**EFFECTS OF REPEATED UREA DILUTION MEASUREMENT ON FEEDLOT
PERFORMANCE AND CONSISTENCY OF ESTIMATED BODY
COMPOSITION IN STEERS OF DIFFERENT BREED TYPES**

by

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LIST OF ABBREVIATIONS

ADG	Average Daily Gain
BF	Back Fat
BIX	<i>Bos indicus</i> cross
BTX	<i>Bos taurus</i> cross
EBF	Empty Body Fat
EBH ₂ O	Empty Body Water
EBW	Empty Body Weight
ECF	Percent Estimated Carcass Fat
d	Day
DMI	Dry Matter Intake
DP	Dressing Percentage
G/1000	Gain Efficiency
HCWT	Hot Carcass Weight
REA	Rib-eye Area
SEM	Standard error of the mean
T ₀	Time zero, prior to infusion
T ₁₂	Time twelve, twelve minutes post infusion
UD	Urea Dilution
UDEBF	Urea Dilution Determined Empty Body Fat
US	Urea Space

CHAPTER I

INTRODUCTION

Accurate determination of the carcass composition of a live animal has long been an enigma for animal scientists. Hammond et al. (1988) stated that there is a need for nondestructive, simple and accurate methods for the measurement of body composition in live animals to be used in studies of nutrient use, nutrient partitioning, growth, and genetic selection. This knowledge is also of practical importance to feedlot operators and managers, producers, and breeding stations. Houghton et al. (1992) stated that the ability to identify and market groups of cattle that will consistently produce carcasses of similar weight with acceptable yield and quality grades is the primary interest of feedlot managers. Dickerson (1978) has estimated that genetic reduction of carcass fat from 32 to 15% would reduce life cycle production costs by nearly 17%.

Researchers have studied many different types of carcass composition determination techniques. Some of these techniques include: chemical composition (Lawes and Gilbert, 1859; Moulton, 1923; Hankins and Howe, 1946; Hopper, 1944; Reid et al., 1968), specific gravity (Garrett and Hinman, 1969; Preston et al., 1974), and dilution procedures using antipyrine

or its derivatives (Wellington et al., 1956; Reid et al., 1963), deuterium oxide (Edelman, 1952; Foot and Greenhalgh, 1970; Robelin, 1977, 1982, Byers, 1979a, 1979b), sodium thiosulfate (Dalton, 1964; Ross et al., 1992), sodium thiocynate (Ashworth et al., 1943; Eder, 1951; Hix et al., 1959; Wrenn et al., 1962; Carlson et al., 1979; Caster and Simon, 1980; Gad and Preston, 1990), tritiated water (Aschbacher et al., 1965; Carnegie and Tulloh, 1968; Preston, 1969; Meissner, 1976; Meissner et al., 1980), urea (Preston and Kock, 1973; Kock and Preston, 1979; Hammond et al., 1984; Rule et al., 1986; Bartle et al., 1987), whole body counting (Ward, 1968; Preston et al., 1968), computerized X-Ray tomography (Groeneveld et al., 1984), nuclear magnetic resonance (NMR) imaging (Mitchell et al., 1991), and ultrasonography (Temple et al., 1956; Stouffer and Cross, 1985).

Research using urea dilution and ultrasound to predict live body composition is substantial but there are still some questions left unanswered. There has been little research conducted on the effects of repeated urea dilution measurements on the performance of feedlot cattle. In conjunction with this, no data are available for the consistency of these measurements over an entire feeding trial and using cattle of *Bos taurus* and *Bos indicus* breed types. Therefore, this thesis research will try to answer these questions.

CHAPTER II

LITERATURE REVIEW

Purpose and Need for Carcass Determination Techniques

As the beef industry moves toward the production of cattle to meet target specifications (i.e., leaner beef), more accurate live animal measurements are needed to predict final carcass merit (Hamlin et al., 1995). To be valid and effective to researchers and the industry, these methods of carcass composition measurement must be non-invasive, non-destructive and should not affect animal performance. Carcass composition determination methods are useful for scientific research as well as for on-farm applications.

