nutrition. Background information might improve the accuracy of prediction of feed required by individuals.

Introduction

Sorting systems have been developed in order to predict carcass composition of cattle to allow marketing of feedlot cattle at an optimum endpoint (Perry and Fox, 1997). Cattle can be sorted in homogeneous groups for maximization of productivity, minimization of non-conformity discounts, and increased economic returns (Perry and Fox, 1997; Guiroy et al, 2002; Tedeschi et al., 2004). In the current market system, the reduction of overweight carcasses, over fat carcasses, and low grading carcasses can improve the value of a group of cattle dramatically (Bruns and Pritchard, 2005). Sorting systems might also allow for more careful and efficient management of cattle because of the improvement in uniformity of BW, biological type, and therefore presumably DMI (Galyean and Abney, 2006).

In custom feedyards, full utilization of these sorting systems would require commingling of cattle owned by multiple costumers, disrupting the billing process. Therefore, models that predict individual feed requirements could be used to assign feed costs to animals of different ownership (Guiroy et al., 2001). About three decades ago, Fox and Black (1977a-c) presented a model for prediction of performance and body composition of growing cattle. This model was modified and improved to develop the Cornell Value Discovery System (**CVDS**; Perry and Fox, 1997; Guiroy et al., 2001; Tedeschi et al., 2004), which has been shown to accurately allocate feed intake among individual animals fed in pens, based on observed growth, BW, and carcass measurements that can be readily obtained (Tedeschi et al., 2006).

The National Research Council (**NRC**) Nutritional Requirements of Beef Cattle (1996; 2000) includes a computer model that allows for description of cattle type, ration components, and environment to predict animal performance (Whetsell et al., 2006). The NRC (2000) is often used in the United States to predict beef cattle (Fox et al., 1992). The NRC (2000) beef model can also be used for prediction of individual intake of cattle when performance is known, which requires manual adjustments on DMI until predicted ADG matches predicted ADG. The objectives of this study are to evaluate the precision and accuracy of CVDS and NRC models in predicting individual feed requirements of group fed growing and finishing cattle and individual feed requirements of feedlot cattle with different levels of nutrition during the growing phase.

Materials and methods

Experimental data

A data set including performance and DMI data from steers (N = 48) fed in individual feeders (American Calan®, Northwood, NH) was obtained from an experiment conducted at the Texas A&M University Agricultural Experiment Station

(Bushland, TX). Steers (BW = 296.0 ± 16.7 kg) were implanted with Synovex-S (20 mg of estradiol benzoate and 200 mg of progesterone; Fort Dodge Animal Health, Overland Park, KS) and individually fed four different growing diets for 56 d (**AL-LS,** a low energy diet fed *ad libitum* for a rate of gain of approximately 1 kg/d; **AL-HS,** a high starch diet fed *ad libitum* for a rate of gain of approximately 1.6 kg/d; **LF-HS**, a limit fed high starch diet with energy for a rate of gain of approximately 1 kg/d; and **AL-IS,** a diet fed *ad libitum* with approximately the midpoint daily energy intake between AL-LS and AL-HS). On d 57, all steers (BW = 400.6 ± 31.9 kg) were placed on AL-HS (finishing diet) for 84 d, until harvest (d140).

Growing (LF-HS, AL-LS, AL-IS, and AL-HS) and finishing (AL-HS) diets are presented in Table 4.1. The ME density of the diets was calculated using the Cornell Net Carbohydrate and Protein System (**CNCPS**; Fox et al., 2004; 2.64, 2.68, and 3.02 Mcal/kg of DM for AL-LS, AL-IS, and AL-HS, respectively). The high starch diet contained approximately 80% corn and 7% roughage (DM basis). This diet was fed in different amounts during growing for treatments AL-HS and LF-HS. The AL-LS dietary treatment was composed of a high roughage containing approximately 38% wheat middlings and 49% cottonseed hulls. The AL-IS dietary treatment was a diet containing approximately half of the amount of corn and forage present on HG and HF, respectively. The AL-LS and AL-IS diets had high CP because of an unexpected excess in CP concentration of the wheat middlings. Formulas also included molasses, tallow, and a supplement containing minerals (calcium, phosphorus, sodium, magnesium, potassium, sulfur, manganese zinc, cupper, selenium, cobalt, iodine, and iron),

Table 4.1. Average composition and analyzed nutrient content of diets fed during growing (56d) and finishing period (84d) of beef steers[a].

Item	Dietary treatments			
	AL-LS	AL-HS [b]	LF-HS [b]	AL-IS
Ingredient [c]				
Corn Grain, Steam Flaked, %	0.0	79.2	79.2	38.0
Cottonseed, Hulls, %	48.5	7.0	7.0	35.0
Fat/Steep/Molasses blend	3.0	3.0	3.0	3.0
Mineral and vitamins premix [d], %	11.0	10.0	10.0	10.0
Wheat, Middlings, %	37.5	0.0	0.0	14.0
Chemical composition				
CP,%	24.7	12.7	12.7	15.2
ME, Mcal/kg	2.64	3.02	3.02	2.68
Ca, %	1.7	0.7	0.7	1.0
P, %	0.9	0.3	0.3	0.4

[a] Diets were based on NRC (2000) requirements.

[b] This diet was fed *ad libitum* to all treatments during finishing (84d).

[c] DM basis.

[d] Composed of 5.44% Ca, 0.20% P, 4.43% NaCl, 0.51% Mg, 3.94% K, 0.29% S, 1.83% Na, 827 ppm Mn, 1286 ppm Zn, 633 ppm Fe, 135 ppm Cu, 0.17 ppm Se, 2.68 ppm Co, 13.64 ppm I, 18,651 IU of Vit. A/kg and 110 IU of Vit. E/kg. All diets contained monensin (30 mg/kg) and tylosin (11 mg/kg).

Vitamin A, Vitamin E, and additives.

On d140, all animals had approximately the same fat thickness (10 mm) as read by real time ultrasound (**RTU**), obtained using a real-time linear array ultrasound instrument (SSD-500V; Aloka Co., Wallingford, CT). Steers were harvested (BW = 569.3 ± 36.2 kg) at a commercial packing plant. Carcass characteristics were determined by the West Texas A&M University (Canyon, TX) Cattlemen's Carcass Data Service (**CCDS**). Individual carcass measurements were taken for hot carcass weight (**HCW**) on the day of harvest. Fat thickness; longissimus area (**LMA**); kidney, pelvic, and heart fat (**KPH**); and marbling scores were collected by CCDS after a 24-h chill at -4°C. The CCDS group determined QG and calculated yield grade (**YG**).

The Cornell Value Discovery System

The CVDS model can predict either ADG when DMI is known or DM required when ADG is known (Tedeschi et al., 2004). As described by Tedeschi et al. (2004), in both scenarios the model has to be supplied with information regarding diet ME concentration, days on feed, animal characteristics (age, gender, breed, initial BW, body condition score), and environmental information (temperature, humidity, hours of sunlight, wind speed, mud, hair depth, and hair coat). Adjusted final BW (**AFBW**) at 28% empty body fat (**EBF**) can be computed using the inputted information of HCW, fat thickness, LMA, and marbling scores from each animal.

The CVDS model computes the individual feed DM required (**DMR**) as the sum of the feed required for maintenance (**FFM**) and feed required for growth (**FFG**; Tedeschi et al., 2004). Feed for maintenance is calculated based on NE required for maintenance and NEm content of the diet. Similarly, FFG is a function of the energy retained in the ADG and the NEg concentration of the diet (Fox et al., 2002). The CVDS prediction of DM required starts with the adjustments for the EQSBW and EBF relationship in the equation adopted by the NRC (2000), which allows a continuous adjustment for DMI with EQSBW greater than 350 kg (Tedeschi et al., 2004). The intake is then predicted after adjustments for the effects of temperature, mud depth, and ionophores.

The National Research Council model

In the NRC, level 1 tabular values of TDN and net energy were used for prediction of DM required. The mean body weight (**MBW**) was calculated based on initial and final shrunk BW (**SBW; 4%**). The actual DMI (an input of the model) was changed iteratively until model predicted ADG matched observed ADG. The DMI necessary for that performance was recorded as model-predicted DMI and used in the evaluation process. The NRC (2000) equations use an equivalent BW to adjust cattle so they are equivalent in body composition to the NRC (1984) medium-framed steer equation - based on the Garrett (1980) database - for differences in mature BW among biological types, gender differences, gain composition, and implants. The equivalent shrunk BW (**EQSBW**) is calculated by multiplying the current SBW by the ratio of the standard reference animal BW (**SRW**) divided by the final SBW at 27.8% EBF of the current animal (Eq. 4.1), which is the AFBW. Despite the innovative approach of the NRC (1996; 2000) equations when compared to the NRC (1984), they still have not been evaluated extensively (Galyean and Abney, 2006).

$$(4.1) \quad EQSBW = SBW \times (SRW/AFBW)$$

Evaluation of the CVDS model

In the present study, the CVDS model was evaluated using two different options, each one with different adjustments for gain composition. The first option used equations based on the MBW and the second option used equations based on the iterative, dynamic growth model (Tedeschi et al., 2004). For both options we computed the unadjusted or adjusted ADG to the composition of the gain. The ADG adjusted for the composition of the gain requires the calculation of the partial efficiency of ME to NE for growth, which was computed from the proportion of retained energy as protein (REp). The REp calculation was done using two methods; method 1 used a decay equation based on the retained energy and gain (Tedeschi et al, 2004) while method 2 used the NRC (2000) equations to compute protein and fat in the gain.

Group intake prediction

Data set of the present study was also used for evaluation of the CVDS and NRC model for group prediction of intake, for the same cattle during growing and finishing. Observed DM required values were calculated using two different approaches: 1) Mean value of the individual predictions for each animal (using the same approach described above) by treatment, and 2) value predicted for MBW, diet composition, and average carcass information by treatment. Each treatment was considered a group for data analyses.

Statistical analysis

Evaluations of the precision and accuracy of CVDS and NRC models on predicting feed intake required were conducted by comparison of both model predictions of DM required to the oDMI. Data were analyzed using the Model Evaluation System v. 2.0.7 (Tedeschi, 2006). Observations with high-studentized residual (>|2.5|) were considered outliers (two and three for the growing and finishing periods, respectively) and removed from the data set when information about the steer obtained during the period of the experiment could explain anomalies. The MES program was also used for calculation of linear regressions and mean bias (**MB**). The MES program computes MB by dividing the difference of the mean Y-variate (observed) and the mean X-variate (predicted) by the mean of the X-variate. The P-value of mean bias is computed using two-sample t-test analysis (Tedeschi, 2006). Indexes used in our evaluation were also calculated using MES included coefficient of determination (r^2); coefficient of model determination (**CD**), which is the ratio of the total variance of observed data to the squared of the difference between model-predicted and mean of the observed data; bias correction (**Cb**), which indicates how far the regression line deviates from the line that passes through the origin and have slope of unity (45^o); and the concordance correlation coefficient (**CCC**), which account for accuracy and precision simultaneously (Tedeschi, 2006).

Results and discussion

Models evaluation

The relationship between oDMI and PrDMI predicted by the various options of the CVDS and by the NRC (2000) is shown in Table 4.2 and Figure 4.1.

The CVDS model using mean BW without adjustment for composition of gain had the best fit for the growing data set whereas the dynamic model without adjustment for composition of gain had the best fit for the finishing data set. For all other CVDS options of calculations and adjustments, we observed a range in r^2 from 0.59 to 0.74; CD varied from 0.18 to 1.04; Cb (accuracy) varied from 0.2 to 0.99, and CCC ranged from 0.17 to 0.78. The r^2 for the NRC level 1 regression of oDMI and predicted intake was 0.59 and 0.57 for growing and finishing, respectively. Tedeschi et al. (2004) observed a range in r^2 from 0.71 to 0.74 with MB varying from -5.7 to 4.2% when predicting DMI for a given animal performance with the CVDS model. Contrary to the present study, however, Tedeschi et al. (2004) observed a best fit for the method using the decay equation. Tedeschi et al. (2004) observed that when ADG was known, the growth model using the decay equation predicted the DM required for that ADG with only 2% of bias and r^2 of 74%. Guiroy et al. (2001) and Williams et al. (2006) also evaluated DM requirements predicted by CVDS against oDMI in finishing cattle. Guiroy et al. (2001) model application of the CVDS accounted for 74% of the variation in actual DM consumed, with low bias (0.34%) and a coefficient of variation of 8.18%. However, Williams et al. (2006) model application of the CVDS accounted for 44% of the variation in oDMI.

Table 4.2. Effect of the use of equations with or without adjustment for composition of gain on prediction of DM required of growing and finishing steers.

Item[b]	NRC	CVDS (mean BW)[a]			CVDS (dynamic model)[a]		
		No adjustment	Adjustment for gain composition		No adjustment	Adjustment for gain composition	
			1	2		1	2
MB, %							
Growing	4.24	1.92	8.40	36.60	5.80	12.40	16.08
Finishing	4.40	-3.76	8.80	29.80	-0.51	12.50	16.09
CD							
Growing	0.76	0.74	1.00	0.46	0.73	0.88	0.87
Finishing	1.05	0.88	0.78	0.18	1.04	0.54	0.39
CCC							
Growing	0.75	0.77	0.72	0.34	0.75	0.68	0.62
Finishing	0.68	0.78	0.58	0.17	0.84	0.50	0.35
R^2							
Growing	0.59	0.61	0.60	0.60	0.60	0.59	0.59
Finishing	0.57	0.71	0.68	0.74	0.69	0.68	0.59
Cb							
Growing	0.98	0.99	0.94	0.44	0.97	0.88	0.81
Finishing	0.90	0.93	0.70	0.20	1.00	0.56	0.45

[a] 1 = Decay and 2 = NRC equations (Tedeschi et al., 2004).

[b] MB = mean bias; CD = coefficient of model determination; Cb = bias correction; CCC = concordance correlation coefficient.

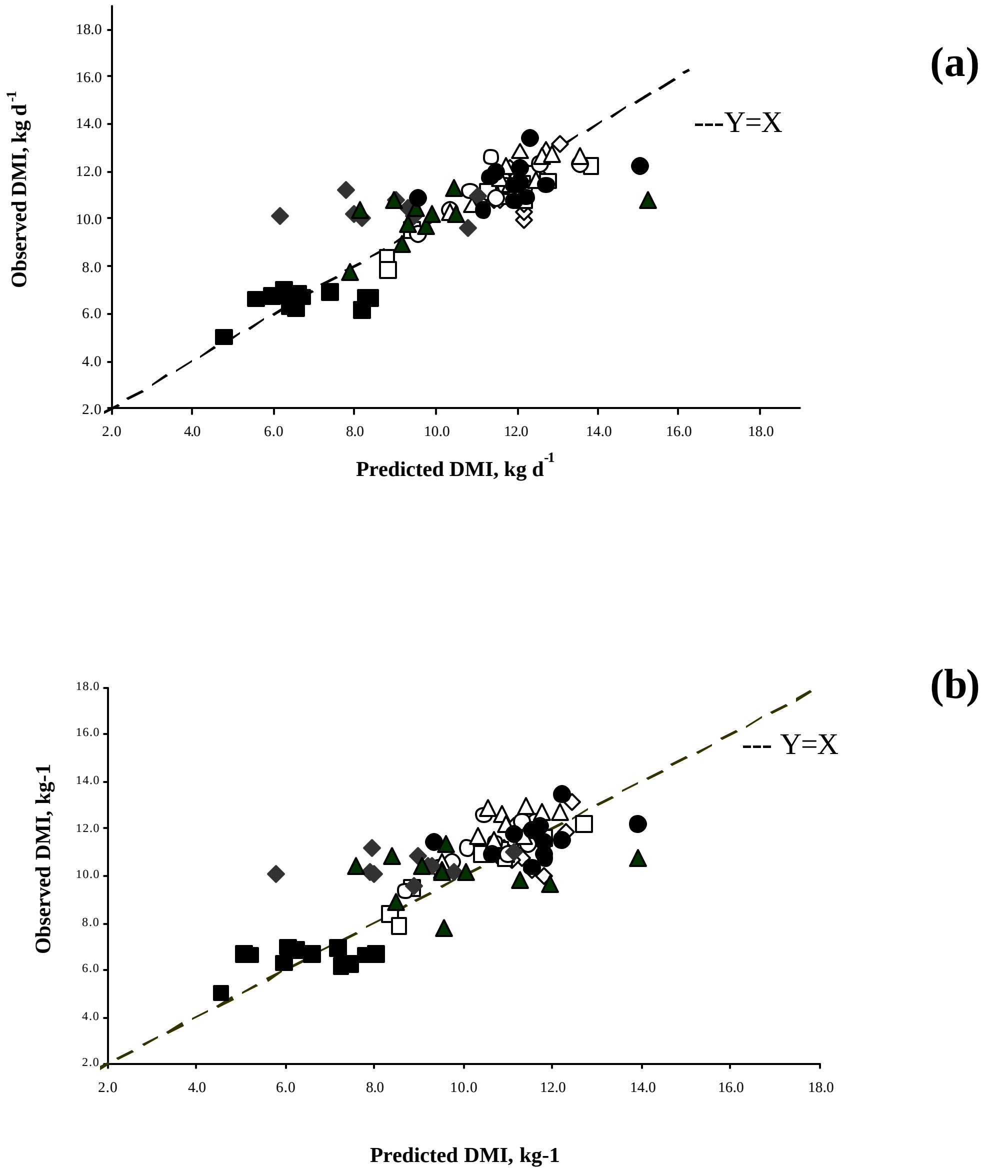

Figure 4.1. Relationship between observed DMI and required DM predicted by the Cornell Value Discovery System and NRC (2000) models for finishing and growing steers by treatment.

For the comparison of CVDS and NRC models, all evaluations between models were conducted using the MBW equations without adjustments because of its similarity with the approach used by the NRC level 1 beef model to compute DM required. In the present study, the NRC model was able to explain 59% of the variation in oDMI adjusted for known performance during the growing period with no bias (*P* > 0.1) and 57% of the variation in oDMI during the finishing period, during finishing, with an average underprediction of 4.40 % (MB of 0.47 kg/d). The NRC predicted DMI values were resultant from manual adjustments on DMI until model predicted ADG matched observed ADG. These adjustments are automated in the CVDS model, where predicted DMI is automatically adjusted until actual and predicted ADG match (Fox et al., 2002). The CVDS model accounted for 61% of the variation in oDMI during the growing period with no bias (*P* > 0.1) and for 71% of the variation in oDMI during the finishing period, with an average overprediction of 3.76 % (MB of -0.48 kg/d). Although model indexes were similar between models evaluation, CCC and Cb values were closer to 1 for CVDS when applied to finishing cattle (Table 4.2).

Data suggest that, in both growing and finishing periods, the CVDS model was able to account for more of the variation in the DM prediction than the NRC model. The variation not accounted for in the model was likely related to factor such as maintenance requirements, diet digestibility and metabolizability, and body composition of individual animals (Perry and Fox, 1997). Additionally, as expected in most models, the CVDS model accumulates errors in each of its components when predicting DM requirements (Fox et al., 2002). The comparison between predictions of DM required by CVDS and NRC is illustrated in Figure 4.2. The R^2 of 0.88 suggest that predictions of both models were similar; however, the CVDS model more precisely accounted for the variation of oDMI in the present data set with lower MB, and higher CCC and Cb.

Regressions comparing predicted DM required might not be the best approach for comparison of adequacy of both models, since models require different set of inputs and sometimes a common input has a different connotation among models (Tedeschi et al., 2005); however, our evaluation of the model's adequacy suggest that the CVDS was able to account for more of the variation of the data set when compared to the NRC model. The prediction of EBF calculated with input data of carcass measurements in the CVDS model is likely an advantage when compared to the NRC model. In the NRC, only FSBW was used as an indicative of BW at 28% EBF for each animal.

Prediction of individual intake of steers by treatments

Data from the present study also were used to evaluate the ability of the CVDS and NRC models of predicting DM required for individual steers during different growing systems by treatments, and also in the same diet during finishing, but coming from different growing systems (i.e., by previous treatments).

Low starch growing diet. During growth, intake predictions for AL-LS steers were the ones with the highest MB (9.9 and 12.55% for the CVDS and NRC treatments, respectively). It might be possible that factors other than animal performance and feed composition might have affected the prediction. Data of finishing steers fed the AL-LS diet during growing suggest that this dietary treatment decreased the ability of both

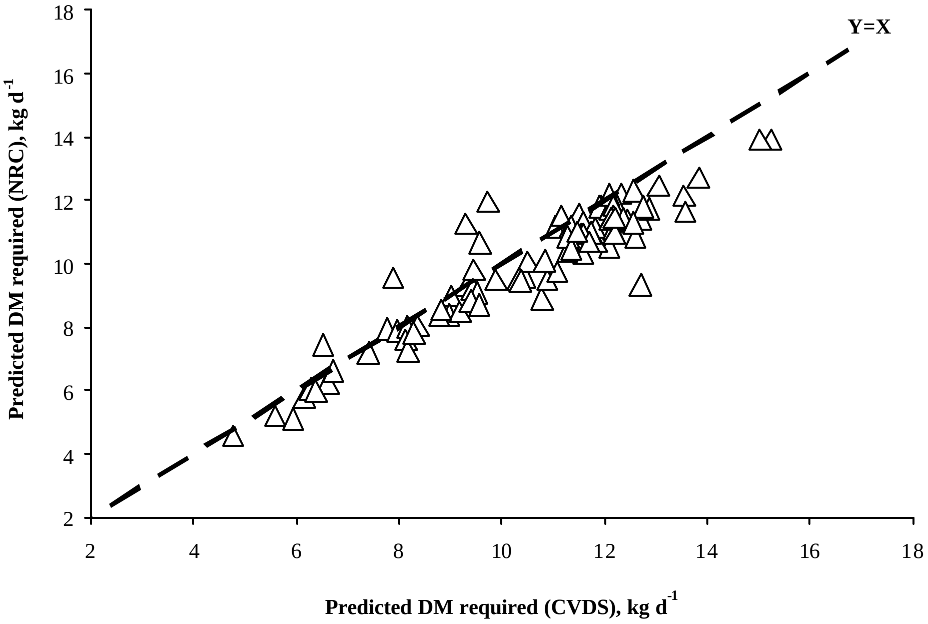

Figure 4.2. Relationship between predicted DM required by the Cornell Value Discovery System and by the NRC (1996) beef model. Dashed line y = x indicates the perfect fit between observed and predicted values. The regression equation was y = 0.14 + 1.04x with a R^2 of 0.88.

models on predicting intake, although MB were decreased when these cattle were placed on a high concentrate diet (Table 4.3). During finishing, the CVDS model was able to explain 23% and the NRC model was able to explain only 37% of the variation. Neither model was able to account for much of the variation in the data set.

High starch growing diet. Comparison of oDMI and model predicted DMI for steers fed a high starch diet during the growing period is presented in Table 4.3 and Figure 4.3. During the growing period neither model explained adequately variation in the prediction for individuals (R^2 = 0.20 and 0.17 with 1.36 and 6.51% of bias for CVDS and NRC, respectively); however, during the finishing period, the two models were able to satisfactorily predict intake. The NRC model was able to account for 62% of the variation on DMI with 10.74% of bias and the CVDS was able to account for 73% of the variation on DMI with only -0.67% of bias which suggests that the model predicted DM required within an acceptable degree of accuracy.

Limited fed growing diet. The relationship between oDMI and predicted DM required by the CVDS and NRC models for growing and finishing steers that had restricted access to a high starch growing diet is also presented in Table 4.3 and Figure 4.3. Although CVDS and NRC were able to account for only 18 and 14% of the variation (-3.9 and 0.50% bias) during the growing period, they were able to account for 90% and 91% of the variation (-6.2 and 0.46% of bias) on oDMI during finishing, respectively. These results suggest that limited fed animals' individual response might be predictable when placed on a finishing diet after a period of restricted nutrition.

Intermediate starch growing diet. Data presented on Table 4.3 show that neither model was able to explain a large amount of variation in the prediction for AL-IS during the growing period (R^2 = 0.17 and 0.11 and -3.59 and -0.67% of bias for CVDS and NRC, respectively). During the finishing period, the NRC model was able to explain 49% of the variation (0.49% of bias) for AL-IS intake. The CVDS model was able to explain 58% of the variation (-3.24% of bias). Overall, data suggest that both models were not able to predict individual DM required for growing animals under our experimental conditions, likely because of the small number of observations, although accuracy was reasonable.

The model evaluation using finishing data by treatments also suggests that different cattle background might affect model prediction of both individual and group intake prediction. More data is needed to effectively evaluate the background effects on prediction of DMI. Figure 4.3 illustrates the relationship between oDMI and predicted DM required of steers by both models by dietary treatments fed prior to finishing.

Table 4.3. Comparison of two different models for prediction of DM required of growing and feedlot steers[1].

	R^2		MB (%)		Cb		CCC		CD	
	CVDS	NRC	CVDS	NRC	CVDS	NRC	CVDS	NRC	CVDS	NRC
Growing (by treatment)										
AL-LS	0.20	0.12	9.90	12.55	0.82	0.76	-0.36	-2.67	0.52	0.47
AL-HS	0.20	0.17	1.36	6.51	0.29	0.58	0.36	-0.23	0.25	0.11
LF-HS	0.18	0.14	-3.91	0.50	0.74	0.77	0.31	0.29	0.20	0.22
AL-IS	0.17	0.11	-3.59	-0.67	0.85	0.96	0.35	0.33	0.38	0.59
Finishing (by treatment)										
AL-LS	0.23	0.37	0.64	0.11	0.57	0.96	0.28	0.58	0.99	0.87
AL-HS	0.73	0.62	-0.67	10.74	1.00	0.53	0.85	0.42	0.99	0.39
LF-HS	0.90	0.91	-6.20	0.46	0.89	0.99	0.85	0.95	0.62	1.01
AL-IS	0.58	0.49	-3.24	0.49	0.93	0.81	0.70	0.57	0.71	0.72

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[1] MB = mean bias; Cb = bias correction; CCC = concordance correlation coefficient. CD = coefficient of model determination;

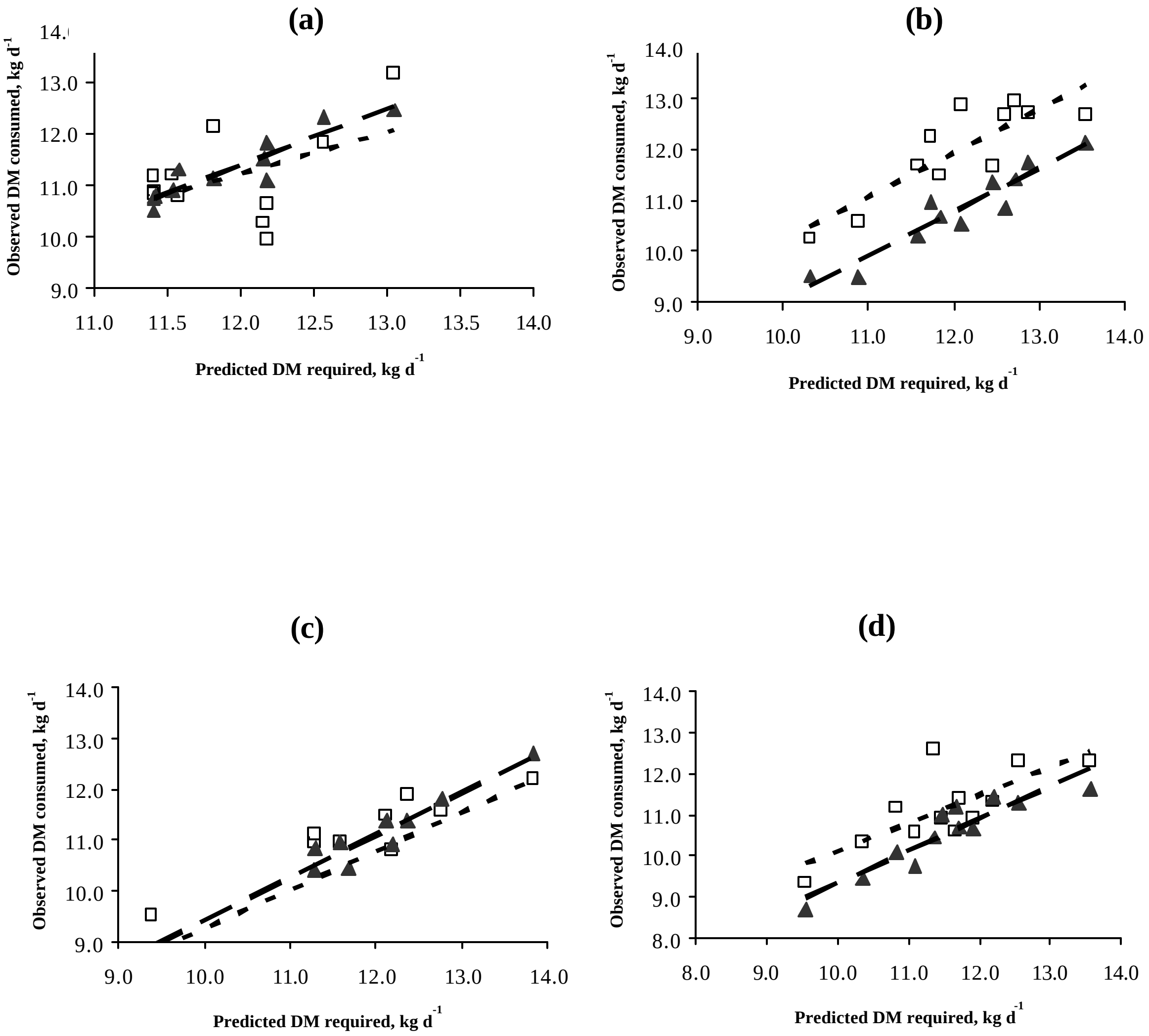

Figure 4.3. Relationship between observed DM consumed and required DM predicted by the Cornell Value Discovery System and by the NRC beef model for finishing steers fed the following experimental diets prior to entering the feedlot: AL-LS (a), AL-HS (b), LF-HS (c), and AL-IS (d) treatments.

Group prediction

Although both models were not able to closely predict group DM required for AL-LS, for all other treatments, both models were able to closely predict DM requirements during growing and finishing periods (Table 4.4). It might also be possible that the error in prediction is reduced when animals are fed higher concentrate diets. Both models precisely predicted DM required for finishing steers fed all different diets during finishing period by groups. These data agree with Fox et al. (2002), and suggest that the prediction of DMI of groups of animals instead of individuals reduces the error of prediction (Fox et al., 2002); however it limits the application for sorting purposes.

Guiroy et al. (2001) evaluated this reduction in error by randomly creating small groups of cattle (5, 10, 20, 40, or 80) within 365 individually fed animals used in a study conducted to validate the CVDS model. The coefficient of variation was reduced more than 50% (from 8.18 to 3.76%) when predicting DM required for groups of 5 animals instead of individuals, and was less than 2% in groups of more than 20 animals (Guiroy et al., 2001).

These data suggest that the error in prediction is greatly reduced when predicting larger groups of animals. This is an important concept for feedyards using models system to allocate feed consumed among small groups of cattle from the same owner within a pen (Fox et al., 2002). The overall group predictions of the CVDS model (average of the two different approaches, Table 4.4) were -10.0, -4.7, 1.8, and 2.2% of oDMI of AL-LS, AL-HS, LF-HS, and AL-IS during the growing period, respectively. For the finishing period, the CVDS predictions were 4.1, -1.5, 6.5, and -1.1% of the actual DMI. Using the NRC,

Table 4.4. Comparison of observed DMI to predicted DMI of group and individual animals by the NRC (2000) and CVDS models.

Treatments	Observed DMI, kg	DM predicted for individual animal, kg[1]		DM predicted for group fed animals, kg[2]	
		CVDS	NRC	CVDS	NRC
Growing					
AL-LS	10.03	9.13	8.91	9.11	9.12
AL-HS	10.19	9.72	9.72	9.69	9.22
LF-HS	6.49	6.75	6.46	6.79	6.50
AL-IS	11.56	11.99	11.64	11.59	11.58
Finishing					
AL-LS	11.17	11.94	11.33	11.91	11.25
AL-HS	11.55	11.97	10.78	11.96	10.75
LF-HS	10.28	11.34	10.55	11.37	10.78
AL-IS	11.15	11.52	10.53	11.52	10.59

[1] Mean value of individual predictions for each animal by treatment.

[2] Value predicted for the average of initial data, period and carcass information by treatment.

predictions were -9.2, -7.2, 2.4, and 0.21% of oDMI for AL-LS, AL-HS, LF-HS, and AL-IS during the growing period. During the finishing period, the NRC predictions were 3.7, -1.7, 7.7, and -0.9% of the actual DMI.

Evaluations of different aspects of the CVDS model

A further analysis of the relationship between oDMI and different equations within the CVDS was conducted in the present study. Data was also used to evaluate the accuracy and the precision of the CVDS model under the input of different concentrations of ME and under the use of environmental information for different equations.

Effects of different concentrations of ME on prediction of DMI by the CVDS model. A sensitivity analysis was of the dietary ME (± 5 and ± 10%) indicated the accuracy decreased when dietary ME used was lower or higher than the diet actual ME concentration. The MBW without adjustments equation was used. Although R^2 values were kept constant, when ME varied (± 5 and ± 10%; Table 4.5), we observed that MB increased, and Cb, CCC, and CD values decreased with oscillating values. The MB, only ranging from -3.76 to 1.92 in the observed ME, increased to a range of -18.72 to 17.14 when ME varied (± 5 and ± 10%). Likewise, CCC, CD, and Cb values decreased considerably when ME was 10% lower or 10% higher than actual ME, which indicates a decrease in the predictability of the model, showing that the input of correct and precise diet composition affects the model ability to precisely predict DM required. The model adequacy indicators in Table 4.5 indicate that ME of finishing diets might have been underpredicted by 5% because at 105% they showed best adequacy.

Effects of the use of environmental information in the CVDS model. The input of environmental information did not affect CVDS predictions based on MBW (equations with or without adjustments) with or without gain composition adjustments (Table 4.6). Effects of the use of environmental information were observed only when the dynamic growth model was used, either without adjustments or with the adjustment equations using a decay to adjust NEg based on the proportion of retained energy as protein, or based on NRC (2000) equations to account degree of maturity (Tedeschi et al., 2004).

Our results showed that there is little difference in the R^2 of equations comparing the different equations with environmental information although MB increased and Cb, CC, and CD values decreased when accounting for gain composition. That is likely because no significant changes in environmental conditions were observed during the experimental period. The dynamic growth model without adjustments and with environmental information was more precise and accurate. These comparisons are illustrated in Figure 4.4. This suggests that animals were above the lower critical temperature and below the upper critical temperature.

Table 4.5. Sensitivity analysis of the effects of different concentrations of ME on prediction of DMI by the CVDS model.

Item[a]	% of ME of experimental diets				
	-10%	-5%	100%	+5%	+10%
R^2					
Growing	0.62	0.62	0.61	0.60	0.60
Finishing	0.71	0.71	0.71	0.71	0.70
MB					
Growing, %	-14.18	-6.01	1.92	9.63	17.14
Finishing, %	-18.72	-11.59	-3.76	2.08	8.68
Cb					
Growing	0.79	0.94	0.98	0.93	0.81
Finishing	0.31	0.56	0.93	0.98	0.73
CCC					
Growing	0.63	0.74	0.77	0.72	0.63
Finishing	0.26	0.47	0.78	0.82	0.62
CD					
Growing	0.38	0.58	0.74	0.77	0.70
Finishing	0.15	0.34	0.88	1.10	0.71

[a] MB = mean bias; Cb = bias correction; CCC = concordance correlation coefficient; CD = coefficient of model determination.

Table 4.6. Comparison of different equations of the CVDS when environmental information is included.

Item [a]	CVDS (dynamic model)		
	No adjustment	Adjustment for gain composition [b]	
		1	2
R^2			
Growing	0.99	0.99	0.99
Finishing	0.99	0.98	0.97
MB			
Growing	3.80	10.29	13.91
Finishing	3.47	16.94	21.10
Cb			
Growing	0.99	1.26	1.20
Finishing	0.94	0.40	0.30
CCC			
Growing	0.99	0.90	0.84
Finishing	0.94	0.39	0.29
CD			
Growing	1.01	0.90	0.85
Finishing	0.90	0.33	0.24

[a] MB = mean bias; Cb = bias correction; CCC = concordance correlation coefficient; CD = coefficient of model determination.

[b] 1 = Decay equation for adjustment of NEg and 2 = NRC equation for adjustment of NEg based on the standard reference animal equations (Tedeschi et al., 2004).

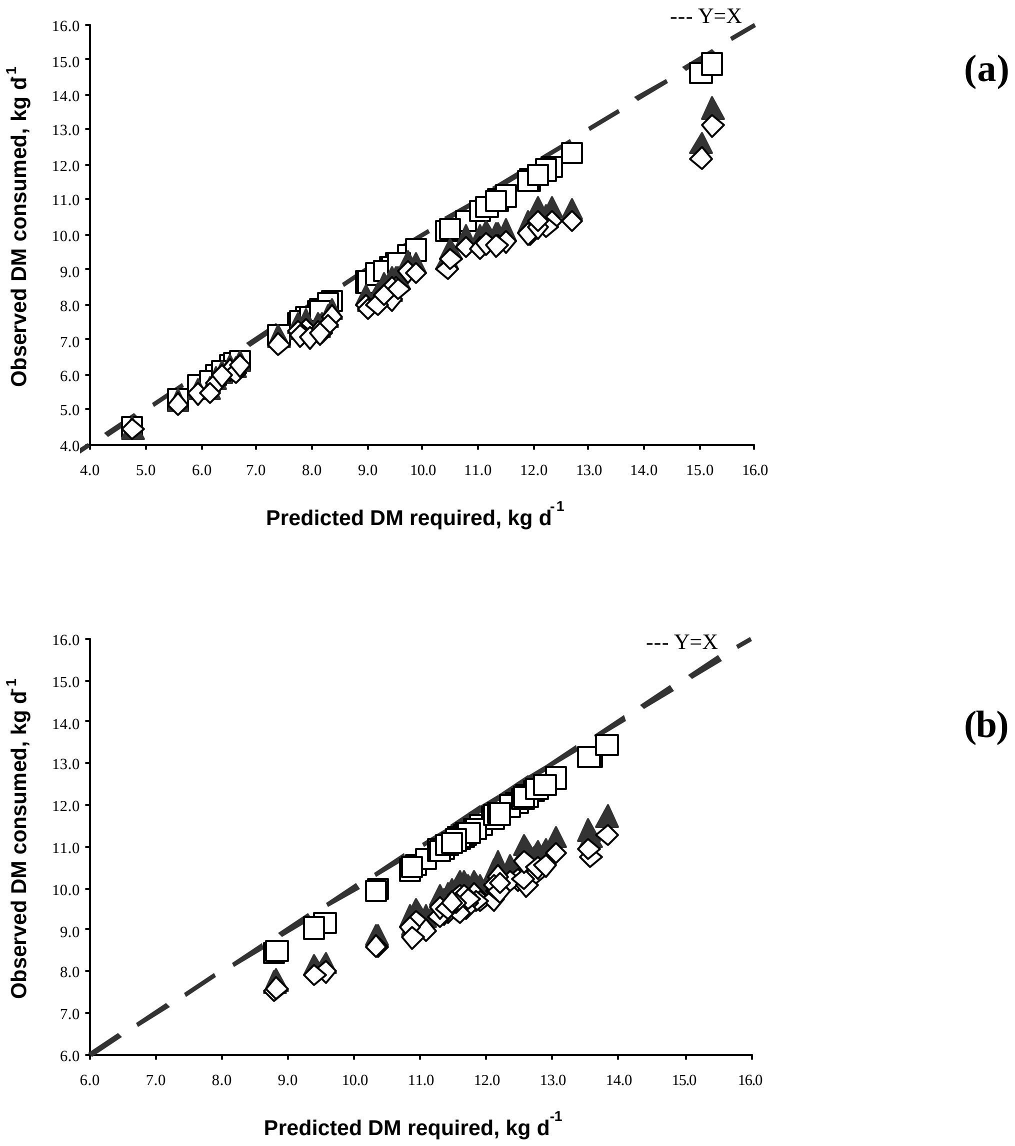

Figure 4.4. Relationship between prediction of DMR for growing (a) and finishing (b) cattle with the CVDS model using different equations under the same environmental conditions. The compared equations compared the dynamic model with no adjustments (✍), or adjustments for gain composition using the decay (?) or NRC (?) equations as described by Tedeschi et al. (2004).

Case study of prediction of individual feed requirements of pen-fed feedlot cattle

Use of an adjustment factor for prediction of DMI. Our finishing data set was used to evaluate the use of both models for prediction of DMI in a commercial feedlot situation. We included adjustment factors to both NRC and CVDS predictions, which were calculated as the total feed consumed, divided by the total feed predicted consumed for each treatment using both models (Table 4.7).

The predictions of DM required by each individual animal were multiplied by the adjustment factors by treatment and by model. Adjusted predicted DM required were regressed on actual DMI. Results on Table 4.8 show that the use of adjustment factors considerably reduced MB when compared to the previous evaluation of the models (Table 4.2). There were no changes in the R^2; however, an improvement in the bias correction factors was observed (Table 4.8).

Variation on DMI within a pen. Data on in Table 4.9 show the standard deviation of differences between oDMI and DM required predicted by both models in a daydaily and monthly basis. Data were presented on monthly periods also shown in 30 d periods because this is the period in which most commercial feedyards charge their customers. Results showed that DMI could vary from approximately 13 up to 26 kg within the same pen, under our experimental conditions. The averaged differences were 18.06 and 19.59 kg per 30 d for the CVDS and NRC models, respectively (Table 4.9). .

Our calculations show that an amount of approximately $2.5 per animal in 30 d is either overcharged or undercharged (considering a $130.0/ton feedlot diet).

Feedlots could improve the accuracy of the billing process for their customers, while still receiving the same for each pen. Predicted and observed intake differences would add up to zero because they were calculated with a correction factor. There would be no change in the income for a pen/month without slippage for a pen.

Both models were able to predict DM required after the adjustment, although the CVDS model had less MB, higher R^2, and Cb, CCC, and CD closer to 1. Slopes are good indicators of accuracy; the closer to unity, the higher the accuracy (Tedeschi, 2006).

Implications

Data suggest that the CVDS model predicted DM required for individual animals with more acceptable degree of accuracy. This model can be used to allocate feed to individual animals with mixed ownership within a pen in customer feedyards. Both models were able to accurately predict DMI for groups, as expected. In the present study, the prediction of DM required for finishing cattle was affected by the diet fed to cattle prior to the finishing phase. Therefore, cattle background information might be useful to increase accuracy of models design to predict individual feed required. More research is needed to more fully evaluate the effects of previous nutrition and management on prediction of individual feed intake.

Table 4.7. Adjustment factors for predicted DMI based on observed DMI for the NRC (2000) and CVDS models.

Treatments	Adjustment factor	
	CVDS	NRC
Growing		
AL-LS	1.04	1.06
AL-HS	1.05	1.05
LF-HS	0.96	1.00
AL-IS	0.96	0.99
Finishing		
AL-LS	0.94	0.97
AL-HS	0.92	1.02
LF-HS	0.92	0.86
AL-IS	0.97	1.06

Table 4.8. Effect of the use of a correction factor on prediction of DM required of growing and finishing steers by the NRC (2000) and CVDS models.

Item [b]	NRC	CVDS
MB, %		
Growing	0.15	0.22
Finishing	2.04	1.93
CD		
Growing	0.73	0.77
Finishing	1.17	1.10
CCC		
Growing	0.76	0.77
Finishing	0.73	0.82
R^2		
Growing	0.59	0.61
Finishing	0.57	0.71
Cb		
Growing	0.99	0.99
Finishing	0.97	0.98

[a] 1 = Decay equation for adjustment of NEg and 2 = NRC equations for adjustment of NEg based on the standard reference animal (Tedeschi et al., 2004).

[b] MB = mean bias; CD = coefficient of model determination; Cb = bias correction; CCC = concordance correlation coefficient.

Table 4.9. Standard deviation of differences between observed DMI and DM required predicted by the NRC (2000) and CVDS models.

Treatments	Daily difference in kg (CVDS)	Daily difference in kg (NRC)	30 d difference in kg (CVDS)	30 d difference in kg (NRC)
Finishing				
AL-LS	0.800	0.864	23.99	25.92
AL-HS	0.483	0.589	14.50	17.67
LF-HS	0.448	0.431	13.45	12.93
AL-IS	0.676	0.729	20.28	21.86
Mean	0.602	0.653	18.06	19.59

CHAPTER V

COMPARISON OF PROFITABILITY OF FEEDLOT CATTLE FROM DIFFERENT GROWING SYSTEMS

Overview

Data of forty eight crossbred individually fed steers was used to evaluate the effects of different growing systems on carcass merit and feedlot profitability. Cattle were fed four growing diets: LF-HS (a limit fed high starch diet designed to provide a rate of gain of 1 kg/d), AL-LS (a low starch diet fed *ad libitum* for a rate of gain of 1 kg/d), AL-IS (a diet with approximately the midpoint daily energy intake between AL-LS and AL-HS fed *ad libitum*), and AL-HS (a high starch diet fed *ad libitum* for a rate of gain of 1.6/d). Steers received dietary treatments until d 56, being then all placed on the same AL-HS diets for finishing until d 140. Carcass data showed that marbling scores were higher for AL-HS and AL-IS (*P* = 0.02). Marbling scores were 452.7 and 490.8 for AL-LS and LF-HS and 524.2 and 538.3 for AL-IS and AL-HS, respectively. Choice and Select grade carcasses resulted with marbling as a key factor on profit. All 140 d economic data (56 d of growing and 84 d of finishing) and carcass data of the 48 steers were combined for the profitability evaluation. The grid calculated values per carcass were $929.10 ± 129.3, 954.20 ± 103.6, 1054.10 ± 75.9, and 1030.70 ± 119.6 (mean grid-value, standard deviation), for LF-HS, AL-LS, AL-IS, and AL-HS, respectively. Profit values were $(-53.44) ± 129.67, $(-76.47) ± 94.7, $16.19 ± 76.6, and $11.99 ± 89.0, for steers from LF-HS, AL-LS, AL-IS, and AL-HS treatments, respectively. Breakeven sale prices per animal (value per 45.4 kg) were \$0.83 ± 0.05, \$0.82 ± 0.05, \$0.81 ± 0.02, and \$0.79 ± 0.05, for LF-HS, AL-LS, AL-IS, and AL-HS, respectively. Costs of gain (per 454g) were \$0.39 ± 0.05, \$0.42 ± 0.05, \$0.42 ± 0.03, and 0.38 ± 0.04, for LF-HS, AL-LS, AL-IS, and AL-HS, respectively. Steers fed AL-HS and AL-IS growing diets had higher marbling scores, which rewarded greater premiums and higher grid values. Data suggest that the improved carcass quality of growing cattle fed high grain diets prior to finishing increase profitability, decrease breakeven sales prices, and lower cost of gain.

Introduction

The number of U.S. fed cattle marketed through a value based grid marketing system has increased significantly (Forristall et al., 2002). Grid marketing evaluates and prices cattle individually, and rewards higher carcass quality grade (**QG**) at slaughter (Ibarburu and Lawrence, 2005). Marbling is a trait based on the amount of intramuscular fat (**IMF**) between the muscle fiber bundles within the muscles. Incresed marbling in the carcass improves QG, which improves economic value of carcasses (Harper and Pethick, 2004).

Different nutritional managements systems are used for growing cattle. Typical growing systems used in the beef cattle industry allow animal body weight (**BW**) development before entering the finishing period, so that cattle are harvested at desirable carcass weights and degrees of fatness (Sainz et al., 1995). Growing systems using nutritional strategies to enhance the IMF development may increase carcass value and profitability (Pyatt et al., 2005b). Recent research (Schoonmaker et al., 2003; Vasconcelos et al., 2005) suggest that growing systems based on high grain diets prior to the finishing phase might increase accretion of IMF, which may in turn generate grid premiums. However, the cost associated with these strategies for production of animals with higher quality grades must be compensated by increased net returns.

The objective of this paper is to evaluate the effects of feeding high starch growing diets to increase IMF deposition, QG, and carcass value on beef cattle production profitability.