Carcass composition is the basis for treatment comparisons in many research studies involving beef cattle and the increased recent emphasis on production of leaner beef has added impetus to this important facet of meat animal research (Lunt et al., 1985). In the field of ruminant nutrition, especially feedlot nutrition, this concept is important because many times subtle changes in diets may change the animal's carcass composition. The importance of chemical composition of the live animal is also related to its central role in the study of energy metabolism, protein nutrition, and mineral

physiology (Heymsfield and Waki, 1991). Live animal carcass composition determination is also useful in reproductive studies when the researcher does not wish to sacrifice the animal. Meat science researchers and agricultural economists are also interested in this area of research since it could lead to more efficient packing plant and feedlot operations.

Live animal carcass composition determination also has many practical, on-farm applications. Accurate estimates of carcass characteristics may allow producers to sort and select cattle that produce a more desirable product (Hamlin et al., 1995). Feedlot operators can use these measurements to place cattle into more uniform groups based on percent carcass fat at specific time intervals than can be performed using visual appraisal (i.e., Micro-Chemicals Corp., Amarillo, Texas; Cornett, 1994). Accomplishing this would reduce the number of animals that would be over-finished or too lean in a given pen of cattle. This translates into increased efficiency of the overall operation and a higher profit margin for each pen of cattle, which would be beneficial in the current cattle and feed market conditions. Also, a future use of live animal carcass composition determination would be to use it as a sire selection criterion. Bulls that are leaner, with less fat cover, and are predisposed for produce calves with less fat and more lean could be selected for this trait. This could be used in a

manner similar to other expected progeny differences (EPD's) already utilized in the industry.

Carcass Composition

Carcass composition has been of interest to researchers since the mid 1800's. John B. Lawes and Joseph H. Gilbert (1859) conducted the pioneer work in animal carcass composition in Rothamsted, England. These researchers were the first to perform the labor intensive experiment of analyzing whole animal bodies (Maynard et al., 1979). Moulton (1923) described statistical relationships within body components (water, lipid, protein and ash). He demonstrated that the water and protein content of the animal's fat-free body is constant after "chemical maturity" is reached, which occurs at approximately 4.6% of the animal's life span, beginning at conception. Later, Reid et al. (1968) calculated the empty body composition of animals to be: $72.91 \pm 2.01\%$ water, $21.64 \pm 1.53\%$ protein, and $5.34 \pm 0.95\%$ ash on a fat-free basis.

In general, fat deposition increases as the animal ages and reaches maturity. Maynard et al. (1979) reported that fat composition increases in steers as they mature: newborn calf, 3%; fat calf, 10%; and a fat steer, 41%. Although this general trend is true, minor differences are known to occur

between breed types. Pure *Bos indicus* (i.e., Brahman, Nelore, and Zebu breeds) cattle usually have a lower percentage of body fat; thus, they grade lower, on average, than do other breeds. Conversely, pure *Bos taurus* (i.e., Angus, and Hereford breeds) cattle will have a higher percent body fat and will usually have a higher quality grade.

Carcass Composition Determination Techniques

Carcass composition determination techniques may be divided into several general categories. They are as follows: carcass chemical composition and specific gravity, dilution techniques, and other non-invasive or non-destructive methods. Chemical composition requires the sacrifice of the experimental animal and all or part of the carcass is rendered unusable for human consumption. Dilution techniques involve the infusion into the animal's blood a known quantity of a tracer chemical thus allowing the *in vivo* determination of the pool size of that chemical in body tissue. The other non-destructive methods that have been developed require the use of newer technological advances such as real-time ultrasonography, computerized X-Ray tomography, and nuclear magnetic resonance (NMR) imaging.

Carcass Chemical Composition and Specific Gravity. Chemical composition is the standard by which other carcass determination techniques

are judged. But, this procedure requires vast amounts of time, labor and money to perform. The most comprehensive analysis would be to utilize tissue dissection followed by chemical analysis of the resulting tissues (Cross, 1982; Miller et al., 1988). Chemical composition (Lawes and Gilbert, 1859) was the first technique used to estimate the percent water, protein, fat and ash of an animal's body. It has since been further studied (Moulton, 1923) and refined (Hankins and Howe, 1946; Hopper, 1944; Reid et al., 1968). Therefore, this method of carcass measurements is now widely accepted and used. Carcass chemical composition determination is performed by slaughtering the experimental animal and then utilizing a sub-portion of the carcass (i.e., the 9-10-11 rib section for analysis; Hopper, 1944). This sample is then physically separated into bone, muscle and fat. The muscle is then further processed via ether extraction to measure any adipose tissue such as marbling and fat that was not trimmed away. Hopper (1944) found that the correlation coefficients for the relationship between the ether extract in the whole body and the edible portions of the 9-10-11 rib cut ranged from +0.987 to +0.989. Hankins and Howe (1946) developed equations to predict the carcass composition from the 9-10-11 rib section composition: water, $Y = .75X + 16.83$; protein, $Y = .65X + 6.19$; and lipid, $Y = .74X + 3.49$; where Y is the percentage of the carcass component and X is