Material and methods

Animals and diets

Data from a study conducted at the Texas Agricultural Experiment Station/USDA-ARS Conservation and Production Laboratory, Bushland, TX was used to evaluate the relative profitability of growing diets that increase carcass quality. Forty eight crossbred steers were fed different growing diets for 56 d. During 56 d, steers received one of the following dietary treatments: **LF-HS** (n = 12; a limit fed high concentrate diet with energy for a rate of gain of approximately 1 kg/d), **AL-LS** (n = 12; a low energy diet fed *ad libitum* for a rate of gain of approximately 1 kg/d), **AL-IS** (n = 12; a diet fed *ad libitum* with approximately the midpoint daily energy intake between AL-LS and AL-HS), and **AL-HS** (n = 12; a high energy diet fed *ad libitum* for a rate of gain of approximately 1.6 kg/d). On d 56 all animals were placed on the same AL-HS diets for finishing (84 d) until d140.

High starch treatments (AL-HS and LF-HS) were fed the same diet in different amounts for 56 d, only and then fed *ad libitum* during finishing (84 d). This diet contained approximately 80% corn and 7% roughage. The AL-LS dietary treatment consisted of a high roughage diet fed for 56 d, until the start of the finishing period. The AL-LS diets contained approximately 50% wheat middlings and 36% cottonseed hulls during the first 28 d. The amount of wheat middlings was then decreased to 25% in the following 28 d because of an unexpected excess in the CP concentration of this feedstuff. The percentage of cottonseed hulls in the diet was then increased to approximately 60%. The IS dietary treatment was a diet containing approximately half of the amount of corn and forage present on HS and LS, respectively. Diets also contained molasses, tallow, and a supplement containing minerals (calcium, phosphorus, sodium, magnesium, potassium, sulfur, manganese, zinc, cupper, selenium, cobalt, iodine, and iron), Vitamin A, Vitamin E, and additives.

Carcass characteristics

Steers were harvested on d 140 at a local commercial packing plant. Individual carcass measurements were taken for hot carcass weight (**HCW**) on the day of harvest. Fat thickness; longissimus area; kidney, pelvic, and heart fat; marbling scores; and USDA QG and calculated yield grade (**YG**) were collected by the West Texas A&M University (Canyon, TX) Cattlemen's Carcass Data Service (**CCDS**) after a 24-h chill at -4°C. Carcasses described as slight, small, and modest marbling scores were adjusted to 300, 400, and 500 scores.

Economic evaluation

Cost and production data from the entire period (140 d; 56 d of growing and 84 d of finishing) and carcass data of the 48 individual steers were used for the economic evaluation. For this evaluation, current market data were used to estimate prices of feedstuffs (Texas Grain and Feed Association; www.tgfa.com; University of Missouri Extension; http://agebb.missouri.edu/dairy/byprod/bplist.asp), feeder cattle price, overall feedlot costs, and choice-select spread (USDA Market News for July, 2006). Feedstuffs and total mixed diet prices were adjusted to a cost per ton of DM. Feedstuff costs (per ton) used in this analysis were: steam flaked corn ($86.00), cottonseed hulls ($150.00), fat/corn steep blend ($120.00), wheat middlings ($74.00), mineral/vitamins/additives supplement ($110.00).

Hot carcass weight, QG and YG data (Table 5.1) were used to compute grid prices as shown in Table 5.2. Final price was calculated by adjusting a base value for carcass quality (prime, certified program, low choice, select, and standard); YG (1, 2A, 2B, 3A, 3B, 4, and 5); and carcass weight (> 454kg, 430 to 453kg, 249 to 429kg, 227 to 250kg, < 225kg; Table 5.1). The “certified program” carcass quality index was included to reflect premium choice branded beef programs that reward for QG high and average choice (i.e., Modest and Moderate amounts of marbling; McKenna et al., 2002).

The final carcass price with premiums and/or discounts for QG, YG, and carcass weight were calculated as described by Forristall et al. (2002):

(5.1) Carcass price = Base/45.4 kg ± prem./disc. for QG ± prem./disc. for YG ± prem./disc. for HCW

Total cost per head was calculated as the sum of each animal’s input costs. Input costs (Table 5.3) included feed cost, veterinary cost ($8.00 per head), yardage ($0.32/d

Table 5.1. Carcass characteristics of the data set used for the analysis.

Item	LF-HS	AL-LS	AL-IS	AL-HS
Carcass Quality				
Prime	-	-	-	-
Certified program [b]	1	-	1	3
Choice [c]	5	3	9	5
Select	6	8	2	4
Standard	-	-	-	-
Yield Grade				
YG 1	5	3	4	-
YG 2A	3	6	5	5
YG 2B	4	-	3	3
YG 3A	-	1	-	3
YG 3B	-	1	-	1
YG 4	-	-	-	-
YG 5	-	-	-	-
Carcass weight, kg [d]				
> 453	-	-	-	-
430- 452	-	-	-	-
249- 429	12	11	12	12
226- 428	-	-	-	-
< 225	-	-	-	-

[a] Base carcass price:.

[b] Based on a commercial certified program for the upper 2/3 of choice. Choice (+) and Choice ( ).

[c] Choice (-) .

[d] Carcass weight was not considered in the present study's grid formula because no variation was observed.

Table 5.2. Description of the carcass pricing-grid used for the analysis and number of observations in the study data set.

Item	Base carcass price adjustments [a]	Number of observations
Carcass Quality		
Prime	-	-
Certified program [b]	$5.00	5
Choice [c]	BASE ($134.6)	22
Select	($20.00)	20
Standard	-	-
Yield Grade		
YG 1	$6.50	12
YG 2A	$2.50	19
YG 2B	$1.00	10
YG 3A	BASE ($134.6)	4
YG 3B	($2.00)	2
YG 4	-	-
YG 5	-	-

[a] No values were included for grid not present in our data set.

[b] Based on a commercial certified program for the upper 2/3 of choice. High choice (+) and average choice ( ).

[c] Low choice (-) .

per head), transport ($10.00 per head), implants ($1.60 per head), beef check off ($1.00 per head), equity (20%), and interest on investment calculations based on 5.5% prime rate (5.5%).

Profit by steer, breakeven sales price (in 45.4 kg), and cost of gain (per 0.454 kg) are industry indicators of feedlot profitability. Net return (profit) is calculated as total returns – total costs (Equation 5.2). Breakeven sale price (Equation 5.3) is the minimum price that must be received for a steer for net returns to equal zero. Cost of gain (Equation 5.4) is the value spent ($) for the observed ADG.

(5.2) Net returns = (HCW*Grid-value) – {[Variable costs (Feed/other costs)] + (IBW*feeder cost)}

(5.3) Breakeven sales price = (Variable costs + Initial cost)/((Final BW/0.454))

(5.4) Cost of gain = (Variable costs)/(Total BW gain/0.454)

Statistical analyses

Carcass traits were analyzed using the Mixed Procedure of SAS (SAS Institute, Cary, NC) as a completely randomized design with each steer considered as an experimental unit, treatment as the fixed effect in the model, and steer (treatment) as the random variable. For all analyses, P-values < 0.05 were considered significant, whereas P-values between 0.05 and 0.10 were discussed as tendencies. For each treatment, the least square means (LS Means) were computed and pairwise comparisons were conducted if and only if the F-test was significant at $P < 0.05$. Quality grade distributions were evaluated using Chi-square analysis.

Table 5.3. Description of economic variables and data inputs used for the evaluation of the profitability of different growing systems.

Item	Value
Animal	
Steer, cost/45.4kg	$1.25
Equity, %	20.00
Interest, %	5.50
Transport, cost/hd	$10.00
Yardage, cost/hd/d	$0.32
Days on feed	140
Feed (DM basis)[1]	
LF-HS Growing diet, cost/ton[2]	$104.55
AL-LS Growing diet, cost/ton	$136.71
AL-IS Growing diet, cost/ton	$129.58
AL-HS Growing diet, cost/ton[2]	$104.55
Feedlot costs, $	
Yardage, cost/hd/d	$0.32
Veterinary expenses, cost/hd	$8.00
Implants, cost/hd	$1.60
Other expenses	
Beef check off, cost/hd	$1.00

[1] Considered feedstuffs costs per ton were: Steam Flaked corn ($86.00), Cottonseed Hulls ($150.00), Fat/Corn Steep blend ($120.00), Wheat middlings ($74.00), TAES supplement ($110.00).

[2] Growing diets were fed during 56 d. The HG diet was fed to all animals during finishing (84 d).

Results and discussion

Different growing diets affected carcass marbling scores and QG of steers in the present study (Table 5.4). Steers from the LF-HS treatment (limit-fed during the growing period) were lighter (*P* = 0.01) and had lighter (*P* = 0.01) HCW at harvest. Marbling scores were highest for AL-HS and AL-IS groups when compared to AL-LS (*P* = 0.02; Table 5.4), with marbling scores for LF-HS intermediate to other treatments. Fat thickness tended to be higher for AL-HS and AL-IS when compared to LF-HS and AL-LS groups (*P* = 0.08). Steers fed the AL-HS diet had the best yield grade (*P* = 0.03). No differences were observed in dressing percent (*P* = 0.64), longissimus area (*P* = 0.25); and percentage of kidney, pelvic and heart fat (*P* = 0.42).

Data from Forristall et al. (2002) show that feedlot profitability is largely determined by marbling, carcass weight, and gain to feed ratio (**G:F**). Their analysis showed that carcass weight was more important at a low Choice-Select (**Ch-Se**; spread difference in unit price paid for choice versus select QG); however, at average Ch-Se spread and higher, marbling became the largest determinant of feedlot profits, and its importance increased with the Ch-Se spread. Data from the present study show that under current market conditions of a high Ch-Se spread, marbling dramatically influenced the feedlot profitability (Table 5.5). Marbling scores were 452.7 and 490.8 for AL-LS and LF-HS respectively and 524.2 and 538.3 for AL-IS and AL-HS, respectively. A chi-square analysis showed that higher number of carcasses with certified beef (high and average choice and low choice grades were observed in steer fed HG and IG during growing (*P* = 0.08; Table 5.6).

Table 5.4. Effects of different growing systems on BW and carcass characteristics of finishing steers.

Item	Treatment				SEM	*P*-value[a]
	LF-HS	AL-LS	AL-IS	AL-HS		
Initial BW, kg[d]	296	297	296	296	5.1	0.99
BW (end of growing/start of finishing period), kg	372^{c}	392^{c}	421^{b}	417^{b}	10.6	< 0.001
Final BW, kg[d]	518^{c}	550^{b}	558^{b}	560^{b}	9.1	0.01
HCW, kg	326^{c}	351^{b}	353^{b}	357^{b}	6.3	0.01
Dressing, %	62.84	63.74	63.27	63.77	0.60	0.64
Marbling score[e]	$490.8^{b,c}$	452.7^{c}	524.2^{b}	538.3^{b}	19.60	0.02
Fat Thickness, cm	$0.96^{b,c}$	0.90^{c}	1.06^{b}	1.26^{b}	0.10	0.08
Longissimus Area, cm^2	87.53	91.03	94.41	88.39	2.58	0.25
Kidney, pelvic, heart fat, %	1.63	1.59	1.58	1.75	0.08	0.42
YG	2.16^{c}	2.14^{c}	2.14^{c}	2.71^{b}	0.15	0.03

[a] Treatment effect.

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

[d] Shrunk BW.

[e] Marbling score: 300 = slight, 400 = small; 500 = modest.

Table 5.5. Mean and SD of economic measurements of finishing steers fed different growing diets.

Item	LF-HS	AL-LS	AL-IS	AL-HS
Steer cost, $/hd	785.80 ± 41.90	786.80 ± 47	785.30 ± 31.4	785.70 ± 60.7
Carcass value, $/hd	929.10 ± 129.3	954.20 ± 103.6	1054.10 ± 75.9	1030.70 ± 119.6
Profit, $/hd	-53.44 ± 129.67	-76.47 ± 94.7	16.19 ± 76.6	11.99 ± 89.0
Breakeven sale price, $/454g	0.83 ± 0.05	0.82 ± 0.05	0.81 ± 0.02	0.79 ± 0.05
Cost of gain, (per 454g)	0.39 ± 0.05	0.42 ± 0.05	0.42 ± 0.03	0.38 ± 0.04

Table 5.6. Chi-square analyses of number of carcasses of steers in each USDA.

Item	LF-HS	AL-LS	AL-IS	AL-HS
Certified program	1	0	1	3
Choice	9	3	5	5
Select	2	8	6	4

[a] $P = 0.08$.

The average grid-values paid per carcass were \$929.10 ± 129.3, 954.20 ± 103.6, 1054.10 ± 75.9, and 1030.70 ± 119.6 (mean grid-value, standard deviation), for LF-HS, AL-LS, AL-IS, and AL-HS, respectively. Profit values were \$(-53.44) ± 129.67, \$(-76.47) ± 94.7, \$16.19 ± 76.6, and \$11.99 ± 89.0, for steers from LF-HS, AL-LS, AL-IS, and AL-HS treatments, respectively. The high standard deviations are likely because of the small number of head available for the present evaluation, and reflect the inherent variation among individual animals rather than among pens of animals. The growing systems based on AL-HS and AL-IS diets were more profitable. The breakeven sale prices per animal (value per 45.4 kg) were \$0.83 ± 0.05, \$0.82 ± 0.05, \$0.81 ± 0.02, and \$0.79 ± 0.05, for LF-HS, AL-LS, AL-IS, and AL-HS respectively. Costs of gain (per 454g produced) were \$0.39 ± 0.05, \$0.42 ± 0.05, \$0.42 ± 0.03, and 0.38 ± 0.04, for LF-HS, AL-LS, AL-IS, and AL-HS respectively. The present grid pricing structure provided added value to carcasses with superior quality grade. Select carcasses were observed in higher frequency on LF-HS and AL-LS (Figure 5.1). Greater premiums were given for carcasses with YG of 1 and 2; however, the higher frequency of these values for AL-LS did not compensate for reduced quality grades (Figure 5.2; Table 5.5). Descriptive graphs for comparison of all profitability parameters by different treatments were included for our economic evaluation (Figures 5.3-5.5). In a sensitivity analysis evaluating factors that influence profitability on grid-based carcass evaluation, Pyatt et al. (2005) observed that YG had little importance accounting for profit variation with increasing Choice-Select spreads. Variation of carcass value in grid pricing also depends heavily on discounted characteristics such as Select and Standard carcasses (Forristall et al, 2002), which were mainly present in cattle fed the high fiber growing diet in this experiment.

A sensitivity analysis was conducted with the data from this study. For the analysis, we evaluated the variation of -20, -10, 10, and 20% on baseline values of factors that may influence profitability (Ch-Se spread, base price, and feedstuffs) and the respective response in % of the profitability of each treatment (Table 5.7). These values were regressed by treatments, and the slopes of these equations were used to indicate the influence of each factor on profitability. Data shown on Table 5.7 show that Ch-Se spread had more influence in the profitability of the treatment AL-HS (slope: -4.82) while the base price had more influence (slope: 113.28) on profitability of AL-IS. The prices of corn, wheat middlings, and cottonseed hulls were evaluated separately. The variability of corn price had more influence on treatment AL-HS (slope: -11.03) than on other treatments, which is likely because of the high amount of corn used in this treatment. Wheat middlings and cottonseed hulls prices had more influence in the profitability of AL-IS than in the profitability of other treatments. There are different growing systems currently used in the beef cattle industry (Sainz et al., 1995). Some are based on forage feeding, but several are based on total diets with high fiber:concentrate ratio, to allow for slow cattle growth for a desirable frame size prior to finishing. Growing diets fed in the present study were designed to provide different types of ruminal fermentation that can affect IMF deposition in different ways. High forage diets fed in the industry usually have lower cost per ton when compared to typical feedlot diets, however, because of the currently high prices of roughages used in the study, growing diets AL-LS and AL-IS cost more than HG diets in our economic evaluation. That is likely because of the current drought and scarcity of hay.

Table 5.7. Slopes of regression equations of sensitivity analysis [a].

Item	LF-HS	AL-LS	AL-IS	AL-HS
Ch-Se spread	-1.31	-1.57	-2.86	-4.82
Base Price	17.59	14.50	113.28	98.32
Corn	-1.68	-0.96	-6.68	-11.03
Wheat middlings	-	-0.25	-2.12	-
CSH	-0.26	-0.80	-10.74	-1.70

[a] Regression of -20, -10, 10 and 20% variation and % price change.

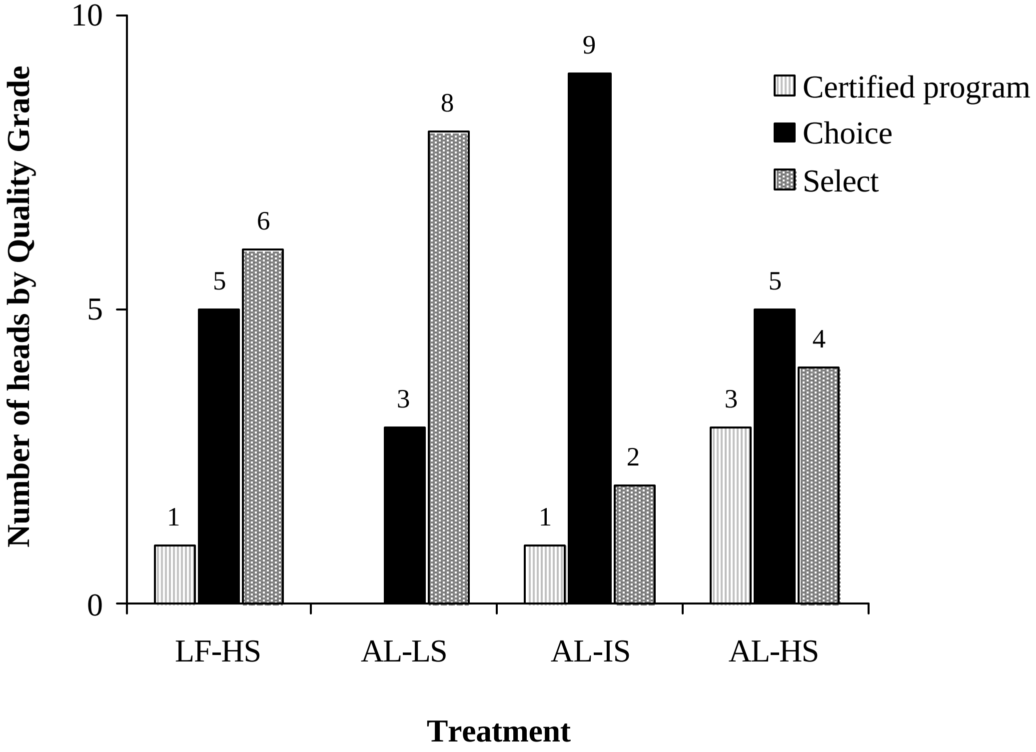

Figure 5.1. Distribution of quality grade of finishing steers fed different growing diets.

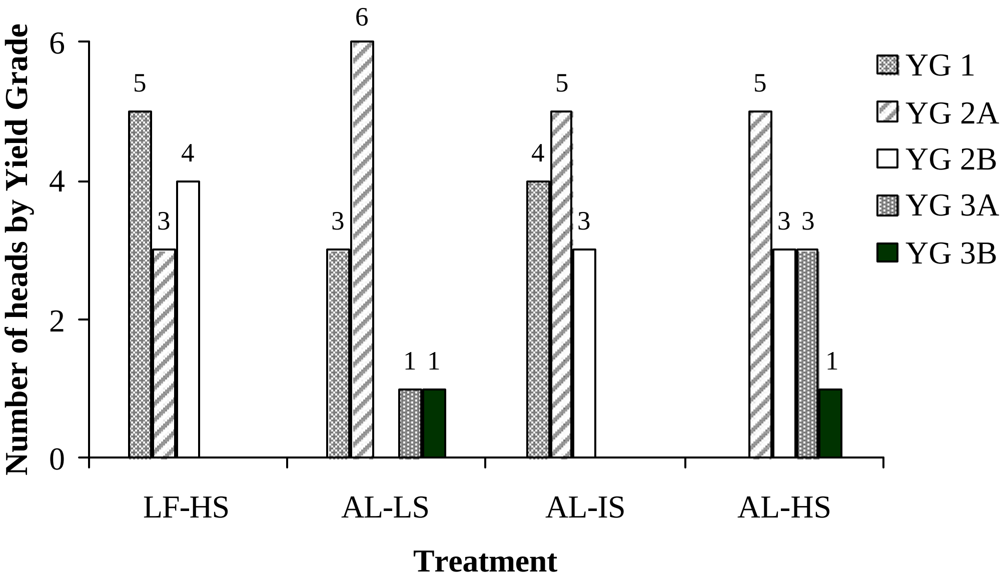

Figure 5.2 Distribution of yield grade of finishing steers fed different growing diets.

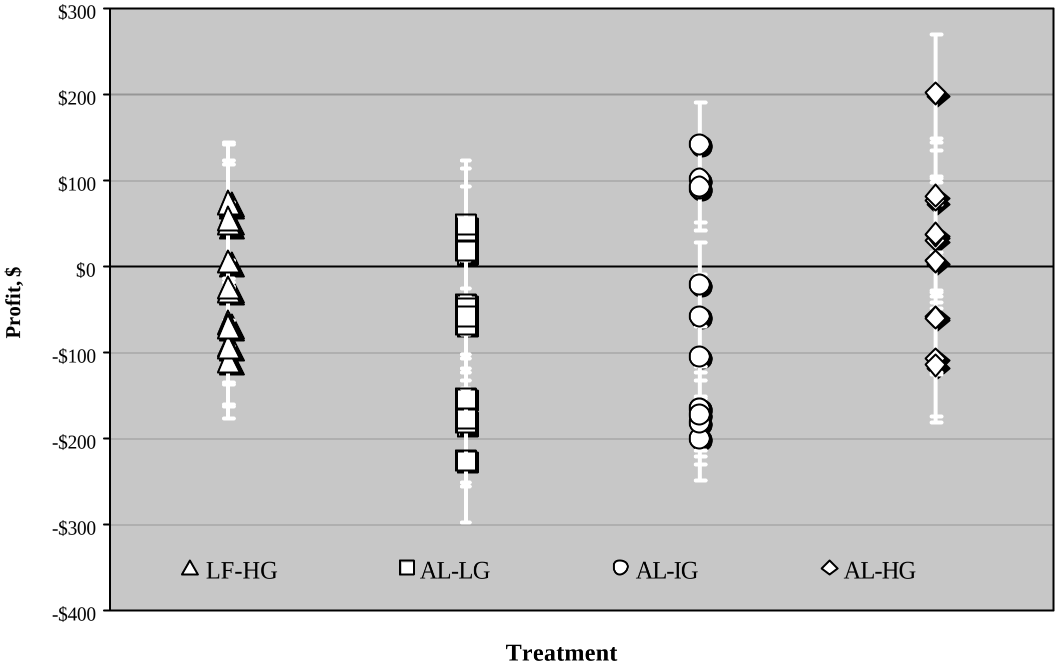

Figure 5.3. Distribution of profit of finishing steers fed different growing diets.

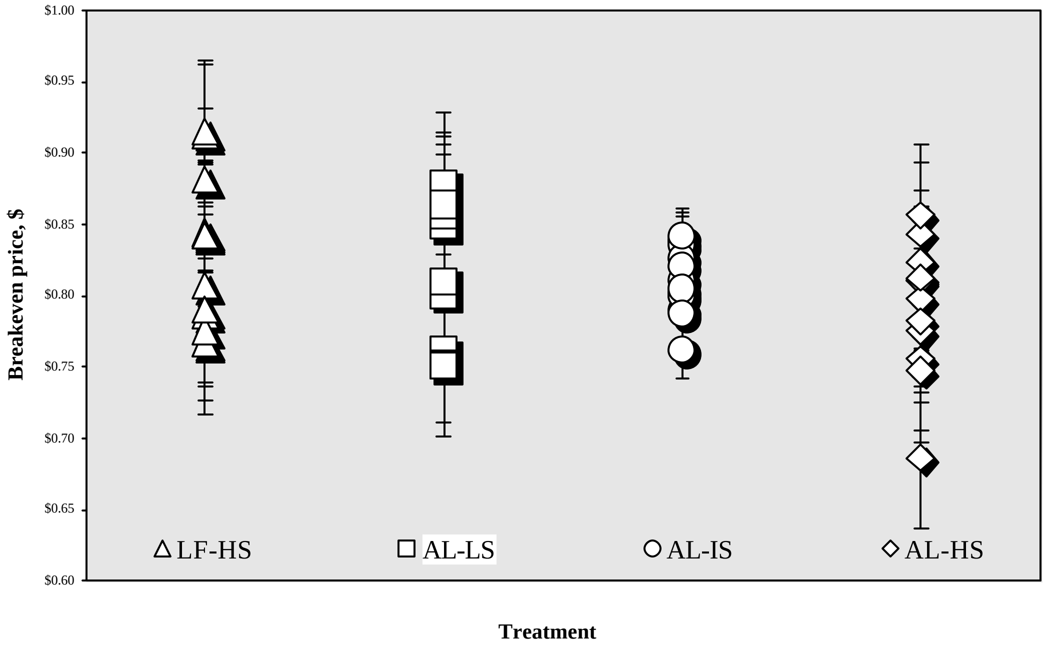

Figure 5.4. Distribution of breakeven price of finishing steers fed different growing diets.