the percentage found in the rib-section component. In later studies, it was determined that the previous equations must be modified for certain breed types. Other researchers (Crouse and Dikeman, 1974; Nour and Thonney, 1994) found that the equations overpredicted water and underpredicted fat by one percentage unit for Holstein and Angus steers, respectively. Crouse and Dikeman (1974) also reported correlations of 0.84 and 0.95 for rib chemical composition and whole side chemical composition of the carcass, respectively.

Carcass specific gravity, or density, differs from traditional carcass chemical composition procedures because none of the carcass must be ground up for chemical analysis; therefore, it can still be sold for human consumption. The procedure of specific gravity entails submerging the carcass under water and then weighing the carcass. The water displacement or how much the animal carcass weighs under water is then used to calculate the percentage fat of the body. The leaner the carcass is the heavier it will be in water. Conversely, a fat carcass will weigh less because fat acts a buoyant and helps to make the carcass float. Garrett and Hinman (1969) reported that carcass density was highly significantly correlated to the empty body chemical constituents for fat, water, nitrogen, and energy concentrations (-0.96, 0.93, 0.92, -0.95, respectively). However, they found

that these correlations were not valid for steers with less than 12% fat. The work of Preston et al. (1974) also supports that of Garrett and Hinman with correlations of -0.96 0.94, and 0.89 for fat, carcass water, and protein, respectively.

Dilution Techniques. The need for accurate live animal carcass measurements encouraged researchers to consider dilution techniques. The chemicals that have been studied for use in dilution procedures are: antipyrine or its derivatives (Wellington et al., 1956; Reid et al., 1963), deuterium oxide (Edelman, 1952; Foot and Greenhalgh, 1970, Robelin, 1977, 1982, Byers, 1979a, 1979b), sodium thiosulfate (Dalton, 1964; Ross et al., 1992), sodium thiocynate (Ashworth et al., 1943; Eder, 1951; Hix et al., 1959; Wrenn et al., 1962; Carlson et al., 1979; Caster and Simon, 1980; Gad and Preston, 1990), tritiated water (Aschbacher et al., 1965; Carnegie and Tulloh, 1968; Preston, 1968; Meissner, 1976; Meissner et al., 1980), and urea (Preston and Kock, 1973; Kock and Preston, 1979; Hammond et al., 1984; Rule et al., 1986; Bartle et al., 1987).

The basic principle for the dilution technique is the infusion of a known quantity of a specific tracer chemical into the subject animal in order to determine the pool size, or dilution space of that chemical *in vivo*. The dilution method is based on two concepts (Robelin, 1984). The first is that

the chemical composition of the animal body is related to its water content which was demonstrated by Moulton (1923). The composition of lean (fat-free) body mass is relatively constant so that determination of water content of the body allows estimation of fat, protein and ash (Hammond et al., 1984; Reid et al., 1955). The second concept is that body water can be measured using a tracer chemical such as those listed above. Also, for the dilution method to be valid useful, the tracer chemical must possess five essential characteristics. Soberman et al. (1949) stated that the ideal tracer substance should have the following characteristics: (1) an even and rapid distribution throughout all of the fluids of the body, (2) it should be non-toxic to the animal, (3) it should not be selectively stored or excreted from the body and have a slow excretion rate, (4) it should not be a foreign substance to the body, and (5) the analytical methods should be rapid and precise. Of the various dilution techniques, urea dilution is the one that best fits Soberman's characteristics.

Other Non-Invasive Methods. There are many other non-invasive methods of body composition analysis that have been and are currently being studied. A review of the literature has delineated whole body counting, computerized X-Ray tomography, nuclear magnetic resonance (NMR) imaging, and real-time ultrasonography as some of the most interesting

technologies that have been used. The major drawback of these procedures, with the exception of ultrasonography, is that all require the use of highly specialized equipment which is costly and not readily available or adaptable for on-farm use.