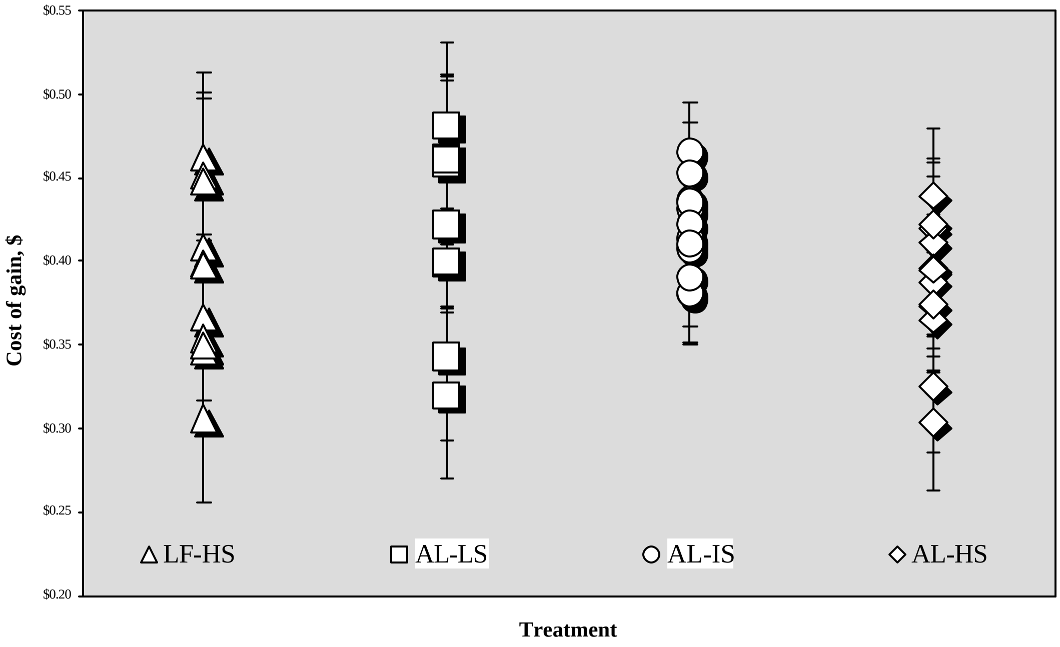

Figure 5.5. Distribution of cost of gain of finishing steers fed different growing diets.

Ruminal fermentation of different feedstuffs might be related to different biochemical responses in terms of fat synthesis in beef cattle. Growing animals fed high starch diets have higher production of ruminal propionate, a glucose precursor. Recent data suggest that this increase in production of glucose stimulates the secretion of insulin, and this might trigger IMF development in growing cattle (Bines and Hart, 1984; Schoonmaker et al., 2003). The increased insulin concentrations may increase uptake of glucose by peripheral tissues such as the IMF in growing steers. Glucose provides 50 to 75% of the carbons needed for synthesis of IMF and only 1 to 10% for the subcutaneous fat (**SCF**), observed in carcasses as the fat thickness. Steers in high fiber based growing systems, however, have higher production of acetate in the rumen. Acetate provides 70 to 80% of the carbons necessary for the SCF synthesis, but only 10 to 25% for the IMF (Smith and Crouse, 1984). No information is available, however, about the costs associated with improvements on carcass quality by changing growing nutrition management.

The low amount of IMF in carcasses of animals fed AL-LS may be explained by differences in ruminal fermentation. Forage ruminal fermentation may have not positively affected intramuscular fat deposition as also observed by Schoonmaker et al. (2003). In the beef cattle industry, however, a fast rate of growth it is not always desirable. Animals can deposit too much fat and reach their end-point at low BW, which can cause carcass discounts. Therefore, the objective of the limited fed treatment in the present study (LF-HS) was to control the rate of growth to allow the growth curve of steers while still achieving a grain fermentation that may result in enhanced intramuscular fat deposition (Schoonmaker et al., 2003).

Production responses in this study are consistent with Schoonmaker et al. (2003), showing that LF-HS had reduced IMF deposition during the finishing period, which resulted in lower marbling scores compared to steers fed HS *ad libitum* for 140 d. Controlling growth rate by limit-feeding grain-based diets penalized overall carcass characteristics and economic returns. However, economic results for LF-HS were still better than results for steers fed the high fiber diet during growth.

Understanding factors contributing to profitability provides cattle producers with important information to help make more cost-effective decisions regarding management (Schroeder et al., 1993). Operations that feed growing cattle could be either independent or part of a retained ownership program. Lawrence (2006) analyzed 11 years of data that showed purchasing calves to background has not been a profitable for the past 11 years (1995-2005); however, in this study the added value resulting from improvement in carcass merit of steers made the starch-based growing systems evaluated profitable. These results suggest that non-optimal rations were used in the Lawrence (2006) study, or that the market failed to pass along potential premiums to growing systems. Data from the present study may support certified beef programs. These programs could make management decisions to manipulate accretion of IMF in growing animals for economic benefit.

Implications

Results indicated that improvement in marbling utilizing a high grain growing system may positively impact net returns per head. Results suggest producers may improve carcass merit, allowing them to capture premiums from certified programs when using a grid-based pricing and improve profitability by utilizing a high grain diet prior to entering the feedlot. Further research is needed to fully evaluate effects of different beef cattle backgrounding systems on carcass value and profit.

CHAPTER VI

USING DECISION SUPPORT SYSTEMS TO PREDICT THE EFFECTS OF DIETARY NITROGEN ON ANIMAL PERFORMANCE AND NITROGEN EXCRETION

Overview

Feeding nutrients at concentrations that closely match animal requirements result in reduced excretion of N and P in concentrated animal feeding operations (CAFO). Data from an experiment conducted at the Texas A&M University Agricultural Experiment Station (Bushland, TX) were used to evaluate the predictions of animal performance by the Cornell Net Carbohydrate and Protein System (CNCPS) version 6.0. One hundred eight-four group-fed crossbred steers were previously fed a diet containing 13% CP (%DM) until reaching 477 kg of BW (70 days on feed). Then, steers were allocated to three treatments formulated to have different levels of dietary CP (10.0, 11.5, and 13%), which were fed until animals reached 567 kg of BW (approximately 60 d on feed). Data from the second half of the experiment (different diets) were used for prediction of urinary, fecal, and total N excretion by the model. The CNCPS was able to explain 66% of the variation in animal performance with an average underprediction of 85 $g \cdot d^{-1}$ (mean bias of 5.9%). The model was also evaluated for predictions of N excretion (urine and feces). As dietary CP decreased from 13 to 11.5%, the model indicated a total N excretion of approximately 16%. An even greater reduction in total N excretion (26%) occurred when dietary CP was decreased from 11.5% to 10%. The overall decrease from 13 to 10% CP resulted in a reduction of total N excretion by 38%.

Data suggest that decision support systems can be used to assist in balancing diets to meet environment restriction.

Introduction

The feedlot cattle industry has become increasingly concentrated in the southern and central great plains of the United States due to favorable climate conditions, availability of feed grains, and location of animal harvesting facilities. These operations concentrate N, P, and trace minerals (e.g., Cu) in this relatively small geographic area. Environmental issues associated with feedlot cattle include nutrient pollution of ground and surface water as well as pollution of air. Nutrient requirement of feedlot cattle changes during the feeding period. Nonetheless, feedlot cattle are usually fed one common diet with a constant level of CP and other nutrients from about d 24 of feeding through the harvest time. Consequently, CP is often underfed early and overfed late in the feeding period. Feeding nutrients at concentrations that closely match animal requirements can prevent excess excretion of nutrients in feedlots. The objective of this study was to evaluate a decision support system (Cornell Net Carbohydrate and Protein System, **CNCPS**, version 6) as a tool to assist in formulating diets for feedlot cattle to minimize environmental pollution.

Materials and methods

The CNCPS v. 6 was used to illustrate the application of nutrition models to assist in formulating and balancing diets for feedlot cattle to minimize environmental pollution. The CNCPS was used to predict urinary, fecal, and total N excretion of 184 group-fed crossbred steers (N = 21 pens; data described by Vasconcelos et al., 2006).

Steers were fed a high concentrate diet containing 13% CP (%DM) during the first half of the experiment, until animals reached 477 kg of BW (70 d on feed). Then, steers were assigned to one of three treatments with diets formulated to contain 10.0, 11.5, or 13% of dietary CP. Steers were harvested when reached 567 kg of BW (approximately 60 d on feed). Animal, environment, and diet data from the second half of the experiment (different diets) were inputted in the model to predict animal used for prediction of animal performance for model evaluation as described by Tedeschi (2006). The CNCPS was also used to predict urinary and fecal N excretion for a hypothetical period of 150 d, which is approximately the common length of a feedlot. Data were analyzed using the Model Evaluation System v. 2.0.7 (**MES**; Tedeschi, 2006; http://nutritionmodels.tamu.edu/mes).

Results and discussion

Model validation

The relationship between observed ADG and ADG predicted by the model is presented on Figure 6.1. The first limiting allowable ADG predicted by the model - either from metabolizable energy (**ME**) or metabolizable protein (**MP**) - was compared to the observed gain. The CNCPS system was able to explain 66% of the variation in animal performance with an average underprediction of 85? g d^{-1} (mean bias of 5.9%). The intercept and the slope of the linear regression (Figure 6.1) were not different from zero and one respectively, which indicates good agreement.

The accuracy of the model was higher (Cb = 0.94; Tedeschi, 2006) than the precision (R^2 = 0.66), suggesting that some variation was not accounted for by the

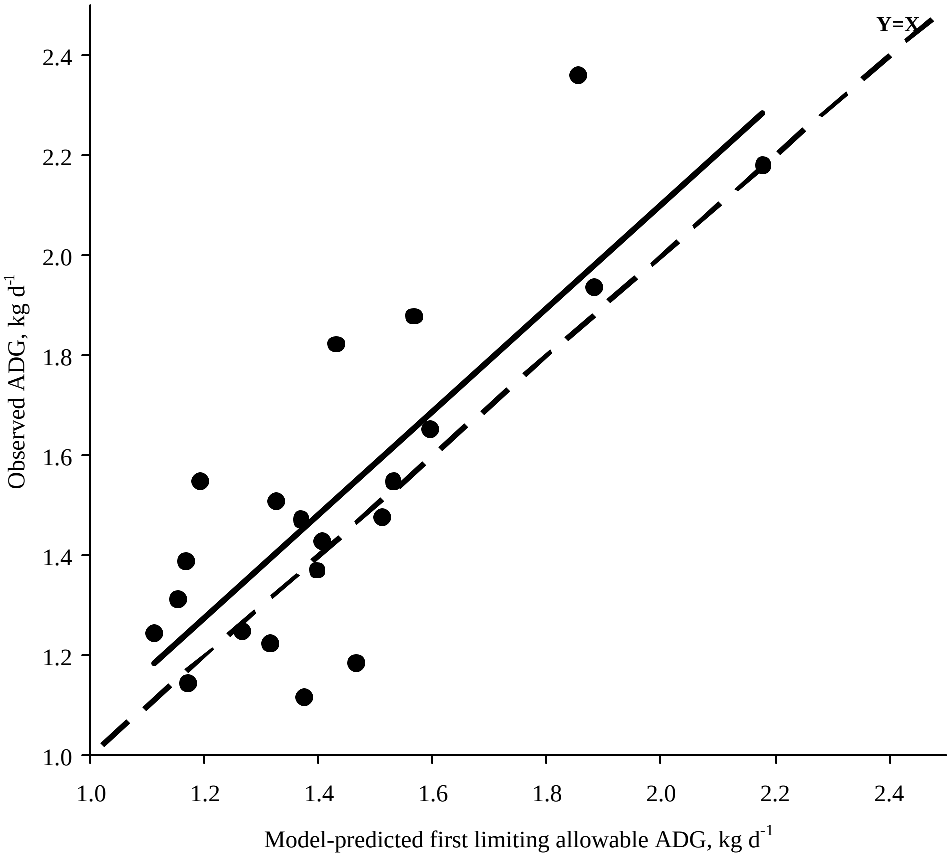

Figure 6.1. Relationship between observed average daily gain (ADG) and first limiting allowable ADG (ME or MP) predicted by the Cornell Net Carbohydrate and Protein System.

model. The CNCPS accurately predicted the performance of these animals. Because of the high accuracy in predicting gain, we used the model to simulate the excretion of N (urine and feces) on different dietary CP diets.

Prediction of N excretion

The CNCPS predictions of urinary and fecal N excretion (150 d) are presented in Figure 6.2. As dietary CP decreased from 13 to 11.5%, the model indicated that the total N excretion was reduced by approximately 16%. A further reduction of dietary CP from 11.5% to 10% caused an even greater reduction in total N excretion (26%), resulting in a total reduction of N excretion by 38% when dietary protein was decreased from 13 to 10% of CP (% DM). Moreover, as dietary CP decreased, the ratio of urinary to fecal N decreased considerably (1:1 to 1:0.55).

The reduction in the ratio of urinary N to fecal N is desirable because most of the volatilization of manure N to NH_3 is from the urinary N (Cole and Greene, 1998; Varel et al., 1999). The lower the volatilization of N, the higher will be the ratio of N to P, being more adequate for manure application as crop fertilizers (Cole and Greene, 1998).

Implications

Feeding nutrients at concentrations that closely match animal requirements can prevent excess excretion of nutrients in feedlots without effects on animal performance. Dietary CP levels can be reduced to conserve N during the final stages of finishing without any reduction in ADG. Reducing supplemental CP from natural CP sources will also reduce dietary P intake and subsequent excretion.

Further research is necessary to determine whether phase feeding of protein can be used as a tool to decrease N and P excretion without affecting animal performance. Decision support systems that integrate animal-plant-soil and environment can greatly enhance improvements in nutrient utilization and recycling. Mathematical nutrition models are powerful tools to assist in formulating and balancing animal diets to minimize environmental pollution while maintaining satisfactory animal performance.

These findings suggest that it is possible to use mathematical models to assist on precision feeding. The model can be used to predict total N excretion. Mathematical models can be a useful tool to assist in formulating and balancing animal diets to minimize environmental pollution.

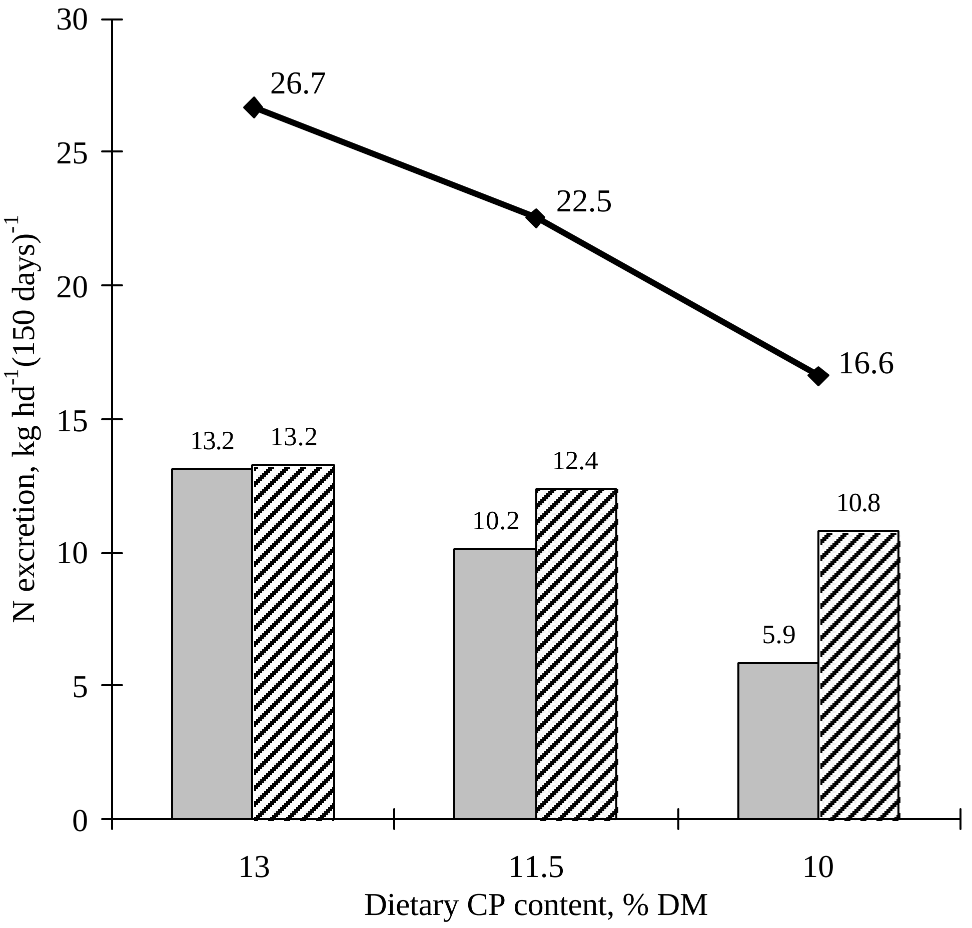

Figure 6.2. Urinary (solid bars), fecal (hash bars), and total N excretion (line) predictions for cattle fed different CP concentrations by the Cornell Net Carbohydrate and Protein System

CHAPTER VII

CONCLUSIONS

Data confirmed that it is possible to manipulate marbling to improve carcass merit and profitability. Results showed that growing animals fed different energy sources during growing had higher changes in intramuscular fat, but these effects might have been overcome by the unexpected differences in amount of energy consumed.

Our results suggest that the expected changes in insulin sensitivity caused by feeding diets with high levels of starch did not occur in our experimental conditions. Therefore, the mechanism by how different growing systems might affect intramuscular fat deposition was not totally elucidated.

In addition, the different growing systems improved marbling scores, which greatly impacted profitability per head. Our results suggested that producers using a grid-based pricing system can improve carcass merit allowing them to capturate premiums and improve profitability by utilizing a high grain diets on growing systems prior to entering the feedlot.

In our model evaluations, we found that the CVDS model predicted DM required for individual animals with an acceptable degree of accuracy. This data suggest that this model might be able to allocate feed to individual animals with mixed ownership within a pen in customer feedyards. When an adjustment factor was included, both models were able to predict DMI; however the NRC predictions were less accurate. Both models were able to accurately predict DMI for groups. When analyzing the data by previous treatment during growing, data show that the prediction of DM required for finishing cattle was affected by the diet fed to cattle prior to the finishing phase. Therefore, cattle background information might be useful to increase accuracy of models design to predict individual feed required.

In the model evaluation for precision feeding, we showed that mathematical models might assist in reducing N excretion by meeting animal requirements more accurately. Therefore, they can useful tools in formulating and balancing animal diets to minimize environmental pollution.

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APPENDIX A

Table A-1. Intake data from growing period (56 d).

Period	Steer ID	CVDS	ObsDMI	NRC	TRT
1	1	9.315	10.45	9.30	1
1	19	9.431	10.45	9.20	1
1	31	10.78	9.59	8.90	1
1	37	9.452	10.16	9.80	1
1	85	11.042	10.98	11.15	1
1	118	9.014	10.81	8.98	1
1	128	11.356	6.32	11.08	1
1	155	7.767	11.22	7.95	1
1	179	6.158	10.12	5.80	1
1	263	7.961	10.17	7.88	1
1	290	8.153	10.08	8.00	1
1	21	9.527	10.43	9.06	2
1	70	8.98	10.82	8.40	2
1	93	7.891	7.79	9.55	2
1	95	15.237	10.77	13.90	2
1	112	10.442	11.34	9.59	2
1	161	10.507	10.17	10.06	2
1	165	7.804	11.97	7.26	2
1	198	9.181	8.92	8.47	2
1	254	8.131	10.41	7.58	2
1	256	9.729	9.66	11.96	2
1	257	9.307	9.81	11.25	2
1	291	9.884	10.18	9.50	2
1	22	5.938	6.72	5.08	3
1	29	8.369	6.67	8.05	3
1	65	6.272	6.98	6.05	3
1	89	4.766	5.02	4.55	3
1	102	6.531	6.25	7.45	3
1	154	6.617	6.83	6.25	3
1	173	5.581	6.63	5.20	3
1	192	6.378	6.30	5.98	3
1	205	8.168	6.18	7.25	3
1	261	7.403	6.94	7.20	3
1	275	8.288	6.63	7.80	3
1	278	6.708	6.70	6.60	3
1	9	15.029	12.19	13.90	4
1	59	11.939	10.74	11.83	4
1	77	12.327	13.43	12.21	4
1	86	12.237	10.91	11.80	4
1	94	12.704	11.44	9.35	4
1	123	11.913	11.42	11.80	4
1	136	12.086	12.12	11.71	4
1	157	11.499	11.95	11.55	4
1	185	11.164	10.37	11.52	4
1	193	11.34	11.75	11.15	4
1	299	9.572	10.90	10.65	4
1	300	12.089	11.51	12.19	4

Table A-2. Intake data from finishing period (84 d).

Period	Steer ID	CVDS	ObsDMI	NRC	TRT
2	1	13.05	13.17	12.45	1
2	19	11.41	11.17	10.5	1
2	31	12.18	9.96	11.81	1
2	37	11.58	10.77	11.305	1
2	85	11.82	12.13	11.12	1
2	118	11.42	10.89	10.8	1
2	128	12.16	10.28	11.52	1
2	155	12.57	11.83	12.31	1
2	179	12.18	10.63	11.1	1
2	263	11.54	11.19	10.91	1
2	290	11.41	10.83	10.75	1
2	21	12.46	11.67	11.35	2
2	70	12.72	12.94	11.41	2
2	93	10.94	6.84	10.4	2
2	95	12.09	12.87	10.54	2
2	112	12.61	12.66	10.85	2
2	161	11.84	11.49	10.68	2
2	165	13.55	12.68	12.14	2
2	198	10.88	10.59	9.5	2
2	254	11.58	11.68	10.3	2
2	256	11.73	12.24	10.96	2
2	257	10.32	10.25	9.52	2
2	291	12.88	12.7	11.74	2
2	22	8.79	8.37	8.36	3
2	29	12.36	11.89	11.4	3
2	65	9.39	9.51	8.83	3
2	89	8.82	7.86	8.55	3
2	102	11.58	10.95	10.95	3
2	154	11.28	10.94	10.4	3
2	173	12.76	11.59	11.8	3
2	192	13.83	12.19	12.7	3
2	205	11.68	6.69	10.45	3
2	261	12.12	11.48	11.4	3
2	275	12.19	10.79	10.93	3
2	278	11.29	11.12	10.84	3
2	9	13.57	12.31	11.62	4
2	59	9.55	9.35	8.69	4
2	77	11.36	12.59	10.45	4
2	86	11.91	10.91	10.66	4
2	94	11.09	10.57	9.75	4
2	123	10.36	10.34	9.45	4
2	136	12.55	12.32	11.3	4
2	157	10.83	11.18	10.08	4
2	185	11.67	10.6	11.2	4
2	193	11.71	11.4	10.7	4
2	299	11.48	10.9	11	4
2	300	12.2	11.32	11.45	4

Table A-3. Insulin data.

ID	TRT	GTT	Fract. Disap. rate	Half Life	AUC TOTAL	Net AUC	Baseline	Peak	Peak time
1	1	1	-0.0144	48.06	172.11	140.21	0.58	5.08	5.0
37	1	1	-0.0060	114.70	197.14	150.94	0.84	5.10	5.0
21	2	1	-0.0257	26.91	252.64	214.69	0.69	7.18	10.0
95	2	1	-0.0138	50.20	233.88	174.55	1.13	6.57	10.0
161	2	1	-0.0078	88.63	108.15	89.45	0.34	2.56	10.0
165	2	1	-0.0510	13.58	302.26	266.51	0.65	9.74	10.0
198	2	1	-0.0133	51.96	229.45	186.55	0.78	5.64	10.0
254	2	1	-0.0181	38.39	198.31	164.76	0.61	4.92	10.0
22	3	1	-0.0125	55.59	197.26	129.06	1.24	4.88	2.5
173	3	1	-0.0323	21.46	217.65	140.65	1.40	5.23	15.0
278	3	1	-0.0121	57.28	233.98	194.38	0.72	6.59	10.0
9	4	1	-0.0268	25.83	235.55	205.85	0.54	9.59	5.0
77	4	1	-0.0158	43.77	179.09	131.24	0.88	5.61	0.0
86	4	1	-0.0155	44.76	121.99	81.29	0.74	3.03	10.0
299	4	1	-0.0235	29.45	136.01	97.51	0.70	4.93	5.0
300	4	1	-0.0371	18.68	251.39	217.84	0.61	8.98	5.0
1	1	2	-0.0231	29.97	160.00	133.05	0.49	5.09	0.0
31	1	2	-0.0732	9.47	72.56	44.74	0.53	2.39	45.0
118	1	2	-0.0204	33.94	143.76	104.71	0.71	4.08	10.0
179	1	2	-0.0141	49.18	358.35	257.15	1.84	10.08	15.0
21	2	2	-0.0298	23.29	235.74	201.09	0.63	8.63	5.0
161	2	2	-0.0558	12.42	74.63	61.43	0.24	2.86	15.0
165	2	2	-0.0432	16.03	343.54	254.44	1.62	15.97	5.0
198	2	2	-0.0058	119.28	167.25	57.80	1.99	4.24	25.0
254	2	2	-0.0334	20.77	274.03	97.63	3.92	10.35	25.0
22	3	2	-0.0195	35.46	171.94	81.19	1.65	6.24	10.0
154	3	2	-0.0529	13.11	212.54	130.59	1.49	10.13	5.0
173	3	2	-0.0302	22.96	1086.79	774.39	5.68	35.43	10.0
192	3	2	-0.0485	14.28	218.63	142.73	1.38	10.88	0.0
278	3	2	-0.0395	17.54	85.25	48.40	0.67	3.54	5.0
9	4	2	-0.0264	26.25	65.28	50.43	0.27	3.02	5.0
77	4	2	-0.0184	37.63	88.64	69.39	0.87	4.79	5.0
86	4	2	-0.0336	20.62	123.93	81.03	0.78	5.29	5.0
193	4	2	-0.0126	54.97	203.58	148.58	1.00	7.26	5.0
299	4	2	-0.0148	46.77	143.98	57.08	1.58	4.10	10.0
300	4	2	-0.0666	10.40	322.96	279.51	0.79	14.24	5.0
1	1	3	-0.0152	45.52	167.29	90.84	1.39	4.98	0.0
31	1	3	-0.0212	32.64	309.33	176.23	2.42	9.33	5.0
37	1	3	-0.0080	86.70	161.45	113.05	0.69	2.98	55.0
179	1	3	-0.0239	28.95	392.83	247.63	2.64	13.85	2.5
95	2	3	-0.0248	27.91	184.75	135.25	0.90	4.96	0.0
161	2	3	-0.0332	20.87	215.33	124.88	2.01	7.77	0.0
165	2	3	-0.0275	25.17	301.03	249.88	0.93	8.97	2.5
198	2	3	-0.0108	64.43	338.01	231.31	1.94	7.84	2.5
254	2	3	-0.0282	24.57	314.86	216.41	1.79	10.38	5.0
22	3	3	-0.0279	24.82	315.33	210.28	1.91	9.19	5.0
154	3	3	-0.0400	17.32	255.10	175.35	1.45	9.83	10.0
173	3	3	-0.0383	18.11	320.05	235.90	1.53	10.64	2.5
192	3	3	-0.0195	35.59	181.56	87.51	1.71	7.17	0.0
278	3	3	-0.0175	39.51	803.86	438.11	6.65	21.22	15.0
9	4	3	-0.0360	19.23	139.21	84.76	0.99	5.96	2.5
77	4	3	-0.0090	76.88	155.63	73.68	1.49	4.42	0.0
86	4	3	-0.0286	24.25	197.85	92.25	1.92	8.41	2.5
193	4	3	-0.0072	96.16	295.43	201.38	1.71	6.87	15.0
299	4	3	-0.0174	39.84	247.95	168.75	1.44	5.64	25.0
300	4	3	-0.0412	16.83	488.20	395.80	1.68	13.97	10.0

Table A-4. Glucose data.

STEER	TRT	GTT	Frac. Disap. rate	Half-Life	AOC$_g$	Baseline	Peak	Peak time	AOCg/ AUCi
1	1	1	-0.0140	49.38	3500.53	60.35	194.91	2.50	25.0
37	1	1	-0.0096	72.45	2764.19	58.43	197.01	0.00	18.3
21	2	1	-0.0103	67.48	3427.42	65.55	193.07	2.50	16.0
95	2	1	-0.0057	122.44	2206.33	91.05	189.14	2.50	12.6
161	2	1	-0.0170	40.76	4474.79	61.39	212.21	0.00	50.0
165	2	1	-0.0230	30.14	5702.86	95.91	235.86	0.00	21.4
198	2	1	-0.0114	60.65	4281.41	87.19	218.45	0.00	23.0
254	2	1	-0.0063	110.02	2717.14	75.89	213.10	0.00	16.5
22	3	1	-0.0023	302.74	1359.44	115.16	182.96	5.00	10.5
173	3	1	-0.0093	74.78	3163.00	78.00	224.89	0.00	22.5
278	3	1	-0.0138	50.11	5512.86	85.81	238.16	0.00	28.4
9	4	1	-0.0089	77.96	5568.41	70.20	231.40	0.00	27.1
77	4	1	-0.0071	97.58	3102.59	94.27	230.00	0.00	23.6
86	4	1	-0.0095	72.59	1151.88	75.10	171.26	0.00	14.2
299	4	1	-0.0034	203.57	1913.58	107.45	188.51	2.50	19.6
300	4	1	-0.0091	76.13	3256.24	80.87	199.81	2.50	14.9
1	1	2	-0.0197	35.20	4138.87	70.18	200.25	5.00	31.1
31	1	2	-0.0038	181.87	2581.16	114.26	226.97	5.00	57.7
118	1	2	-0.0115	60.49	3961.32	79.21	225.54	0.00	37.8
179	1	2	-0.0045	153.42	1014.53	107.11	213.43	0.00	3.9
21	2	2	-0.0106	65.62	1139.85	97.93	163.18	0.00	5.7
161	2	2	-0.0025	280.01	2105.20	106.30	185.45	0.00	34.3
165	2	2	-0.0127	54.58	4715.33	70.15	173.63	0.00	18.5
198	2	2	-0.0044	157.40	1778.73	185.18	230.19	0.00	30.8
254	2	2	-0.0059	117.16	699.88	121.47	174.14	0.00	7.2
22	3	2	-0.0038	183.84	3984.22	95.42	233.67	2.50	49.1
154	3	2	-0.0100	69.60	5324.70	87.95	204.06	0.00	40.8
173	3	2	-0.0115	60.35	3823.46	75.64	212.27	0.00	4.9
192	3	2	-0.0065	106.74	2613.84	103.52	190.32	2.50	18.3
278	3	2	-0.0069	100.55	2408.91	73.21	204.97	0.00	49.8
9	4	2	-0.0126	54.79	3386.68	107.21	191.18	0.00	67.2
77	4	2	-0.0058	119.47	2864.37	170.90	216.76	5.00	41.3
86	4	2	-0.0045	152.55	1590.13	88.31	159.61	0.00	19.6
193	4	2	-0.0158	43.77	2172.62	105.30	187.53	0.00	14.6
299	4	2	-0.0050	137.51	2657.96	101.14	193.00	5.00	46.6
300	4	2	-0.0100	69.53	4798.98	84.43	216.51	0.00	17.2
1	1	3	-0.0117	59.47	2746.00	68.58	164.87	0.00	30.2
31	1	3	-0.0158	43.91	3939.34	101.65	223.64	0.00	22.4
37	1	3	-0.0107	64.57	7367.48	66.30	240.74	0.00	65.2
179	1	3	-0.0080	86.56	1806.44	88.04	157.94	2.50	7.3
95	2	3	-0.0118	58.64	2748.69	.	159.15	0.00	20.3
161	2	3	-0.0115	60.03	3274.66	92.22	179.22	0.00	26.2
165	2	3	-0.0137	50.60	3719.57	83.95	175.81	2.50	14.9
198	2	3	-0.0104	66.65	2577.91	93.77	186.79	0.00	11.1
254	2	3	-0.0114	60.90	1540.78	73.10	187.15	0.00	7.1
22	3	3	-0.0110	62.73	2974.43	.	181.93	2.50	14.1
154	3	3	-0.0138	50.35	4594.17	99.49	189.55	0.00	26.2
173	3	3	-0.0136	51.03	4190.73	74.83	194.12	0.00	17.8
192	3	3	-0.0074	94.03	3254.73	101.49	197.92	2.50	37.2
278	3	3	-0.0152	45.69	2071.62	128.82	188.40	0.00	4.7
9	4	3	-0.0165	42.00	3106.59	60.45	146.27	2.50	36.7
77	4	3	-0.0070	98.35	3031.76	76.17	210.08	0.00	41.2
86	4	3	-0.0099	70.30	1901.01	70.40	146.04	0.00	20.6
193	4	3	-0.0035	200.04	2265.35	104.05	186.67	2.50	11.2
299	4	3	-0.0029	241.97	1682.08	77.48	194.44	2.50	10.0
300	4	3	-0.0175	39.50	6445.82	80.15	228.15	0.00	16.3

Table A-5. Carcass data.

TRT	FBW	HCW	DRSS	MAR	FATTH	RAA	INTFA	YGRD
1	578.6	366.1	63.27	510	0.48	15.1	1.5	2.24
1	533.0	329.0	61.72	520	0.36	13.3	2	2.31
1	590.8	393.2	66.56	410	0.28	16.1	1.5	1.65
1	557.3	364.7	65.44	420	0.32	17.5	2	1.16
1	571.7	367.4	64.27	510	0.28	13.8	1.5	2.17
1	548.6	338.0	61.61	460	0.28	14.8	1.5	1.60
1	562.5	357.0	63.47	410	0.48	12.4	1.5	3.03
1	527.8	329.9	62.50	400	0.16	12.4	1.5	2.00
1	510.8	324.4	63.51	480	0.48	11.8	1.5	2.95
1	532.6	336.7	63.21	430	0.32	13.4	1.5	2.14
1	532.6	349.3	65.59	430	0.48	14.6	1.5	2.26
2	590.8	375.1	63.50	610	0.4	15	1.5	2.15
2	576.4	373.8	64.84	730	0.52	15.9	2	2.25
2	520.8	327.1	62.81	420	0.28	13.2	2	2.12
2	596.4	390.0	65.40	560	0.68	13.3	1.5	3.52
2	573.0	369.2	64.44	560	0.72	13.3	1.5	3.44
2	581.2	357.5	61.50	560	0.32	12.6	2	2.67
2	552.1	343.0	62.12	410	0.6	13.6	2	2.93
2	510.8	322.6	63.16	530	0.6	11.6	2	3.40
2	526.9	355.7	67.50	510	0.8	14.9	2	3.12
2	551.2	347.5	63.04	490	0.28	12.6	1.5	2.39
2	546.5	354.8	64.92	630	0.36	14.5	1.5	2.04
2	596.4	370.1	62.06	450	0.4	13.9	1.5	2.46
3	461.8	286.9	62.13	430	0.28	12.9	1.5	1.78
3	551.7	357.9	64.88	520	0.48	14.1	2	2.59
3	464.8	300.5	64.64	430	0.44	12.4	1.5	2.46
3	445.7	282.4	63.35	410	0.28	12.5	1.5	1.87
3	510.4	324.9	63.65	550	0.32	14	1.5	1.85
3	513.4	325.3	63.36	520	0.4	12.2	1.5	2.63
3	543.9	319.5	58.74	540	0.32	15.7	1.5	1.26
3	554.7	360.6	65.01	620	0.4	12.7	2	2.86
3	549.5	334.4	60.85	480	0.48	13.3	2	2.65
3	539.5	348.0	64.50	550	0.36	14.4	1.5	2.01
3	545.6	315.8	57.89	430	0.4	13	1	2.19
3	540.4	351.6	65.06	410	0.36	15.6	2	1.76
4	608.6	375.1	61.64	610	0.64	14.8	2	2.91
4	507.8	317.2	62.46	520	0.44	14	1	1.98
4	564.7	366.1	64.82	470	0.28	14.1	1.5	2.06
4	567.7	347.1	61.13	510	0.36	11.3	1.5	3.00
4	541.7	347.1	64.07	560	0.68	14.9	2	2.75
4	522.1	334.4	64.04	580	0.48	15	1.5	2.01
4	572.1	362.9	63.43	520	0.56	15.7	1.5	2.22
4	551.7	351.1	63.65	540	0.28	13.6	1.5	2.10
4	584.7	370.6	63.38	410	0.24	16.3	1.5	1.30
4	546.9	324.0	59.24	530	0.28	13.7	1.5	1.84
4	541.7	343.9	63.49	530	0.28	16.6	2	1.18
4	589.0	400.0	67.91	510	0.48	15.6	1.5	2.37

Table A-6. Grid Calculation (I).

TRT	ID	Marbling	QG	YG	Value/hd	QG			YG					WT	Value/hd
						Ch. upper 2/3	Choice- (BASE)	Select	1	2A	2B	3A (BASE)	3B	551-949lb. (BASE)	
						$5.00	$0.00	-$20.00	$6.50	$2.50	$1.00	$0.00	-$2.00	$0.00	
1	1	SM10	Choice -	2.24	$1,091.74		$0.0			$2.5				$0.0	
1	19	SM20	Choice -	2.31	$961.33		$0.0			$2.5				$0.0	
1	31	SL10	Select -	1.65	$1,156.52			-$20.0	$6.5					$0.0	
1	37	SL20	Select -	1.16	$1,091.70			-$20.0	$6.5					$0.0	
1	85	SM10	Choice -	2.17	$1,075.78		$0.0			$2.5				$0.0	
1	118	SL60	Select +	1.60	$992.26			-$20.0	$6.5					$0.0	
1	128	SL10	Select -	3.03	$1,042.31			-$20.0				$0.0		$0.0	
1	155	SL0	Select -	2.00	$964.03			-$20.0		$2.5				$0.0	
1	179	SL80	Select +	2.95	$943.37			-$20.0					-$2.0	$0.0	
1	263	SL30	Select -	2.14	$984.22			-$20.0		$2.5				$0.0	
1	290	SL30	Select -	2.26	$1,041.92			-$20.0		$2.5				$0.0	
					$11,345.2									$0.0	$1,031.4
2	21	MT10	Choice	2.15	$1,123.67	$5.0				$2.5				$0.0	
2	70	MD30	Choice +	2.25	$1,094.63	$5.0				$2.5				$0.0	
2	93	SL20	Select -	2.12	$975.95			-$20.0		$2.5				$0.0	
2	95	SM60	Choice -	3.52	$1,158.60		$0.0						-$2.0	$0.0	
2	112	SM60	Choice -	3.44	$1,098.66		$0.0					$0.0		$0.0	
2	161	SM60	Choice -	2.67	$1,044.66		$0.0				$1.0			$0.0	
2	165	SL10	Select -	2.93	$1,021.57			-$20.0			$1.0			$0.0	
2	198	SM30	Choice -	3.40	$959.98		$0.0					$0.0		$0.0	
2	254	SM10	Choice -	3.12	$1,038.27		$0.0					$0.0		$0.0	
2	256	SL90	Select +	2.39	$1,040.04			-$20.0			$1.0			$0.0	
2	257	MT30	Choice	2.04	$1,038.08	$5.0				$2.5				$0.0	
2	291	SL50	Select	2.46	$1,103.86			-$20.0		$2.5				$0.0	
					$12,697.9									$0.0	$1,058.2

Table A-7. Grid Calculation (II).

TRT	ID	Marbling	QG	YG	Value/hd	QG			YG					WT	Value/hd
						Ch. upper 2/3	Choice- (BASE)	Select	1	2A	2B	3A (BASE)	3B	551-949lb. (BASE)	
						$5.00	$0.00	-$20.00	$6.50	$2.50	$1.00	$0.00	-$2.00	$0.00	
3	22	SL30	Select -	1.78	$860.12			-$20.0	$6.5					$0.0	
3	29	SM20	Choice -	2.59	$1,046.00		$0.0				$1.0			$0.0	
3	65	SL30	Select -	2.46	$876.51			-$20.0		$2.5				$0.0	
3	89	SL10	Select -	1.87	$846.65			-$20.0	$6.5					$0.0	
3	102	SM50	Choice -	1.85	$973.22		$0.0		$6.5					$0.0	
3	154	SM20	Choice -	2.63	$969.06		$0.0				$1.0			$0.0	
3	173	SM40	Choice -	1.26	$962.06		$0.0		$6.5					$0.0	
3	192	MT20	Choice	2.86	$1,054.08	$5.0					$1.0			$0.0	
3	205	SL80	Select +	2.65	$995.99			-$20.0			$1.0			$0.0	
3	261	SM50	Choice -	2.01	$1,017.88		$0.0			$2.5				$0.0	
3	275	SL30	Select -	2.19	$922.29			-$20.0		$2.5				$0.0	
3	278	SL10	Select -	1.76	$1,052.65			-$20.0	$6.5					$0.0	
					$11,576.5									$0.0	$964.7
4	9	MT10	Choice	2.91	$1,117.17	$5.0					$1.0			$0.0	
4	59	SM20	Choice -	1.98	$930.33		$0.0		$6.5					$0.0	
4	77	SL70	Select +	2.06	$1,091.74			-$20.0		$2.5				$0.0	
4	86	SM10	Choice -	3.00	$1,033.69		$0.0				$1.0			$0.0	
4	94	SM60	Choice -	2.75	$1,033.69		$0.0				$1.0			$0.0	
4	123	SM80	Choice -	2.01	$997.49		$0.0			$2.5				$0.0	
4	136	SM20	Choice -	2.22	$1,082.31		$0.0			$2.5				$0.0	
4	157	SM40	Choice -	2.10	$1,027.31		$0.0			$2.5				$0.0	
4	185	SL10	Select -	1.30	$1,109.20			-$20.0	$6.5					$0.0	
4	193	SM30	Choice -	1.84	$970.52		$0.0		$6.5					$0.0	
4	299	SM30	Choice -	1.18	$1,029.76		$0.0		$6.5					$0.0	
4	300	SM10	Choice -	2.37	$1,192.72		$0.0			$2.5				$0.0	
					$12,615.9									$0.0	$1,051.3

Table A-8. Real-time ultrasound readings and changes on accretion (I).

ID	TRT	MA 1	BF 1	MA 56	BF 56	MA 0-56	BF 0-56d	MA 140	BF 140	MA 0-140	BF 0-140	MA 113-140	BF 113-140	MARB 56-140	BF 56-140
1	1	2.71	2.00	3.05	2.00	0.34	0.00	4.80	11.70	2.09	9.70	-0.24	3.38	1.75	9.70
9	4	4.36	0.80	3.99	3.33	-0.37	2.53	6.18	12.82	1.82	12.02	0.13	3.23	2.19	9.49
19	1	2.76	0.80	2.99	0.80	0.23	0.00	4.38	5.86	1.62	5.06	-0.99	1.89	1.39	5.06
21	2	3.00	0.80	3.43	3.47	0.43	2.67	5.64	8.67	2.64	7.87	0.89	1.68	2.21	5.20
22	3	2.69	0.80	3.08	2.00	0.39	1.20	4.18	7.62	1.49	6.82	0.26	2.25	1.10	5.62
29	3	2.73	0.80	3.33	0.92	0.60	0.12	4.51	12.05	1.78	11.25	-0.13	4.71	1.18	11.13
31	1	2.88	0.80	2.96	0.80	0.08	0.00	3.30	5.79	0.42	4.99	0.35	2.95	0.34	4.99
37	1	2.72	0.80	3.60	0.80	0.88	0.00	5.43	3.12	2.71	2.32	1.37	-1.90	1.83	2.32
59	4	2.97	2.00	4.13	4.32	1.16	2.32	5.15	8.11	2.18	6.11	0.67	-2.95	1.02	3.79
65	3	2.77	0.80	3.34	2.00	0.57	1.20	5.30	6.22	2.53	5.42	0.74	1.27	1.96	4.22
70	2	3.59	0.80	3.69	3.26	0.10	2.46	5.77	9.94	2.18	9.14	0.96	-2.32	2.08	6.68
77	4	2.65	0.80	3.31	4.11	0.66	3.31	3.92	9.45	1.27	8.65	-0.48	2.39	0.61	5.34
85	1	2.72	0.80	3.01	1.28	0.29	0.48	5.11	4.95	2.39	4.15	1.17	0.42	2.10	3.67
86	4	2.62	0.80	2.94	2.00	0.32	1.20	3.88	6.57	1.26	5.77	0.72	1.41	0.94	4.57
89	3	2.75	0.80	3.03	2.00	0.28	1.20	4.79	5.37	2.04	4.57	-0.08	1.90	1.76	3.37
93	2	2.90	0.80	3.10	2.21	0.20	1.41	3.88	7.48	0.98	6.68	0.50	-1.34	0.78	5.27
94	4	3.06	0.80	4.70	4.81	1.64	4.01	5.63	13.03	2.57	12.23	0.08	0.42	0.93	8.22
95	2	3.68	0.80	5.74	4.11	2.06	3.31	6.17	10.43	2.49	9.63	-0.03	2.18	0.43	6.32
102	3	3.43	0.80	3.94	0.80	0.51	0.00	6.13	9.52	2.70	8.72	0.44	2.46	2.19	8.72
112	2	3.31	0.80	3.69	4.67	0.38	3.87	4.67	10.50	1.36	9.70	-1.26	2.95	0.98	5.83
118	1	2.71	0.80	2.91	2.14	0.20	1.34	4.66	7.20	1.95	6.40	1.10	2.67	1.75	5.06
123	4	4.14	3.68	5.50	2.28	1.36	-1.40	5.83	6.71	1.69	3.03	1.13	1.06	0.33	4.43
128	1	4.36	0.80	5.07	2.14	0.71	1.34	5.39	6.00	1.03	5.20	0.65	-0.22	0.32	3.86
136	4	2.75	0.80	3.86	3.12	1.11	2.32	5.10	13.24	2.35	12.44	0.38	3.65	1.24	10.12

Table A-9. Real-time ultrasound readings and changes on accretion (II).