The first whole body counters were developed in the 1950's for use in monitoring personnel working in the field of nuclear technology (Ward, 1968). Potassium, which is found primarily found in muscle and not in fat, was determined by Lohman et al. (1966) to be measured precisely enough to predict lean muscle mass in live steers. This method estimates the quantity of lean muscle in the body of the live animal by counting the emission of gamma rays from ^{40}K which is naturally present in potassium. Martin et al. (1963) reported that grams of potassium per kilogram of live pig was significantly correlated (-0.79) with back fat thickness. Breidenstein et al. (1965) noted that using a regression model which included breed, sex, live weight, carcass weight, live animal ^{40}K count, and carcass ^{40}K count accounted for 91.3% of the variation in the carcass lean and resulted in a standard error of estimate of 1.12 kg of carcass lean in pigs weighing 95 kg. Conversely, research conducted by Preston et al. (1968) in sheep concluded that ^{40}K was not a good estimator ($r = 0.496$) of protein, or lean muscle.

Computerized X-Ray tomography (X-Ray CT) is a computer based method which depicts a cross-sectional image of the body being examined. Groeneveld et al. (1984) stated that in X-Ray CT the absorption rates of ionizing radiation is measured to create the cross sectional image. This technology is still relatively new and has been used on sheep, goats and swine but has not been studied in cattle.

Nuclear magnetic resonance (NMR) imaging is also a relatively new computerized technology in the animal sciences. NMR is similar to X-Ray CT in that both systems produce a data matrix which is used in the reconstruction of the multidimensional image. NMR operates by utilizing a strong static magnetic field and pulsed radio waves which will induce resonance of protons in the body; thus, it does not produce any ionizing radiation (Groeneveld et al., 1984). Mitchell et al. (1991) reported regression analysis of measurements made on turkey poults that resulted in R^2 values of 0.94 for NMR water proton peak area and total body water, 0.93 for NMR lipid proton peak and total lipid, and 0.96 for NMR water proton peak area and total body protein. This technology shows the most promise for success in small animals.

Another important non-invasive method of body composition is the use of real-time ultrasonography. Stouffer et al. (1961) stated that ultrasonic

imaging technology offers an impartial, nondestructive, and humane means of estimating 12th-rib fat thickness and longissimus muscle area in live beef animals. The procedure involves clipping of the hair, applying mineral oil to the area of the body to be measured, and the correct placement of the transducer onto the animal for analysis. The basic principle of ultrasound is to measure the echo that will rebound at various magnitudes from the interfaces of soft tissues in the body (Houghton and Turlington, 1992).

Ultrasonic technology was first tested on steers at Colorado State University by Temple et al. (1956) to measure subcutaneous fat thickness over the twelfth rib in cattle. They reported a correlation of 0.63 for ultrasound back fat to carcass back fat thickness. Hedrick et al. (1962) also found a good relationship measuring back fat thickness via ultrasound with a correlation coefficient of 0.63 ($P < .01$). Although, Leymaster et al. (1985) found that prediction equations developed from ultrasonic measurements were not accurate enough to warrant the use of ultrasound technology as a research tool in sheep, studies with beef cattle (Stouffer and Cross, 1985; Smith et al., 1990; and Perkins et al., 1992a) have shown similar results to that of Temple et al. (1956) and Hedrick et al. (1962) when using the same generation of ultrasonic equipment. Recio et al. (1986), Robinson et al. (1992), and Perkins et al., (1992) noted that ultrasound fat thickness' and