ID	TRT	MA 1	BF 1	MA 56	BF 56	MA 0-56	BF 0-56d	MA 140	BF 140	MA 0-140	BF 0-140	MA 113-140	BF 113-140	MARB 56-140	BF 56-140
154	3	3.33	2.00	3.73	3.68	0.40	1.68	4.94	11.63	1.61	9.63	-0.11	2.25	1.21	7.95
155	1	3.48	0.80	3.07	0.80	-0.41	0.00	4.12	6.00	0.64	5.20	0.12	1.68	1.05	5.20
157	4	2.88	0.80	3.61	6.14	0.73	5.34	5.84	12.12	2.96	11.32	0.28	2.46	2.23	5.98
161	2	2.69	0.80	4.03	2.42	1.34	1.62	4.98	11.13	2.29	10.33	0.19	2.95	0.95	8.71
165	2	2.59	0.80	3.61	2.00	1.02	1.20	3.33	14.93	0.74	14.13	-0.78	6.11	-0.28	12.93
173	3	2.80	0.92	3.61	2.20	0.81	1.28	5.91	6.92	3.11	6.00	0.35	0.00	2.30	4.72
179	1	4.11	0.80	3.78	1.53	-0.33	0.73	5.04	9.87	0.93	9.07	0.05	5.27	1.26	8.34
185	4	2.90	0.80	3.35	2.00	0.45	1.20	4.07	4.95	1.17	4.15	1.03	0.56	0.72	2.95
192	3	4.13	0.80	3.87	2.30	-0.26	1.50	5.48	10.43	1.35	9.63	0.10	2.53	1.61	8.13
193	4	3.60	0.80	4.23	3.68	0.63	2.88	5.11	8.25	1.51	7.45	0.41	0.70	0.88	4.57
198	2	3.74	0.80	4.58	3.26	0.84	2.46	6.02	7.20	2.28	6.40	0.33	-2.25	1.44	3.94
205	3	2.86	0.80	3.24	3.97	0.38	3.17	5.32	9.17	2.46	8.37	-0.09	2.95	2.08	5.20
254	2	3.38	2.00	4.87	2.56	1.49	0.56	5.49	7.90	2.11	5.90	-0.18	0.84	0.62	5.34
256	2	3.47	0.80	4.04	1.28	0.57	0.48	5.24	5.79	1.77	4.99	-0.21	0.56	1.20	4.51
257	2	3.47	0.80	3.99	3.33	0.52	2.53	6.06	6.36	2.59	5.56	0.45	0.92	2.07	3.03
261	3	3.40	0.80	5.06	2.07	1.66	1.27	5.33	12.54	1.93	11.74	0.28	3.09	0.27	10.47
263	1	2.72	0.80	2.85	2.00	0.13	1.20	4.84	12.33	2.12	11.53	-0.44	5.34	1.99	10.33
275	3	3.39	0.80	3.73	2.00	0.34	1.20	6.20	7.90	2.81	7.10	1.30	-1.69	2.47	5.90
278	3	2.80	0.80	2.61	2.07	-0.19	1.27	3.98	6.43	1.18	5.63	0.05	1.20	1.37	4.36
290	1	2.89	0.80	2.70	2.00	-0.19	1.20	4.18	11.13	1.29	10.33	0.44	3.30	1.48	9.13
291	2	2.78	1.41	3.81	3.76	1.03	2.35	4.70	13.10	1.92	11.69	-0.41	4.10	0.89	9.34
299	4	2.75	0.80	3.51	2.42	0.76	1.62	4.54	6.64	1.79	5.84	-0.64	4.22	1.03	4.22
300	4	2.87	0.80	4.30	2.42	1.43	1.62	4.78	6.85	1.91	6.05	-0.32	1.06	0.48	4.43

Table A-10. Glucose kinetics calculation.

Glucose	ID	TIME	GC#	TRT				Peak	Peak time	Ln [ ]	Fr. Dis. Rate	Half Life
60.4	1	-5	1	1								
193.8	1	0	1	1				194.9	2.5	5.27	-0.014	49.38
194.9	1	2.5	1	1						5.27		
131.2	1	5	1	1						4.88		
144.2	1	10	1	1						4.97		
140.5	1	35	1	1						4.95		
103.0	1	45	1	1	Tot AUC	Total Area	AOC			4.63		
69.1	1	55	1	1	6732.246	10232.775	3500.53			4.24		
70.2	1	-5	2	1								
150.5	1	0	2	1						5.01	-0.020	35.20
167.0	1	2.5	2	1						5.12		
200.3	1	5	2	1						5.30		
197.9	1	15	2	1				200.3	5	5.29		
110.0	1	25	2	1						4.70		
87.3	1	35	2	1						4.47		
46.8	1	45	2	1	Tot AUC	Total Area	AOC			3.85		
90.6	1	55	2	1	5873.633	10012.5	4138.868			4.51		
68.6	1	-5	3	1								
164.9	1	0	3	1						5.11	-0.012	59.47
154.0	1	2.5	3	1						5.04		
150.7	1	10	3	1				164.9	0	5.02		
130.9	1	15	3	1						4.87		
106.5	1	25	3	1						4.67		
84.0	1	35	3	1						4.43		
108.0	1	45	3	1	Tot AUC	Total Area	AOC			4.68		
87.4	1	55	3	1	6321.846	9067.85	2746.00			4.47		
70.2	9	-5	1	4								
231.4	9	0	1	4						5.44	-0.009	77.96
126.5	9	2.5	1	4				231.4	0	4.84		
173.5	9	5	1	4						5.16		
148.4	9	10	1	4						5.00		
119.0	9	25	1	4						4.78		
125.1	9	35	1	4						4.83		
111.0	9	45	1	4	Tot AUC	Total Area	AOC			4.71		
114.0	9	55	1	4	7158.313	12726.725	5568.41			4.74		
107.2	9	-5	2	4								
191.2	9	0	2	4				191.2	0	5.25	-0.013	54.79
176.5	9	2.5	2	4						5.17		
166.3	9	5	2	4						5.11		
150.2	9	10	2	4						5.01		
150.1	9	15	2	4						5.01		
132.3	9	25	2	4						4.89		
103.0	9	35	2	4						4.63		
115.5	9	45	2	4	Tot AUC	Total Area	AOC			4.75		
87.8	9	55	2	4	7127.944	10514.625	3386.681			4.48		
60.5	9	-5	3	4								
62.0	9	0	3	4						4.13	-0.017	42.00
146.3	9	2.5	3	4						4.99		
137.1	9	5	3	4				146.3	2.5	4.92		
134.5	9	10	3	4						4.90		
93.6	9	15	3	4						4.54		
75.1	9	35	3	4						4.32		
72.8	9	45	3	4	Tot AUC	Total Area	AOC			4.29		
35.8	9	55	3	4	4572.326	7678.9125	3106.59			3.58		
65.6	21	-5	1	2								
157.7	21	0	1	2						5.06	-0.010	67.48
193.1	21	2.5	1	2						5.26		
180.3	21	5	1	2				193.1	2.5	5.19		
138.1	21	10	1	2						4.93		
135.9	21	15	1	2						4.91		
125.2	21	25	1	2						4.83		

125.1	21	35	1	2						4.83		
108.9	21	45	1	2	Tot AUC	Total Area	AOC			4.69		
98.2	21	55	1	2	6708.75	10136.175	3427.42			4.59		
97.9	21	-5	2	2								
163.2	21	0	2	2						5.09	-0.011	65.62
162.7	21	2.5	2	2						5.09		
170.0	21	5	2	2						5.14		
163.5	21	10	2	2				163.2	0	5.10		
141.7	21	20	2	2						4.95		
153.9	21	25	2	2						5.04		
150.7	21	35	2	2						5.02		
125.3	21	45	2	2	Tot AUC	Total Area	AOC			4.83		
76.6	21	55	2	2	7835.05	8974.9	1139.85			4.34		
115.2	22	-5	1	3								
139.2	22	0	1	3						4.94	-0.002	302.74
134.0	22	2.5	1	3						4.90		
183.0	22	5	1	3				183.0	5	5.21		
161.7	22	10	1	3						5.09		
140.1	22	15	1	3						4.94		
181.0	22	25	1	3						5.20		
169.0	22	35	1	3						5.13		
136.9	22	45	1	3	Tot AUC	Total Area	AOC			4.92		
120.4	22	55	1	3	8525.97	7654.35	-871.62			4.79		
95.4	22	-5	2	3								
219.3	22	0	2	3						5.39	-0.004	183.84
233.7	22	2.5	2	3				233.7	2.5	5.45		
189.7	22	5	2	3						5.25		
145.2	22	10	2	3						4.98		
125.4	22	15	2	3						4.83		
164.4	22	25	2	3						5.10		
166.1	22	35	2	3						5.11		
150.6	22	45	2	3	Tot AUC	Total Area	AOC			5.01		
175.0	22	55	2	3	9709.42	5725.2	3984.22	8078.9		5.17		
	22	-5	3	3								
174.8	22	0	3	3						5.16	-0.011	62.73
181.9	22	2.5	3	3				181.9	2.5	5.20		
154.0	22	5	3	3						5.04		
153.1	22	10	3	3						5.03		
154.0	22	15	3	3						5.04		
127.7	22	25	3	3						4.85		
102.6	22	35	3	3						4.63		
102.7	22	45	3	3	Tot AUC	Total Area	AOC			4.63		
104.2	22	55	3	3	6576.64	9551.0625	2974.43			4.65		
79.5	31	-5	1	1								
208.6	31	0	1	1						5.34	-0.007	93.17
199.9	31	2.5	1	1				208.6	0	5.30		
156.4	31	5	1	1						5.05		
141.4	31	10	1	1						4.95		
158.6	31	15	1	1						5.07		
149.9	31	25	1	1						5.01		
140.0	31	35	1	1						4.94		
133.1	31	45	1	1	Tot AUC	Total Area	AOC			4.89		
122.8	31	55	1	1	8086.96	11473.55	3386.59			4.81		
114.3	31	-5	2	1								
146.8	31	0	2	1						4.99	-0.004	181.87
194.8	31	2.5	2	1						5.27		
227.0	31	5	2	1						5.42		
198.1	31	10	2	1				227.0	5	5.29		
190.6	31	15	2	1						5.25		
176.9	31	35	2	1						5.18		
132.6	31	45	2	1	Tot AUC	Total Area	AOC			4.89		
169.6	31	55	2	1	8767.34	11348.5	2581.16			5.13		
101.6	31	-5	3	1								
223.6	31	0	3	1						5.41	-0.016	43.91
215.0	31	2.5	3	1						5.37		
204.0	31	5	3	1						5.32		

177.2	31	10	3	1				223.6	0	5.18		
161.1	31	15	3	1						5.08		
157.0	31	25	3	1						5.06		
172.6	31	35	3	1						5.15		
95.1	31	45	3	1	Tot AUC	Total Area	AOC			4.55		
87.5	31	55	3	1	8360.59	12299.925	3939.34			4.47		
58.4	37	-5	1	1								
197.0	37	0	1	1						5.28	-0.010	72.45
165.5	37	2.5	1	1				197.0	0	5.11		
184.0	37	5	1	1						5.21		
144.4	37	10	1	1						4.97		
151.5	37	15	1	1						5.02		
180.5	37	25	1	1						5.20		
124.8	37	35	1	1						4.83		
132.5	37	45	1	1	Tot AUC	Total Area	AOC			4.89		
97.2	37	55	1	1	8071.36	10835.55	2764.19			4.58		
66.3	37	-5	3	1								
240.7	37	0	3	1						5.48	-0.011	64.57
120.1	37	2.5	3	1				240.7	0	4.79		
106.9	37	5	3	1						4.67		
85.1	37	10	3	1						4.44		
141.6	37	15	3	1						4.95		
106.0	37	25	3	1						4.66		
103.6	37	35	3	1						4.64		
89.5	37	45	3	1	Tot AUC	Total Area	AOC			4.49		
78.7	37	55	3	1	5873.22	13240.70	7367.48			4.37		
94.3	77	-5	1	4								
230.0	77	0	1	4				230.0	0	5.44	-0.007	97.58
184.2	77	2.5	1	4						5.22		
182.1	77	5	1	4						5.20		
183.2	77	10	1	4						5.21		
124.0	77	15	1	4						4.82		
158.3	77	25	1	4						5.06		
179.0	77	35	1	4						5.19		
148.5	77	45	1	4	Tot AUC	Total Area	AOC			5.00		
120.4	77	55	1	4	9547.41	12650.00	3102.59			4.79		
170.9	77	-5	2	4								
178.3	77	0	2	4						5.18	-0.006	119.47
189.9	77	2.5	2	4				216.8	5	5.25		
216.8	77	5	2	4						5.38		
177.7	77	10	2	4						5.18		
140.0	77	15	2	4						4.94		
163.6	77	25	2	4						5.10		
142.3	77	35	2	4						4.96		
181.9	77	45	2	4	Tot AUC	Total Area	AOC			5.20		
123.0	77	55	2	4	7973.38	10837.75	2864.37			4.81		
76.2	77	-5	3	4								
210.1	77	0	3	4				210.1	0	5.35	-0.007	98.35
137.5	77	2.5	3	4						4.92		
156.6	77	10	3	4						5.05		
173.5	77	15	3	4						5.16		
138.6	77	25	3	4						4.93		
130.9	77	35	3	4						4.87		
128.1	77	45	3	4	Tot AUC	Total Area	AOC			4.85		
120.1	77	55	3	4	8522.37	11554.13	3031.76			4.79		
75.1	86	-5	1	4								
171.3	86	0	1	4				171.3	0	5.14	-0.010	72.59
164.6	86	2.5	1	4						5.10		
171.2	86	5	1	4						5.14		
161.0	86	10	1	4						5.08		
157.4	86	15	1	4						5.06		
140.0	86	25	1	4						4.94		
131.5	86	35	1	4						4.88		
120.2	86	45	1	4	Tot AUC	Total Area	AOC			4.79		
96.5	86	55	1	4	8267.42	9419.30	1151.88			4.57		
88.3	86	-5	2	4								

159.6	86	0	2	4						5.07	-0.005	152.55
138.0	86	2.5	2	4				159.6	0	4.93		
130.4	86	5	2	4						4.87		
126.0	86	10	2	4						4.84		
127.9	86	15	2	4						4.85		
112.1	86	25	2	4						4.72		
120.0	86	35	2	4						4.79		
100.1	86	45	2	4	Tot AUC	Total Area	AOC			4.61		
124.8	86	55	2	4	7188.15	8778.28	1590.13			4.83		
70.4	86	-5	3	4								
146.0	86	0	3	4						4.98	-0.010	70.30
150.0	86	2.5	3	4				146.0	0	5.01		
159.5	86	5	3	4						5.07		
156.3	86	10	3	4						5.05		
80.0	86	25	3	4						4.38		
85.1	86	35	3	4						4.44		
104.5	86	45	3	4	Tot AUC	Total Area	AOC			4.65		
103.3	86	55	3	4	6130.91	8031.925	1901.01			4.64		
107.8	89	-5	2	3								
232.0	89	0	2	3				232.0	0	5.45	0.000	77238
235.3	89	2.5	2	3						5.46		
205.4	89	5	2	3						5.32		
225.2	89	15	2	3						5.42		
187.3	89	25	2	3						5.23		
243.6	89	42	2	3	Tot AUC	Total Area	AOC			5.50		
219.2	89	55	2	3	12020.26	12758.9	738.64			5.39		
91.1	95	-5	1	2								
189.1	95	2.5	1	2				189.1	2.5	5.24	-0.006	122.44
146.1	95	5	1	2						4.98		
122.7	95	10	1	2						4.81		
187.5	95	15	1	2						5.23		
157.2	95	25	1	2						5.06		
140.3	95	35	1	2						4.94		
137.8	95	45	1	2	Tot AUC	Total Area	AOC			4.93		
113.3	95	55	1	2	7723.52	9929.85	2206.33			4.73		
102.2		-5										
195.2	95	0	2	2						5.27	-0.013	54.54
170.0	95	2.5	2	2				195.2	0	5.14		
202.7	95	5	2	2						5.31		
172.3	95	15	2	2						5.15		
134.1	95	25	2	2						4.90		
114.3	95	35	2	2						4.74		
128.3	95	42	2	2	Tot AUC	Total Area	AOC			4.85		
94.6	95	55	2	2	7869.72	10734.35	2864.63			4.55		
	95	-5	3	2								
159.2	95	0	3	2								
158.5	95	2.5	3	2				159.2	0	5.07	-0.012	58.64
164.0	95	5	3	2						5.10		
117.7	95	10	3	2						4.77		
112.3	95	15	3	2						4.72		
121.6	95	25	3	2						4.80		
96.4	95	35	3	2						4.57		
68.7	95	45	3	2	Tot AUC	Total Area	AOC			4.23		
99.3	95	55	3	2	6004.56	8753.25	2748.69			4.60		
78.0	118	-5	1	1								
253.6	118	0	1	1				253.6	0	5.54	-0.014	51.32
154.5	118	5	1	1						5.04		
162.4	118	10	1	1						5.09		
93.4	118	30	1	1						4.54		
116.1	118	35	1	1						4.75		
114.6	118	45	1	1	Tot AUC	Total Area	AOC			4.74		
102.7	118	55	1	1	7132.68	13946.625	6813.95			4.63		
79.2	118	-5	2	1								
225.5	118	0	2	1						5.42	-0.011	60.49
189.0	118	2.5	2	1				225.5	0	5.24		
155.6	118	5	2	1						5.05		

145.0	118	15	2	1						4.98		
156.5	118	25	2	1						5.05		
137.4	118	35	2	1						4.92		
102.4	118	45	2	1	Tot AUC	Total Area	AOC			4.63		
108.4	118	55	2	1	8443.38	12404.7	3961.32			4.69		
87.9	154	-5	2	3								
204.1	154	0	2	3				204.1	0	5.32	-0.010	69.60
123.0	154	2.5	2	3						4.81		
119.6	154	5	2	3						4.78		
135.0	154	10	2	3						4.91		
103.6	154	15	2	3						4.64		
115.5	154	25	2	3						4.75		
93.5	154	35	2	3						4.54		
87.4	154	45	2	3	Tot AUC	Total Area	AOC			4.47		
94.4	154	55	2	3	5898.61	11223.3	5324.70			4.55		
99.5	154	-5	3	3								
189.6	154	0	3	3						5.24	-0.014	50.35
177.8	154	2.5	3	3				189.6	0	5.18		
146.7	154	5	3	3						4.99		
78.2	154	10	3	3						4.36		
137.0	154	15	3	3						4.92		
108.5	154	25	3	3						4.69		
91.7	154	35	3	3						4.52		
75.9	154	45	3	3	Tot AUC	Total Area	AOC			4.33		
84.2	154	55	3	3	5831.08	10425.25	4594.17			4.43		
		-5										
177.8	155	0	1	1								
207.9	155	2.5	1	1				207.9	2.5	5.34	-0.006	118.63
166.3	155	5	1	1						5.11		
190.1	155	10	1	1						5.25		
183.3	155	15	1	1						5.21		
168.5	155	25	1	1						5.13		
164.9	155	35	1	1						5.11		
146.0	155	45	1	1	Tot AUC	Total Area	AOC			4.98		
	155	55	1	1	7272.15	8834.48	1562.33					
111.9	155	-5	2	1								
154.5	155	0	2	1						5.04	-0.016	44.16
165.4	155	2.5	2	1				154.5	0	5.11		
176.6	155	5	2	1						5.17		
204.6	155	10	2	1						5.32		
155.1	155	15	2	1						5.04		
83.7	155	25	2	1						4.43		
109.4	155	35	2	1						4.70		
43.6	155	45	2	1	Tot AUC	Total Area	AOC			3.77		
130.2	155	55	2	1	7138.83	8496.95	1358.12			4.87		
68.3	155	-5	3	1								
186.4	155	0	3	1						5.23	-0.008	84.44
154.3	155	2.5	3	1				186.4	0	5.04		
138.7	155	5	3	1						4.93		
133.0	155	10	3	1						4.89		
100.0		15								4.61		
148.9	155	25	3	1						5.00		
91.5	155	45	3	1	Tot AUC	Total Area	AOC			4.52		
109.9	155	55	3	1	8190.67	10251.175	2060.50			4.70		
61.4	161	-5	1	2								
212.2	161	0	1	2				212.2	0	5.36	-0.017	40.76
194.1	161	2.5	1	2						5.27		
158.2	161	10	1	2						5.06		
136.1	161	15	1	2						4.91		
172.2	161	25	1	2						5.15		
95.1	161	35	1	2						4.55		
84.6	161	45	1	2	Tot AUC	Total Area	AOC			4.44		
86.4	161	55	1	2	7196.48	11671.275	4474.79			4.46		
106.3	161	-5	2	2								
185.5	161	0	2	2				185.5	0	5.22	-0.002	280.01
119.7	161	2.5	2	2						4.78		

191.3	161	5	2	2						5.25		
149.0	161	10	2	2						5.00		
155.6	161	15	2	2						5.05		
123.3	161	25	2	2						4.81		
154.5	161	35	2	2						5.04		
145.7	161	45	2	2	Tot AUC	Total Area	AOC			4.98		
139.8	161	55	2	2	8094.28	10199.475	2105.20			4.94		
92.2	161	-5	3	2								
179.2	161	0	3	2				179.2	0	5.19	-0.012	60.03
156.7	161	2.5	3	2						5.05		
125.0	161	5	3	2						4.83		
126.4	161	10	3	2						4.84		
128.6	161	15	3	2						4.86		
77.4	161	35	3	2	Tot AUC	Total Area	AOC			4.35		
96.9		45								4.57		
90.0	161	55	3	2	6582.44	9857.1	3274.66			4.50		
95.9	165	-5	1	2								
235.9	165	0	1	2				235.9	0	5.46	-0.023	30.14
189.5	165	2.5	1	2						5.24		
53.5	165	5	1	2						3.98		
161.1	165	10	1	2						5.08		
162.1	165	15	1	2						5.09		
96.8	165	25	1	2						4.57		
65.1	165	35	1	2						4.18		
60.4	165	45	1	2	Tot AUC	Total Area	AOC			4.10		
					4910.84	10613.70	5702.86					
70.2	165	-5	2	2								
173.6	165	0	2	2				173.6	0	5.16	-0.013	54.58
165.0	165	2.5	2	2						5.11		
154.7	165	5	2	2						5.04		
35.2	165	10	2	2						3.56		
73.8	165	15	2	2						4.30		
98.1	165	25	2	2						4.59		
92.9	165	35	2	2						4.53		
66.0	165	45	2	2	Tot AUC	Total Area	AOC			4.19		
65.2	165	55	2	2	4834.32	9549.65	4715.33			4.18		
83.9	165	-5	3	2								
131.3	165	0	3	2						4.88	-0.014	50.60
175.8	165	2.5	3	2				175.8	2.5	5.17		
167.8	165	5	3	2						5.12		
101.0	165	10	3	2						4.61		
132.4	165	15	3	2						4.89		
102.8	165	25	3	2						4.63		
83.3	165	35	3	2						4.42		
96.1	165	45	3	2	Tot AUC	Total Area	AOC			4.57		
68.3	165	55	3	2	5510.45	9230.03	3719.57			4.22		
78.0	173	-5	1	3								
224.9	173	0	1	3				224.9	0	5.42	-0.009	74.78
162.9	173	2.5	1	3						5.09		
181.4	173	10	1	3						5.20		
149.3	173	15	1	3						5.01		
119.6	173	25	1	3						4.78		
140.3	173	45	1	3	Tot AUC	Total Area	AOC			4.94		
111.1	173	55	1	3	9205.95	12368.95	3163.00			4.71		
75.6	173	-5	2	3								
212.3	173	0	2	3						5.36	-0.011	60.35
184.0	173	2.5	2	3				212.3	0	5.21		
188.6	173	5	2	3						5.24		
143.1	173	10	2	3						4.96		
155.3	173	15	2	3						5.05		
150.4	173	25	2	3						5.01		
148.7	173	35	2	3						5.00		
102.6	173	45	2	3	Tot AUC	Total Area	AOC			4.63		
104.2	173	55	2	3	7851.39	11674.85	3823.46			4.65		
74.8	173	-5	3	3								
194.1	173	0	3	3				194.1	0	5.27	-0.014	51.03

175.5	173	2.5	3	3						5.17		
162.2	173	5	3	3						5.09		
110.8	173	10	3	3						4.71		
117.4	173	15	3	3						4.77		
130.1		35								4.87		
82.0	173	45	3	3	Tot AUC	Total Area	AOC			4.41		
80.7	173	55	3	3	6485.87	10676.6	4190.73			4.39		
90.8	179	-5	1	1								
220.7	179	0	1	1						5.40	-0.001	653.92
82.3	179	2.5	1	1				220.7	0	4.41		
198.1	179	5	1	1						5.29		
181.6	179	10	1	1						5.20		
173.6	179	15	1	1						5.16		
182.0	179	25	1	1						5.20		
134.4	179	35	1	1						4.90		
153.7	179	45	1	1	Tot AUC	Total Area	AOC			5.03		
156.8	179	55	1	1	8918.93	12136.025	3217.10			5.06		
107.1	179	-5	2	1								
213.4	179	0	2	1				213.4	0	5.36	-0.005	153.42
203.2	179	2.5	2	1						5.31		
202.3	179	5	2	1						5.31		
220.0	179	10	2	1						5.39		
193.0	179	15	2	1						5.26		
198.2	179	25	2	1						5.29		
200.9	179	35	2	1						5.30		
192.0	179	45	2	1	Tot AUC	Total Area	AOC			5.26		
146.3	179	55	2	1	10723.85	11738.375	1014.53			4.99		
88.0	179	-5	3	1								
132.6	179	0	3	1				175.8	5	4.89	-0.008	86.56
157.9	179	2.5	3	1						5.06		
175.8	179	5	3	1						5.17		
135.9	179	10	3	1						4.91		
128.4	179	15	3	1						4.86		
120.9	179	25	3	1						4.79		
112.3	179	35	3	1	Tot AUC	Total Area	AOC			4.72		
119.0		45								4.78		
92.9	179	55	3	1	6067.99	8291.5875	2223.60			4.53		
		-5										
220.3	192	0	1	3				220.3	0	5.39	-0.005	128.47
90.7	192	10	1	3						4.51		
164.4	192	15	1	3						5.10		
197.1	192	25	1	3						5.28		
120.8	192	35	1	3						4.79		
145.9	192	45	1	3	Tot AUC	Total Area	AOC			4.98		
117.8	192	55	1	3	8241.45	12115.125	3873.67			4.77		
103.5	192	-5	2	3								
169.9	192	0	2	3						5.14	-0.006	106.74
190.3	192	2.5	2	3						5.25		
190.8	192	5	2	3				190.3	2.5	5.25		
175.4	192	10	2	3						5.17		
117.4	192	15	2	3						4.77		
141.6	192	35	2	3						4.95		
131.1	192	45	2	3	Tot AUC	Total Area	AOC			4.88		
129.0	192	55	2	3	7377.96	9991.8	2613.84			4.86		
101.5	192	-5	3	3								
151.8	192	0	3	3				197.9	2.5	5.02	-0.007	94.03
197.9	192	2.5	3	3						5.29		
158.0	192	5	3	3						5.06		
154.2	192	10	3	3						5.04		
142.8	192	15	3	3						4.96		
158.0	192	25	3	3						5.06		
113.7	192	35	3	3						4.73		
111.2	192	45	3	3	Tot AUC	Total Area	AOC			4.71		
125.0	192	55	3	3	7136.08	10390.8	3254.73			4.83		
96.9	193	-5	1	4								
183.7	193	2.5	1	4				183.7	2.5	5.21	-0.011	63.99

204.2	193	5	1	4						5.32		
133.8	193	10	1	4	Tot AUC	Total Area	AOC			4.90		
177.1		35								5.18		
72.9		45								4.29		
123.8	193	55	1	4	7448.79	9645.3	2196.51			4.82		
105.3	193	-5	2	4								
187.5	193	0	2	4						5.23	-0.016	43.77
199.6	193	2.5	2	4				187.5	0	5.30		
181.1	193	5	2	4						5.20		
172.5	193	10	2	4						5.15		
172.3	193	25	2	4						5.15		
110.8	193	35	2	4						4.71		
143.1	193	45	2	4	Tot AUC	Total Area	AOC			4.96		
62.2	193	55	2	4	8141.26	10313.875	2172.62			4.13		
104.1	193	-5	3	4								
186.7	193	2.5	3	4				186.7	2.5	5.23	-0.003	200.04
136.0	193	5	3	4						4.91		
134.6	193	10	3	4						4.90		
133.1	193	15	3	4						4.89		
140.9	193	25	3	4						4.95		
172.0	193	35	3	4						5.15		
143.8	193	45	3	4	Tot AUC	Total Area	AOC			4.97		
110.7	193	55	3	4	7534.83	9800.175	2265.35			4.71		
87.2	198	-5	1	2								
218.5	198	0	1	2						5.39	-0.011	60.65
202.8	198	2.5	1	2				218.5	0	5.31		
184.8	198	5	1	2						5.22		
166.3	198	10	1	2						5.11		
140.1	198	15	1	2						4.94		
156.6	198	25	1	2						5.05		
121.1	198	35	1	2						4.80		
93.8	198	45	1	2	Tot AUC	Total Area	AOC			4.54		
132.6	198	55	1	2	7733.34	12014.75	4281.41			4.89		
185.2	198	-5	2	2								
230.2	198	0	2	2				230.2	0	5.44	-0.004	157.40
228.8	198	2.5	2	2						5.43		
198.6	198	5	2	2						5.29		
207.2	198	10	2	2						5.33		
185.8	198	15	2	2						5.22		
212.6	198	25	2	2						5.36		
189.0	198	35	2	2						5.24		
205.6	198	45	2	2	Tot AUC	Total Area	AOC			5.33		
155.0	198	55	2	2	10881.73	12660.45	1778.73			5.04		
93.8	198	-5	3	2								
186.8	198	0	3	2				186.8	0	5.23	-0.010	66.65
188.7	198	2.5	3	2						5.24		
172.5	198	5	3	2						5.15		
162.5	198	10	3	2						5.09		
146.6	198	15	3	2						4.99		
127.8	198	25	3	2						4.85		
134.4	198	35	3	2						4.90		
134.1	198	45	3	2	Tot AUC	Total Area	AOC			4.90		
93.7	198	55	3	2	7695.55	10273.45	2577.91			4.54		
75.9	254	-5	1	2								
213.1	254	0	1	2						5.36	-0.006	110.02
197.8	254	2.5	1	2				213.1	0	5.29		
190.3	254	5	1	2						5.25		
175.2	254	10	1	2						5.17		
162.7	254	15	1	2						5.09		
162.4	254	25	1	2						5.09		
155.2	254	35	1	2						5.04		
156.0	254	45	1	2	Tot AUC	Total Area	AOC			5.05		
139.2	254	55	1	2	9003.36	11720.5	2717.14			4.94		
121.5	254	-5	2	2								
174.1	254	0	2	2				174.1	0	5.16	-0.006	117.16
159.6	254	2.5	2	2						5.07		

155.3	254	5	2	2						5.05		
230.0	254	10	2	2						5.44		
197.0	254	15	2	2						5.28		
127.3	254	25	2	2						4.85		
167.7	254	35	2	2	Tot AUC	Total Area	AOC			5.12		
151.2		45								5.02		
117.8	254	55	2	2	8877.54	9577.425	699.88			4.77		
73.1	254	-5	3	2								
187.2	254	0	3	2				187.2	0	5.23	-0.011	60.90
210.2	254	2.5	3	2						5.35		
195.0	254	5	3	2						5.27		
172.6	254	10	3	2						5.15		
154.7	254	15	3	2						5.04		
148.2	254	25	3	2						5.00		
125.8	254	35	3	2	Tot AUC	Total Area	AOC			4.83		
125.4	254	45	3	2	6880.98	8421.75	1540.78			4.83		
85.8	278	-5	1	3								
238.2	278	0	1	3				238.2	0	5.47	-0.014	50.11
231.0	278	2.5	1	3						5.44		
189.8	278	5	1	3						5.25		
164.3	278	10	1	3						5.10		
116.3	278	15	1	3						4.76		
164.3	278	25	1	3						5.10		
111.8	278	35	1	3						4.72		
94.4	278	45	1	3	Tot AUC	Total Area	AOC			4.55		
120.0	278	55	1	3	7585.95	13098.8	5512.86			4.79		
73.2	278	-5	2	3								
205.0	278	0	2	3				205.0	0	5.32	-0.007	100.55
171.5	278	2.5	2	3						5.14		
181.0	278	5	2	3						5.20		
153.3	278	10	2	3						5.03		
137.7	278	15	2	3						4.93		
157.7	278	25	2	3						5.06		
134.7	278	45	2	3	Tot AUC	Total Area	AOC			4.90		
124.0	278	55	2	3	8864.17	11273.075	2408.91			4.82		
128.8	278	-5	3	3								
188.4	278	0	3	3				188.4	0	5.24	-0.015	45.69
189.7	278	2.5	3	3						5.25		
187.7	278	5	3	3						5.23		
208.0	278	10	3	3						5.34		
174.4	278	15	3	3						5.16		
169.1	278	25	3	3						5.13		
142.3	278	35	3	3						4.96		
100.4	278	45	3	3	Tot AUC	Total Area	AOC			4.61		
82.3	278	55	3	3	8290.39	10362	2071.62			4.41		
107.5	299	-5	1	4								
168.1	299	0	1	4						5.12	-0.003	203.57
188.5	299	2.5	1	4						5.24		
143.7	299	5	1	4						4.97		
153.2	299	10	1	4				188.5	2.5	5.03		
174.0	299	15	1	4						5.16		
133.1	299	45	1	4	Tot AUC	Total Area	AOC			4.89		
147.3	299	55	1	4	7983.20	9896.775	1913.58			4.99		
101.1	299	-5	2	4								
157.3	299	0	2	4						5.06	-0.005	137.51
137.6	299	2.5	2	4						4.92		
193.0	299	5	2	4				193.0	5	5.26		
140.1	299	10	2	4						4.94		
161.4	299	15	2	4						5.08		
155.7	299	25	2	4						5.05		
131.6	299	35	2	4						4.88		
101.2	299	45	2	4	Tot AUC	Total Area	AOC			4.62		
142.8	299	55	2	4	6992.04	9650	2657.96			4.96		
77.5	299	-5	3	4								
194.4	299	2.5	3	4						5.27	-0.003	241.97
160.3	299	10	3	4						5.08		

164.6	299	15	3	4				194.4	2.5	5.10		
157.3	299	25	3	4						5.06		
155.5	299	35	3	4						5.05		
168.7	299	45	3	4	Tot AUC	Total Area	AOC			5.13		
149.1	299	55	3	4	8525.76	10207.838	1682.08			5.00		
80.9	300	-5	1	4								
162.3	300	0	1	4						5.09	-0.009	76.13
199.8	300	2.5	1	4						5.30		
158.3	300	5	1	4						5.06		
157.0	300	10	1	4				199.8	2.5	5.06		
143.0	300	15	1	4						4.96		
163.7	300	25	1	4						5.10		
138.4	300	35	1	4						4.93		
92.4	300	45	1	4	Tot AUC	Total Area	AOC			4.53		
117.7	300	55	1	4	7233.78	10490.025	3256.24			4.77		
84.4	300	-5	2	4								
216.5	300	0	2	4				216.5	0	5.38	-0.010	69.53
203.1	300	2.5	2	4						5.31		
152.4	300	5	2	4						5.03		
136.4	300	10	2	4						4.92		
112.2	300	35	2	4						4.72		
115.9	300	45	2	4	Tot AUC	Total Area	AOC			4.75		
118.2	300	55	2	4	7109.08	11908.05	4798.98			4.77		
80.2	300	-5	3	4								
228.2	300	0	3	4						5.43	-0.018	39.50
202.0	300	2.5	3	4				228.2	0	5.31		
174.8	300	5	3	4						5.16		
135.0	300	10	3	4						4.91		
104.7	300	15	3	4						4.65		
91.3	300	25	3	4						4.51		
98.9	300	35	3	4						4.59		
90.6	300	45	3	4	Tot AUC	Total Area	AOC			4.51		
77.7	300	55	3	4	6102.43	12548.25	6445.82			4.35		

Table A-11. Insulin kinetics calculation.

Ins.	ID	TIME	GC#	TRT	Ln[]	Fr. Dis. Rate	Half Life				
0.58	1	-5	1	1							
2.21	1	0	1	1		-0.014	48.06	7.0			
5.06	1	2.5	1	1	1.62			9.1			
5.08	1	5	1	1	1.63			12.7			
3.26	1	10	1	1	1.18			20.9			
3.5	1	15	1	1	1.25			16.9			
2.71	1	35	1	1	1.00			62.1			
2.61	1	45	1	1	0.96			26.6	Tot AUC	Basal Area	Net Area
2.17	1	55	1	1	0.77			23.9	179.09	34.8	144.29
0.49	1	-5	2	1		-0.023	29.97				
5.09	1	0	2	1	1.63			14.0			
4.11	1	2.5	2	1	1.41			11.5			
4.09	1	5	2	1	1.41			10.3			
3.69	1	10	2	1	1.31			19.5			
4.53	1	15	2	1	1.51			20.6			
4.02	1	25	2	1	1.39			42.8			
0.44	1	35	2	1	-0.82			22.3			
2.01	1	45	2	1	0.70			12.3	Tot AUC	Basal Area	Net Area
2.18	1	55	2	1	0.78			21.0	173.95	29.4	144.55
1.39	1	-5	3	1		-0.015	45.52				
4.98	1	0	3	1	1.61			15.9			
4.87	1	2.5	3	1	1.58			12.3			
4.39	1	10	3	1	1.48			34.7			
3.43	1	15	3	1	1.23			19.6			
2.71	1	25	3	1	1.00			30.7			
2.02	1	25	3	1	0.70			0.0			
2.26	1	35	3	1	0.82			21.4	Tot AUC	Basal Area	Net Area
2.6	1	55	3	1	0.96			48.6	183.2125	83.4	99.8125
0.54	9	-5	1	4							
5.29	9	0	1	4				14.6			
8.26	9	2.5	1	4				16.9			
9.59	9	5	1	4	2.26	-0.027	25.83	22.3			
4.93	9	10	1	4	1.60			36.3			
4.49	9	25	1	4	1.50			70.7			
3.3	9	35	1	4	1.19			39.0			
2.32	9	45	1	4	0.84			28.1	Tot AUC	Basal Area	Net Area
2.14	9	55	1	4	0.76			22.3	250.125	32.4	217.725
0.27	9	-5	2	4							
2.68	9	0	2	4				7.4			
2.97	9	2.5	2	4				7.1			
3.02	9	5	2	4	1.11	-0.026	26.25	7.5			
1.91	9	10	2	4	0.65			12.3			
1.33	9	15	2	4	0.29			8.1			
0.65	9	25	2	4	-0.43			9.9			
0.72	9	35	2	4	-0.33			6.9			
0.57	9	45	2	4	-0.56			6.5	Tot AUC	Basal Area	Net Area
0.85	9	55	2	4	-0.16			7.1	72.65	16.2	56.45
0.99	9	-5	3	4							
5.78	9	0	3	4				16.9			
5.96	9	2.5	3	4	1.79	-0.036	19.23	14.7			
5.41	9	5	3	4	1.69			14.2			
4.41	9	10	3	4	1.48			24.6			
2.94	9	15	3	4	1.08			18.4			
2.2	9	25	3	4	0.79			25.7			
0.97	9	45	3	4	-0.03			31.7	Tot AUC	Basal Area	Net Area
1.03	9	55	3	4	0.03			10.0	156.1375	59.4	96.7375
0.69	21	-5	1	2							
4.54	21	0	1	2				13.1			
5.9	21	2.5	1	2				13.1			
5.99	21	5	1	2				14.9			
7.18	21	10	1	2	1.97	-0.026	26.91	32.9			
5.94	21	15	1	2	1.78			32.8			

5.14	21	25	1	2	1.64			55.4			
3.96	21	35	1	2	1.38			45.5			
2.69	21	45	1	2	0.99			33.3	Tot AUC	Basal Area	Net Area
2.28	21	55	1	2	0.82			24.9	265.7125	41.4	224.3125
0.63	21	-5	2	2							
4	21	0	2	2				11.6			
5.69	21	2.5	2	2				12.1			
8.63	21	5	2	2	2.16	-0.03	23.29	17.9			
7.84	21	10	2	2	2.06			41.2			
5.46	21	20	2	2	1.70			66.5			
3.34	21	25	2	2	1.21			22.0			
1.66	21	35	2	2	0.51			25.0			
3.24	21	45	2	2	1.18			24.5	Tot AUC	Basal Area	Net Area
2.07	21	55	2	2	0.73			26.6	247.3125	37.8	209.5125
1.24	22	-5	1	3							
2.99	22	0	1	3				10.6			
4.88	22	2.5	1	3	1.59	-0.012	55.59	9.8			
4.12	22	5	1	3	1.42			11.3			
4.4	22	10	1	3	1.48			21.3			
4.63	22	15	1	3	1.53			22.6			
2.96	22	25	1	3	1.09			38.0			
4.23	22	35	1	3	1.44			36.0			
2.53	22	45	1	3	0.93			33.8	Tot AUC	Basal Area	Net Area
2.39	22	55	1	3	0.87			24.6	207.8375	74.4	133.4375
1.65	22	-5	2	3							
2.1	22	0	2	3				9.4			
4.53	22	2.5	2	3				8.3			
4.71	22	5	2	3				11.6			
6.24	22	10	2	3	1.83	-0.02	35.46	27.4			
2.61	22	15	2	3	0.96			22.1			
2.91	22	25	2	3	1.07			27.6			
3.08	22	35	2	3	1.12			30.0			
2.03	22	45	2	3	0.71			25.6	Tot AUC	Basal Area	Net Area
1.87	22	55	2	3	0.63			19.5	181.3125	99	82.3125
1.91	22	-5	3	3							
8.47	22	0	3	3				26.0			
8.2	22	2.5	3	3				20.8			
9.19	22	5	3	3	2.22	-0.028	24.82	21.7			
8.29	22	10	3	3	2.12			43.7			
7.71	22	15	3	3	2.04			40.0			
6.86	22	25	3	3	1.93			72.9			
4.2	22	35	3	3	1.44			55.3			
2.67	22	45	3	3	0.98			34.4	Tot AUC	Basal Area	Net Area
2.64	22	55	3	3	0.97			26.6	341.275	114.6	226.675
1.04	31	-5	1	1							
1.9	31	0	1	1				7.4			
2.26	31	2.5	1	1				5.2			
2.65	31	5	1	1				6.1			
2.72	31	10	1	1	1.00	-0.003	254.18	13.4			
1.97	31	15	1	1	0.68			11.7			
2.17	31	25	1	1	0.77			20.7			
2.66	31	35	1	1	0.98			24.2			
1.97	31	45	1	1	0.68			23.2	Tot AUC	Basal Area	Net Area
2.13	31	55	1	1	0.76			20.5	132.3375	62.4	69.9375
0.53	31	-5	2	1							
1.05	31	2.5	2	1				2.6			
1.04	31	5	2	1				6.2			
1.45	31	10	2	1				5.6			
0.78	31	15	2	1				9.6			
1.13	31	25	2	1				12.3			
1.33	31	35	2	1				18.6	Tot AUC	Basal Area	Net Area
2.39	31	45	2	1	0.87	-0.073	9.47	17.7	74.1188	31.8	42.3188
1.15	31	55	2	1	0.14						
2.42	31	-5	3	1				23.6			
7.03	31	0	3	1				18.0			
7.37	31	2.5	3	1				20.9			

9.33	31	5	3	1	2.23	-0.021	32.64	42.7			
7.76	31	10	3	1	2.05			36.3			
6.77	31	15	3	1	1.91			60.5			
5.32	31	25	3	1	1.67			52.5			
5.18	31	35	3	1	1.64			44.8	Tot AUC	Basal Area	Net Area
3.77	31	45	3	1	1.33			33.7	332.95	145.2	187.75
2.97	31	55	3	1	1.09						
0.84	37	-5	1	1				9.7			
3.05	37	0	1	1				8.3			
3.62	37	2.5	1	1				10.9			
5.1	37	5	1	1				22.0			
3.69	37	10	1	1				20.3			
4.44	37	15	1	1	1.49	-0.006	114.70	41.1			
3.78	37	25	1	1	1.33			34.1			
3.03	37	35	1	1	1.11			27.8	Tot AUC	Basal Area	Net Area
2.52	37	45	1	1	0.92			32.7	206.8625	50.4	156.4625
4.02	37	55	1	1	1.39						
0.69	37	-5	2	1				5.2			
1.38	37	0	2	1				5.2			
2.78	37	2.5	2	1				6.6			
2.53	37	5	2	1				13.8			
2.98	37	10	2	1	1.09	-0.008	86.70	10.5			
1.22	37	15	2	1	0.20			10.8			
0.94	37	25	2	1	-0.06			9.4			
0.94	37	35	2	1	-0.06			10.7	Tot AUC	Basal Area	Net Area
1.2	37	45	2	1	0.18			13.9	86.0875	41.4	44.6875
1.58	37	55	2	1	0.46						
0.88	37	-5	3	1				16.2			
5.61	37	0	3	1	1.72	-0.016	43.77	12.8			
4.6	37	2.5	3	1	1.53			11.4			
4.55	37	5	3	1	1.52			21.4			
4.01	37	10	3	1	1.39			16.6			
2.63	37	15	3	1	0.97			26.7			
2.7	37	25	3	1	0.99			24.5			
2.19	37	35	3	1	0.78			24.2	Tot AUC	Basal Area	Net Area
2.65	37	45	3	1	0.97			24.0	177.675	52.8	124.875
2.14	37	55	3	1	0.76						
0.87	77	-5	1	4				9.1			
2.76	77	0	1	4				7.4			
3.12	77	2.5	1	4				9.9			
4.79	77	5	1	4	1.57	-0.018	37.63	23.1			
4.44	77	10	1	4	1.49			20.7			
3.83	77	15	1	4	1.34			37.2			
3.61	77	25	1	4	1.28			31.5			
2.68	77	35	1	4	0.99			27.2	Tot AUC	Basal Area	Net Area
2.75	77	45	1	4	1.01			22.3	188.1625	52.2	135.9625
1.71	77	55	1	4	0.54						
0.35	77	-5	2	4				3.3			
0.97	77	0	2	4				3.0			
1.4	77	2.5	2	4				4.1			
1.86	77	5	2	4				10.1			
2.18	77	10	2	4				11.4			
2.36	77	15	2	4	0.86	-0.024	28.59	18.9			
1.42	77	25	2	4	0.35			17.8			
2.14	77	35	2	4	0.76			14.8	Tot AUC	Basal Area	Net Area
0.81	77	45	2	4	-0.21			8.7	91.9375	21	70.9375
0.93	77	55	2	4	-0.07						
1.49	77	-5	3	4				14.8			
4.42	77	0	3	4	1.49	-0.009	76.88	10.5			
4.01	77	2.5	3	4	1.39			9.5			
3.62	77	5	3	4	1.29			17.9			
3.53	77	10	3	4	1.26			15.9			
2.84	77	15	3	4	1.04			26.0			
2.35	77	25	3	4	0.85			23.2			
2.29	77	35	3	4	0.83			25.3	Tot AUC	Basal Area	Net Area
2.76	77	45	3	4	1.02			27.4	170.4	89.4	81

2.71	77	55	3	4	1.00						
0.74	86	-5	1	4				7.9			
2.41	86	0	1	4				5.3			
1.8	86	2.5	1	4				5.8			
2.8	86	5	1	4				14.6			
3.03	86	10	1	4	1.11	-0.015	44.76	13.2			
2.23	86	15	1	4	0.80			25.2			
2.81	86	25	1	4	1.03			24.1			
2	86	35	1	4	0.69			18.6	Tot AUC	Basal Area	Net Area
1.71	86	45	1	4	0.54			15.5	129.8625	44.4	85.4625
1.38	86	55	1	4	0.32						
0.78	86	-5	2	4				9.7			
3.11	86	0	2	4				9.1			
4.15	86	2.5	2	4				11.8			
5.29	86	5	2	4	1.67	-0.034	20.62	21.4			
3.26	86	10	2	4	1.18			17.3			
3.65	86	15	2	4	1.29			26.9			
1.72	86	25	2	4	0.54			15.0			
1.28	86	35	2	4	0.25			12.0	Tot AUC	Basal Area	Net Area
1.12	86	45	2	4	0.11			10.6	133.65	46.8	86.85
0.99	86	55	2	4	-0.01						
1.92	86	-5	3	4				19.2			
5.77	86	0	3	4				17.7			
8.41	86	2.5	3	4	2.13	-0.029	24.25	19.2			
6.91	86	5	3	4	1.93			30.9			
5.43	86	10	3	4	1.69			24.2			
4.24	86	15	3	4	1.44			37.7			
3.3	86	25	3	4	1.19			26.9			
2.07	86	35	3	4	0.73			21.2	Tot AUC	Basal Area	Net Area
2.17	86	45	3	4	0.77			20.2	217.075	115.2	101.875
1.87	86	55	3	4	0.63						
1.56	89	-5	1	3				6.6			
1.08	89	0	1	3				5.8			
1.23	89	5	1	3				7.3			
1.67	89	10	1	3	0.51	-0.021	33.21	42.5			
4	89	25	1	3	1.39			52.3	Tot AUC	Basal Area	Net Area
1.23	89	45	1	3	0.21			10.4	124.85	93.6	31.25
0.85	89	55	1	3	-0.16						
0.44	89	-5	2	3				2.8			
0.67	89	0	2	3				1.6			
0.58	89	2.5	2	3				1.4			
0.56	89	5	2	3				2.9			
0.59	89	10	2	3				2.6			
0.46	89	15	2	3		-0.007	97.88	7.3			
1	89	25	2	3	0.00			9.2			
0.84	89	35	2	3	-0.17			6.4	Tot AUC	Basal Area	Net Area
1	89	42	2	3	0.00			11.5	45.7075	26.4	19.3075
0.77	89	55	2	3	-0.26						
1.13	95	-5	1	2				19.5			
4.08	95	2.5	1	2				12.9			
6.2	95	5	1	2				31.9			
6.57	95	10	1	2	1.88	-0.014	50.20	32.8			
6.53	95	15	1	2	1.88			49.9			
3.44	95	25	1	2	1.24			34.6			
3.48	95	35	1	2	1.25			35.3	Tot AUC	Basal Area	Net Area
3.58	95	45	1	2	1.28			36.6	253.4125	67.8	185.6125
3.74	95	55	1	2	1.32						
6.7	95	0	2	2				17.7			
7.49	95	2.5	2	2	2.01	-0.014	49.97	16.0			
5.33	95	5	2	2	1.67			30.4			
6.84	95	10	2	2	1.92			33.1			
6.41	95	15	2	2	1.86			50.8			
3.74	95	25	2	2	1.32			40.3			
4.31	95	35	2	2	1.46			25.9	Tot AUC	Basal Area	Net Area
3.08	95	42	2	2	1.12			45.5	259.6775	368.5	-108.8225
3.92	95	55	2	2	1.37						