carcass fat thickness' were similar for animals with ≤ 10 mm of fat. Above this thickness ultrasound scanning measurements underestimated the carcass values. Miller et al. (1988) found that ultrasonic twelfth rib fat thickness accounted for a large portion of the variation ($R^2 = 0.72$) in percentage of carcass fat. Faulkner et al. (1990) created prediction equations for beef cattle with high R^2 values for predicting percent and kilograms of carcass fat as follows: $y = 36.1x - 14.9$ ($R^2 = .85$); and $y = 42.1x - 28.6$ ($R^2 = .90$), respectively. More recently, the major area of interest has been the use of ultrasound technology to predict intramuscular fat or marbling. Park et al. (1994) produced a nonlinear model that is capable of predicting intramuscular fat concentration with 90% accuracy for $> 8\%$ fat and 76.4% accuracy for $< 8\%$ fat ($P < 0.001$). Waldner et al. (1992) found that the most accurate prediction equation of empty body weight of Brangus bulls occurred at 16 months and incorporated ultrasound fat thickness, live weight, and hip height as variables in the equation ($R^2 = .99$, $SD = 6.65$ kg). Stouffer (1966) and Faulkner et al. (1990) stated that possible sources of variation in ultrasound measurement could be due to equipment, operator skill, hide, haircoat, weight, fat level, and slaughter technique. Hedrick et al. (1962) also stated that a possible error is not being able to rib the carcass at the exact angle each time and at the same location where the ultrasonic

measurements were taken. Perkins et al. (1992a,b) and Waldner et al. (1992) addressed the operator skill question and found no difference between operators, even if they had little experience operating an ultrasound instrument.

Urea Dilution

Of the preceding list of tracer substances, three chemicals, deuterium oxide, tritiated water, and urea have shown the most promise for use in scientific body composition research. While all three chemicals possess the necessary traits as stated by Soberman et al. (1949), urea is the most practical (Topel and Kauffman, 1988) since it is not radioactive, does not require special testing equipment, is inexpensive, only two blood samples are required, and the time interval between the samples is brief. Because urea is inexpensive and the technical requirements for measuring plasma urea N are minimal, the urea dilution technique could be applicable in both research and industry where measurement of body composition during growth are necessary (Rule, 1986). San Pietro and Rittenberg (1953) concluded that urea appears to cross all mammalian membranes with little resistance.

Moulton (1923) stated that all other chemical components of the body can be estimated from the quantity of body water found to exist in the animal.

San Pietro and Rittenberg (1953) defined urea space as the volume of liquid that would be necessary for solution of the total urea nitrogen of the body at a concentration equal to that in the blood. These researchers expressed urea space (US) using the following equation:

$$\text{US (in liters)} = \text{Total urea N} \times \text{blood urea N} \times 10.$$

If it is assumed that US is related to empty body water, then urea space measurements may be used as a predictor for estimating body composition in cattle (Kock and Preston, 1979). Thus, the body water would be expected to show a strong positive relationship with lean tissue and an inverse relationship with of body fat (Preston et al., 1968; Jones et al., 1982).

The process of urea dilution in the ruminant animal entails the collection of a baseline blood sample (T_0), followed by the infusion of a known quantity of a tracer substance, urea, into the jugular vein of the test animal. After a given period of time the substance will reach equilibrium with the empty body water of the animal. A second blood sample is collected from the catheter after an equilibration time of twelve minutes post infusion (T_{12}). The T_0 and T_{12} blood samples are then analyzed to measure the amounts of urea nitrogen present. This analysis yields a value is called the plasma urea nitrogen or PUN, which will be used in the subsequent calculations.

Preston and Kock (1973) were the first to investigate urea dilution (UD) as a possible technique for estimating body carcass composition in cattle. Jugular blood samples were taken at 9, 12 and 15 minutes post infusion. They concluded that the second blood sample should be taken between 12 and 15 minutes after infusion. They found that UD was highly correlated (-0.96) to empty body fat determined by carcass specific gravity. The researchers also discovered that correlations were higher for US expressed as a percentage of empty body weight than for US expressed as a percentage of live weight. Body water was also underestimated using US in this study.

Kock and Preston (1979) found that 12 minutes post-infusion was judged to be the best time from correlation coefficients with rib soft tissue composition and carcass specific gravity. The correlation coefficients between US and the percentage of water in the rib was highest at 12 minutes after infusion for weanling and yearling cattle, 0.91 and 0.76, respectively, and 0.84 overall. The correlations between carcass specific gravity and US at T_{12} or percentage fat in the rib were high for the heavier, fatter cattle but were lower for the lighter, thinner cattle. This is because carcass specific gravity had a lower correlation with rib composition than did US in the thinner cattle.

Bennett et al. (1982) evaluated the use of US and ultrasonic measurement to estimate carcass composition. Moderate correlation coefficients were observed comparing US to ultrasonic back fat thickness, 12th rib fat thickness, carcass ether extract determined from specific gravity, and percentage cutability, -0.65, -0.64, -0.74, and 0.63, respectively. Carcass ether extract determined from specific gravity, and percentage cutability were estimated from other measures rather than by direct measurement.