0.9	95	-5	3	2				14.7			
4.96	95	0	3	2	1.60	-0.025	27.91	12.1			
4.68	95	2.5	3	2	1.54			11.8			
4.78	95	5	3	2	1.56			21.3			
3.72	95	10	3	2	1.31			21.5			
4.87	95	15	3	2	1.58			48.8			
4.89	95	25	3	2	1.59			35.9			
2.29	95	35	3	2	0.83			19.2	Tot AUC	Basal Area	Net Area
1.55	95	45	3	2	0.44			14.3	199.4	54	145.4
1.3	95	55	3	2	0.26						
0.68	118	-5	1	1				9.8			
3.25	118	0	1	1				9.4			
4.28	118	2.5	1	1				10.5			
4.14	118	5	1	1				23.2			
5.15	118	10	1	1	1.64	-0.018	38.39	40.0			
2.84	118	20	1	1	1.04			28.4			
2.83	118	30	1	1	1.04			16.8			
3.88	118	35	1	1	1.36			31.3	Tot AUC	Basal Area	Net Area
2.37	118	45	1	1	0.86			21.3	190.5625	40.8	149.7625
1.88	118	55	1	1	0.63						
0.71	118	-5	2	1				9.8			
3.2	118	0	2	1				7.6			
2.88	118	2.5	2	1				7.6			
3.23	118	5	2	1				18.3			
4.08	118	10	2	1	1.41	-0.02	33.94	20.3			
4.02	118	15	2	1	1.39			30.4			
2.06	118	25	2	1	0.72			20.6			
2.05	118	35	2	1	0.72			20.7	Tot AUC	Basal Area	Net Area
2.09	118	45	2	1	0.74			18.4	153.5375	42.6	110.9375
1.58	118	55	2	1	0.46						
1.49	154	-5	2	3				23.6			
7.94	154	0	2	3				20.6			
8.53	154	2.5	2	3				23.3			
10.1	154	5	2	3	2.32	-0.053	13.11	39.6			
5.71	154	10	2	3	1.74			33.5			
7.68	154	15	2	3	2.04			47.3			
1.78	154	25	2	3	0.58			21.4			
2.49	154	35	2	3	0.91			18.1	Tot AUC	Basal Area	Net Area
1.13	154	45	2	3	0.12			8.8	236.1125	89.4	146.7125
0.63	154	55	2	3	-0.46						
1.45	154	-5	3	3				20.2			
6.62	154	0	3	3				19.8			
9.24	154	2.5	3	3				23.8			
9.82	154	5	3	3				49.1			
9.83	154	10	3	3	2.29	-0.04	17.32	39.5			
5.98	154	15	3	3	1.79			51.8			
4.37	154	25	3	3	1.47			33.4			
2.31	154	35	3	3	0.84			20.5	Tot AUC	Basal Area	Net Area
1.79	154	45	3	3	0.58			17.2	275.275	87	188.275
1.64	154	55	3	3	0.49						
2.02	155	2.5	1	1				5.4			
2.3	155	5	1	1				14.4			
3.44	155	10	1	1	1.24	-0.035	19.75	16.5			
3.15	155	15	1	1	1.15			26.2			
2.09	155	25	1	1	0.74			24.4			
2.79	155	35	1	1	1.03			20.7			
1.34	155	45	1	1	0.29			0.0	Tot AUC	Basal Area	Net Area
2.12	155	45	1	1	0.75			12.7	120.125	106.05	14.075
0.41	155	55	1	1	-0.89						
0.28	155	-5	2	1				5.4			
1.86	155	0	2	1				12.0			
7.71	155	2.5	2	1	2.04	-0.039	17.99	16.3			
5.31	155	5	2	1	1.67			24.4			
4.44	155	10	2	1	1.49			26.0			
5.95	155	15	2	1	1.78			41.0			
2.25	155	25	2	1	0.81			17.4			

1.22	155	35	2	1	0.20			13.4	Tot AUC	Basal Area	Net Area
1.45	155	45	2	1	0.37			12.5	168.0875	16.8	151.2875
1.04	155	55	2	1	0.04						
1.23	155	-5	3	1				21.9			
7.54	155	0	3	1				19.8			
8.27	155	2.5	3	1	2.11	-0.028	24.78	17.9			
6.04	155	5	3	1	1.80			29.6			
5.8	155	10	3	1	1.76			65.9			
2.99	155	25	3	1	1.10			27.7			
2.55	155	35	3	1	0.94			26.3	Tot AUC	Basal Area	Net Area
2.7	155	45	3	1	0.99			21.3	230.3	73.8	156.5
1.55	155	55	3	1	0.44						
0.34	161	-5	1	2				5.5			
1.84	161	0	1	2				5.1			
2.27	161	2.5	1	2				5.8			
2.4	161	5	1	2				12.4			
2.56	161	10	1	2	0.94	-0.008	88.63	11.4			
2.01	161	15	1	2	0.70			17.4			
1.46	161	25	1	2	0.38			18.1			
2.16	161	35	1	2	0.77			20.9	Tot AUC	Basal Area	Net Area
2.02	161	45	1	2	0.70			17.0	113.6	20.4	93.2
1.38	161	55	1	2	0.32						
0.24	161	-5	2	2				3.7			
1.25	161	0	2	2				4.1			
1.99	161	2.5	2	2				5.2			
2.13	161	5	2	2				12.0			
2.66	161	10	2	2				13.8			
2.86	161	15	2	2	1.05	-0.056	12.42	20.3			
1.2	161	25	2	2	0.18			10.4			
0.88	161	35	2	2	-0.13			5.8	Tot AUC	Basal Area	Net Area
0.27	161	45	2	2	-1.31			3.2	78.35	14.4	63.95
0.37	161	55	2	2	-0.99						
2.01	161	-5	3	2				24.5			
7.77	161	0	3	2	2.05	-0.033	20.87	16.1			
5.14	161	2.5	3	2	1.64			16.0			
7.67	161	5	3	2	2.04			37.4			
7.3	161	10	3	2	1.99			34.5			
6.48	161	15	3	2	1.87			55.9			
4.69	161	25	3	2	1.55			35.5	Tot AUC	Basal Area	Net Area
2.41	161	35	3	2	0.88			20.0	239.775	100.5	139.275
1.58	161	45	3	2	0.46						
0.65	165	-5	1	2				9.0			
2.96	165	0	1	2				10.5			
5.43	165	2.5	1	2				15.4			
6.85	165	5	1	2				41.5			
9.74	165	10	1	2	2.28	-0.051	13.58	47.7			
9.32	165	15	1	2	2.23			83.6			
7.4	165	25	1	2	2.00			56.5			
3.9	165	35	1	2	1.36			30.9	Tot AUC	Basal Area	Net Area
2.28	165	45	1	2	0.82			16.3	311.2875	39	272.2875
0.98	165	55	1	2	-0.02						
1.62	165	-5	2	2				35.0			
12.4	165	0	2	2				31.2			
12.6	165	2.5	2	2				35.7			
16.0	165	5	2	2	2.77	-0.043	16.03	60.0			
8.04	165	10	2	2	2.08			45.2			
10.1	165	15	2	2	2.31			74.7			
4.89	165	25	2	2	1.59			44.4			
3.98	165	35	2	2	1.38			32.5	Tot AUC	Basal Area	Net Area
2.51	165	45	2	2	0.92			19.9	378.5375	97.2	281.3375
1.47	165	55	2	2	0.39						
0.93	165	-5	3	2				23.4			
8.43	165	0	3	2				21.8			
8.97	165	2.5	3	2	2.19	-0.028	25.17	22.3			
8.89	165	5	3	2	2.18			42.9			
8.26	165	10	3	2	2.11			39.9			

7.71	165	15	3	2	2.04			65.3			
5.35	165	25	3	2	1.68			49.0			
4.44	165	35	3	2	1.49			35.0	Tot AUC	Basal Area	Net Area
2.56	165	45	3	2	0.94			24.9	324.425	55.8	268.625
2.42	165	55	3	2	0.88						
1.4	173	-5	1	3				12.9			
3.74	173	0	1	3				10.1			
4.35	173	2.5	1	3				32.1			
4.2	173	10	1	3				23.6			
5.23	173	15	1	3	1.65	-0.032	21.46	50.8			
4.92	173	25	1	3	1.59			49.2			
4.91	173	35	1	3	1.59			34.1	Tot AUC	Basal Area	Net Area
1.91	173	45	1	3	0.65			17.9	230.5	84	146.5
1.67	173	55	1	3	0.51						
5.68	173	-5	2	3				70.5			
22.5	173	0	2	3				69.9			
33.4	173	2.5	2	3				72.9			
24.9	173	5	2	3				150.8			
35.4	173	10	2	3	3.57	-0.03	22.96	148.2			
23.8	173	15	2	3	3.17			213.1			
18.8	173	25	2	3	2.93			181.8			
17.6	173	35	2	3	2.87			150.9	Tot AUC	Basal Area	Net Area
12.6	173	45	2	3	2.53			99.3	1157.2625	340.8	816.46
7.26	173	55	2	3	1.98						
1.53	173	-5	3	3				28.0			
9.66	173	0	3	3				25.4			
10.6	173	2.5	3	3	2.36	-0.038	18.11	25.3			
9.58	173	5	3	3	2.26			47.8			
9.53	173	10	3	3	2.25			44.2			
8.16	173	15	3	3	2.10			146.3			
1.59	173	45	3	3	0.46			0.0	Tot AUC	Basal Area	Net Area
5.12	173	45	3	3	1.63			31.2	348.025	91.8	256.23
1.11	173	55	3	3	0.10						
4.02	179	0	1	1				9.8			
3.82	179	2.5	1	1				9.9			
4.12	179	5	1	1				25.0			
5.86	179	10	1	1				35.8			
8.45	179	15	1	1	2.13	-0.024	28.86	49.3			
1.4	179	25	1	1	0.34			0.0			
5.47	179	25	1	1	1.70			42.7			
3.07	179	35	1	1	1.12			31.9	Tot AUC	Basal Area	Net Area
3.31	179	45	1	1	1.20			26.2	230.5	221.1	9.4
1.93	179	55	1	1	0.66						
1.84	179	-5	2	1				16.6			
4.79	179	0	2	1				15.3			
7.42	179	2.5	2	1				18.1			
7.07	179	5	2	1				35.1			
6.97	179	10	2	1				42.6			
10.1	179	15	2	1	2.31	-0.014	49.18	88.0			
7.52	179	25	2	1	2.02			59.4			
4.36	179	35	2	1	1.47			45.0	Tot AUC	Basal Area	Net Area
4.63	179	45	2	1	1.53			54.9	374.925	110.4	264.53
6.35	179	55	2	1	1.85						
2.64	179	-5	3	1				39.0			
12.9	179	0	3	1				33.5			
13.9	179	2.5	3	1	2.63	-0.024	28.95	32.4			
12.1	179	5	3	1	2.49			52.8			
9.05	179	10	3	1	2.20			44.4			
8.7	179	15	3	1	2.16			77.2			
6.74	179	25	3	1	1.91			61.0	Tot AUC	Basal Area	Net Area
5.46	179	35	3	1	1.70			91.6	431.775	158.4	273.38
3.7	179	55	3	1	1.31						
4.13	192	0	1	3				27.6			
6.92	192	5	1	3	1.93	-0.024	28.45	31.9			
5.85	192	10	1	3	1.77			78.5			
4.62	192	25	1	3	1.53			0.0			

5.52	192	25	1	3	1.71			45.9			
3.65	192	35	1	3	1.29			35.8	Tot AUC	Basal Area	Net Area
3.51	192	45	1	3	1.26			26.0	245.725	227.15	18.58
1.69	192	55	1	3	0.52						
1.38	192	-5	2	3				30.7			
10.9	192	0	2	3	2.39	-0.049	14.28	25.1			
9.18	192	2.5	2	3	2.22			24.1			
10.1	192	5	2	3	2.31			42.3			
6.86	192	10	2	3	1.93			38.1			
8.38	192	15	2	3	2.13			51.2			
1.86	192	25	2	3	0.62			15.6			
1.26	192	35	2	3	0.23			10.9	Tot AUC	Basal Area	Net Area
0.91	192	45	2	3	-0.09			11.5	249.275	82.8	166.48
1.38	192	55	2	3	0.32						
1.71	192	-5	3	3				22.2			
7.17	192	0	3	3	1.97	-0.019	35.59	17.3			
6.66	192	2.5	3	3	1.90			15.5			
5.76	192	5	3	3	1.75			26.7			
4.91	192	10	3	3	1.59			19.9			
3.06	192	15	3	3	1.12			26.4			
2.22	192	25	3	3	0.80			22.0			
2.17	192	35	3	3	0.77			26.0	Tot AUC	Basal Area	Net Area
3.03	192	45	3	3	1.11			27.8	203.7625	102.6	101.16
2.53	192	55	3	3	0.93						
1.12	193	-5	1	4				5.7			
1.14	193	0	1	4				4.3			
2.33	193	2.5	1	4		-0.007	105.57	5.7			
2.2	193	5	1	4				14.8	Tot AUC	Basal Area	Net Area
3.7	193	10	1	4	1.31			85.5	115.9	44.8	71.1
3.14	193	35	1	4	1.14						
1	193	-5	2	4				17.3			
5.9	193	0	2	4				15.5			
6.5	193	2.5	2	4				17.2			
7.26	193	5	2	4	1.98	-0.013	54.97	30.1			
4.77	193	10	2	4	1.56			18.5			
2.63	193	15	2	4	0.97			27.4			
2.85	193	25	2	4	1.05			32.4			
3.63	193	35	2	4	1.29			33.5	Tot AUC	Basal Area	Net Area
3.06	193	45	2	4	1.12			29.1	220.825	60	160.83
2.75	193	55	2	4	1.01						
1.71	193	-5	3	4				16.8			
5.01	193	0	3	4				14.4			
6.5	193	2.5	3	4				16.6			
6.77	193	5	3	4				33.2			
6.52	193	10	3	4				33.5			
6.87	193	15	3	4	1.93	-0.007	96.16	57.0			
4.52	193	25	3	4	1.51			46.0			
4.68	193	35	3	4	1.54			47.5	Tot AUC	Basal Area	Net Area
4.82	193	45	3	4	1.57			47.3	312.225	102.6	209.63
4.64	193	55	3	4	1.53						
0.78	198	-5	1	2				10.1			
3.25	198	0	1	2				10.0			
4.74	198	2.5	1	2				12.3			
5.13	198	5	1	2				26.9			
5.64	198	10	1	2	1.73	-0.013	51.96	25.3			
4.46	198	15	1	2	1.50			45.2			
4.58	198	25	1	2	1.52			43.1			
4.04	198	35	1	2	1.40			36.1	Tot AUC	Basal Area	Net Area
3.17	198	45	1	2	1.15			30.6	239.525	46.8	192.73
2.95	198	55	1	2	1.08						
1.99	198	-5	2	2				7.4			
0.96	198	0	2	2				2.2			
0.82	198	2.5	2	2				2.8			
1.44	198	5	2	2				9.3			
2.29	198	10	2	2				12.5			
2.72	198	15	2	2		-0.006	119.28	34.8			

4.24	198	25	2	2	1.44			37.9			
3.34	198	35	2	2	1.21			33.5	Tot AUC	Basal Area	Net Area
3.35	198	45	2	2	1.21			34.2	174.625	119.4	55.23
3.49	198	55	2	2	1.25						
1.94	198	-5	3	2				18.7			
5.53	198	0	3	2				16.7			
7.84	198	2.5	3	2	2.06	-0.011	64.43	19.1			
7.44	198	5	3	2	2.01			37.1			
7.41	198	10	3	2	2.00			33.5			
5.98	198	15	3	2	1.79			63.0			
6.62	198	25	3	2	1.89			64.6			
6.3	198	35	3	2	1.84			58.1	Tot AUC	Basal Area	Net Area
5.31	198	45	3	2	1.67			46.0	356.6875	116.4	240.288
3.88	198	55	3	2	1.36						
0.61	254	-5	1	2				11.8			
4.11	254	0	1	2				9.5			
3.51	254	2.5	1	2				9.4			
4.02	254	5	1	2				22.4			
4.92	254	10	1	2	1.59	-0.018	38.39	24.2			
4.75	254	15	1	2	1.56			44.6			
4.17	254	25	1	2	1.43			35.6			
2.94	254	35	1	2	1.08			27.9	Tot AUC	Basal Area	Net Area
2.63	254	45	1	2	0.97			24.9	210.1125	36.6	173.51
2.34	254	55	1	2	0.85						
3.92	254	-5	2	2				16.3			
2.59	254	0	2	2				7.9			
3.69	254	2.5	2	2				10.5			
4.67	254	5	2	2				19.3			
3.06	254	10	2	2				19.0			
4.52	254	15	2	2				74.4			
10.4	254	25	2	2	2.34	-0.033	20.77	84.2	Tot AUC	Basal Area	Net Area
6.48	254	35	2	2	1.87			59.0	290.3	196	94.3
5.31	254	45	2	2	1.67						
1.79	254	-5	3	2				24.8			
8.13	254	0	3	2				20.8			
8.51	254	2.5	3	2				23.6			
10.4	254	5	3	2	2.34	-0.028	24.57	90.1			
7.64	254	15	3	2	2.03			64.3			
5.22	254	25	3	2	1.65			49.6			
4.69	254	35	3	2	1.55			38.6	Tot AUC	Basal Area	Net Area
3.02	254	45	3	2	1.11			28.0	339.6625	107.4	232.26
2.57	254	55	3	2	0.94						
0.72	278	-5	1	3				13.2			
4.54	278	0	1	3				12.7			
5.64	278	2.5	1	3	1.73	-0.012	57.28	12.3			
4.22	278	5	1	3	1.44			27.0			
6.59	278	10	1	3	1.89			28.9			
4.97	278	15	1	3	1.60			43.2			
3.66	278	25	1	3	1.30			45.5			
5.43	278	35	1	3	1.69			35.8	Tot AUC	Basal Area	Net Area
1.72	278	45	1	3	0.54			28.7	247.125	43.2	203.93
4.01	278	55	1	3	1.39						
0.67	278	-5	2	3				7.8			
2.46	278	0	2	3				7.0			
3.11	278	2.5	2	3				8.3			
3.54	278	5	2	3	1.26	-0.039	17.54	16.6			
3.1	278	10	2	3	1.13			14.2			
2.59	278	15	2	3	0.95			18.9			
1.18	278	25	2	3	0.17			8.9			
0.6	278	35	2	3	-0.51			4.5	Tot AUC	Basal Area	Net Area
0.3	278	45	2	3	-1.20			6.9	93.075	40.2	52.88
1.08	278	55	2	3	0.08						
6.65	278	-5	3	3				53.4			
14.7	278	0	3	3				42.1			
190	278	2.5	3	3				48.9			
20.2	278	5	3	3				92.3			

16.8	278	10	3	3				95.0			
21.2	278	15	3	3	3.05	-0.018	39.51	174.8			
13.7	278	25	3	3	2.62			121.1			
10.5	278	35	3	3	2.35			118.6	Tot AUC	Basal Area	Net Area
13.2	278	45	3	3	2.58			111.2	857.2625	399	458.26
8.99	278	55	3	3	2.20						
0.7	299	-5	1	4				10.5			
3.48	299	0	1	4				8.6			
3.43	299	2.5	1	4				10.5			
4.93	299	5	1	4	1.60	-0.024	29.45	24.5			
4.86	299	10	1	4	1.58			17.7			
2.22	299	15	1	4	0.80			41.5			
1.93	299	35	1	4	0.66			17.7	Tot AUC	Basal Area	Net Area
1.61	299	45	1	4	0.48			15.6	146.4625	42	104.46
1.5	299	55	1	4	0.41						
1.58	299	-5	2	4				9.7			
2.3	299	0	2	4				6.1			
2.54	299	2.5	2	4				7.8			
3.72	299	5	2	4	1.31	-0.015	46.77	19.6			
4.1	299	10	2	4	1.41			18.1			
3.12	299	15	2	4	1.14			30.8			
3.03	299	25	2	4	1.11			19.1			
0.78	299	35	2	4	-0.25			17.8	Tot AUC	Basal Area	Net Area
2.77	299	45	2	4	1.02			25.0	153.675	94.8	58.88
2.22	299	55	2	4	0.80						
1.44	299	-5	3	4				11.9			
3.3	299	0	3	4				9.6			
4.4	299	2.5	3	4				12.2			
5.38	299	5	3	4				26.9			
5.39	299	10	3	4				25.9			
4.96	299	15	3	4				53.0			
5.64	299	25	3	4	1.73	-0.017	39.84	47.6			
3.88	299	35	3	4	1.36			38.1	Tot AUC	Basal Area	Net Area
3.73	299	45	3	4	1.32			34.7	259.8	86.4	173.4
3.2	299	55	3	4	1.16						
0.61	300	-5	1	4				12.2			
4.25	300	0	1	4				13.0			
6.14	300	2.5	1	4				18.9			
8.98	300	5	1	4	2.19	-0.037	18.68	44.2			
8.7	300	10	1	4	2.16			39.6			
7.12	300	15	1	4	1.96			53.7			
3.61	300	25	1	4	1.28			36.3			
3.64	300	35	1	4	1.29			28.2	Tot AUC	Basal Area	Net Area
1.99	300	45	1	4	0.69			17.7	263.5375	36.6	226.94
1.55	300	55	1	4	0.44						
0.79	300	-5	2	4				18.0			
6.41	300	0	2	4				22.0			
11.2	300	2.5	2	4				31.8			
14.2	300	5	2	4	2.66	-0.067	10.40	67.6			
12.8	300	10	2	4	2.55			53.0			
8.38	300	15	2	4	2.13			66.7			
4.96	300	25	2	4	1.60			44.3			
3.9	300	35	2	4	1.36			27.6	Tot AUC	Basal Area	Net Area
1.62	300	45	2	4	0.48			10.0	340.9625	47.4	293.56
0.38	300	55	2	4	-0.97						
1.68	300	-5	3	4				29.5			
10.1	300	0	3	4				26.6			
11.2	300	2.5	3	4				31.2			
13.8	300	5	3	4				69.5			
14.0	300	10	3	4	2.64	-0.041	16.83	68.0			
13.2	300	15	3	4	2.58			125.1			
11.8	300	25	3	4	2.47			90.8			
6.35	300	35	3	4	1.85			47.8	Tot AUC	Basal Area	Net Area
3.21	300	45	3	4	1.17			29.2	517.7	100.8	416.9
2.63	300	55	3	4	0.97						

VITA

Judson Tadeu de Vasconcelos is the son of Pedro Saturnino de Vasconcelos and Aparecida Helena Pavese Vasconcelos. He was born on June 14th, 1976 in Presidente Prudente, São Paulo, Brazil and grew up in Campo Grande, Mato Grosso do Sul. In January, 1999, Judson graduated from the Universidade Federal de Mato Grosso do Sul with a Degree in Veterinary Medicine. From 1999 to 2002, he worked for the Brazilian division of Unipro International (XF Enterprises), headquartered in Greeley, CO, as an assistant feedlot nutritionist to over 200,000 heads. In June 2002, Judson started his graduate studies in the United States. He received a degree in Animal Science from West Texas A&M University in May of 2004, after working at the Texas Agricultural Experiment Station located in Amarillo under the direction of Dr. L. W. Greene. Judson started a Doctor of Philosophy program in beef cattle nutrition at Texas A&M University in January of the same year. During his graduate studies, Judson was awarded several scholarships, including the Texas Cattle Feeders Association Scholarship for four consecutive years (2003, 2004, 2005, and 2006).

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