Jones et al. (1982) concluded that US was not a valid technique for carcass determination in sheep, steers or cows. Regression equations developed by the researchers which incorporated US and live weight for steer, and lambs had unsatisfactory low predictions of half-carcass fat, $R^2 = 0.39$, and 0.33 , respectively. Conversely, the same variables yielded a moderately useful equation for cows, $R^2 = 0.69$. Several factors may have played a role in the researchers obtaining results which contradicts other studies; the subject animals were not fasted prior to performing the procedure and the animals were thin, mature cows and steers and lambs with lean body conditions. This supports the data of Kock and Preston (1979) which resulted in lower correlation of coefficients in light, thin cattle when compared to carcass fat estimated by specific gravity but not when carcass fat was estimated from rib soft tissue analysis.

Bartle et al. (1983) studied the UD technique as an estimator of body composition in mature beef and dairy cows. Coefficients of determination in beef and dairy type cows was 0.50 and 0.28, respectively, for estimating percentage fat calculated from carcass specific gravity using US as a percentage of empty body weight (EBW) were not as high as those, 0.64 and 0.41, determined from the estimation of chemical composition using US and EBW, respectively for beef and dairy type cows (Bartle et al., 1983). The researchers found that including the change in plasma urea-nitrogen (Δ PUN) as an additional factor in a multiple regression with live weight improved the estimation of chemical composition; $R^2 = .66$ and $.62$ for beef and dairy cows, respectively.

Hammond et al. (1984, 1988) used 68 mixed breed and 50 Angus steers to estimate empty body water and empty body components by UD and chemical analysis. The researchers found correlations between EBW and US to be within a range of 0.73 to 0.96, 0.88 to 0.94 and 0.84 to 0.96 for mixed breeds, Angus and pooled data, respectively (Hammond et al., 1984). Later, they used the same data and created prediction equations for empty body fat (EBFAT) and empty body protein (EBPRO) with low standard errors of the estimate and high coefficients of determination (Hammond et al., 1988);

$EBFAT = -35.9 - .80 US + .76 EBW; S_{y.x} = 9.4 \text{ kg}, R^2 = .93;$ and

$EBPRO = 4.2 + 0.15 US + .078 EBW; S_{y.x} = 2.5 \text{ kg}, R^2 = .94.$

Rule et al. (1986) validated the UD technique comparing chemical analysis and US values derived from 6-, 12-, and 18-month-old steers. Their multiple regression equations had high coefficients of determination and low standard errors of the estimate, ranging from 0.84 to 0.89, and .96% to 3.94%, respectively.

Bartle and Preston (1986) studied the effects of urea dilution on the plasma, rumen and urine pools in beef cattle. This research was to answer the question which was posed by Preston and Kock (1973) that some urea may diffuse into these pools before equilibration in the body has been reached. Four two-year-old heifers were fitted with a rumen fistula and jugular and urinary catheters to monitor the respective fluid pools. The results indicate that reticulo-rumen water is not a major component of urea space. Renal clearance of urea appeared to be the major component of the second pool, while the first pool was the empty body water, which is associated with the lean body mass. Thus, urea dilution determines empty body water plus urine; therefore, UD overestimates empty body water by the urine volume produced in the 12-minute period it takes for equilibration.

Bartle et al. (1987) evaluated UD in cattle of different breed types and both sexes. In this experiment, the researchers used 27 Hereford X Angus (13 heifers and 14 steers) and 27 Chianina (14 heifers and 13 steers) cattle to see if there was a sex or breed type difference. Their conclusion was that sex did not affect US values while breed type was significant but the partial coefficient of determination was only 0.03.

Bartle et al. (1988) studied the urea dilution procedure using lambs. It was found that urea kinetics were similar but the regression equation that relates US to empty body water is different in lambs as compared to cattle. It was reported that an equilibration time of 9 to 12 minutes provided the best estimate of body composition in lambs. Again, animals which were not fasted prior to weighing and infusion had lower coefficients of determination. These results support that of Jones et al. (1982), which stated that animals that were not shrunk had lower correlations to carcass composition. Bartle et al. (1988) also indicated that infusion of a solution with a concentration of urea higher than 20% may yield better predictions of carcass composition.

Conclusions

In summary, many carcass composition determination procedures have been proposed throughout the years. More recently, live animal

carcass composition evaluation has been of great interest. Urea dilution has been proposed as an efficient dilution method of carcass composition determination since it meets Soberman et al. (1949) list of criteria for the ideal tracer chemical to be used. Ultrasound has received much attention as a method to determine fat composition of the animal. This process is rapid and yields high correlation coefficients with fat thickness and carcass chemical composition.

Topel and Kauffman (1988) suggest there are four factors that determine the utility of any technique of assessing body composition; high accuracy and precision, practicality, and low cost. The techniques of ultrasound and urea dilution both fit these criteria in addition to being fairly rapid measures of body composition.

CHAPTER III

EXPERIMENT 1: EFFECTS OF REPEATED UREA DILUTION
MEASUREMENT ON FEEDLOT PERFORMANCE AND
CONSISTENCY OF ESTIMATED BODY
COMPOSITION IN STEERS OF
DIFFERENT BREED TYPES

Abstract

Forty steers (20 *Bos indicus* cross and 20 *Bos taurus* cross) were randomly assigned to a 2 x 2 factorial design to study the effects of repeated urea dilution measurement on feedlot performance and consistency of estimated body composition in steers of different breed types. All steers were fed the same High Plains finishing diet. Steers were implanted with Revalor-S® on d 0 and 84. Weights were taken on d 0, 42, 84, 126, and 140. Urea dilution procedure and ultrasonic measurement of back fat were performed on d 0, 42, 84 and 126. Pen means were used in the analysis of variance. No interactions were observed; therefore, only main effects will be discussed. ADG data were inconsistent within periods between controls and steers on which UD was determined (1.95 vs. 2.11, 1.61 vs. 1.28, 1.51 vs. 1.71 and 1.77 vs. 1.47 kg, P=0.23, 0.02, 0.09 and 0.11 respectively, for periods 1, 2, 3, and 4). UD had no overall effect (control vs. UD,

respectively) on ADG (1.70 vs. 1.68 kg, $P=0.77$), DMI (8.26 vs. 8.03 kg, $P=0.69$), gain efficiency (207 vs. 209 G/1000 DM, $P=0.78$), hot carcass weight, (HCWT; 360 vs. 358 kg, $P=0.90$) or percent estimated carcass fat, (ECF; 38.8% vs. 37.0%, $P=0.61$). Breed types had similar backfat thickness (16.4 vs. 15.0 mm, $P=0.30$), ECF (38.9% vs. 36.6%, $P=0.48$), ADG (1.74 vs. 1.64 kg, $P=0.27$), and DMI (7.96 vs. 8.30 kg, $P=0.50$). UD estimated empty body fat values increased with days on feed (14.4 ± 1.36 ; 22.7 ± 1.47 ; 26.0 ± 1.36 ; $30.4 \pm 1.47\%$, respectively for d 0, 42, 84 and 126). In this experiment, ECF using yield grade factors consistently produced a value that was higher than empty body fat determined by UD 14 d prior to slaughter ($36.9\% \pm 1.4$ vs. $30.4\% \pm 0.17$). RBC percentages increased with days on feed, as the steers gained more weight. Significant correlation coefficients were calculated for the pooled data of UDEBF versus BF, $r=0.84$, UDEBF versus live weight, $R=0.99$, UDEBF versus ECF, $r=0.82$ and UDEBF versus percent carcass protein, $r=-0.99$. *Bos indicus* cross (BIX) steers had moderate to high correlations between UDEBF versus live weight, $r=0.74$. *Bos taurus* cross (BTX) steers had moderate to high correlations between UDEBF and live weight, $r=0.91$ and $r=0.73$ for periods 3 and 4, respectively, UDEBF versus percent carcass protein, $r=-0.99$ and UDEBF versus BF, $r=0.74$.

Introduction

The determination of live animal carcass composition has become of special importance because of the reduced profit margins in the feedlot industry, reduced revenue available to researchers and the desire to avoid sacrifice of the animal. Thus, many methods have been evaluated. Of those, the urea dilution (UD) procedure (Preston and Kock, 1973; Kock and Preston, 1979; Rule et al., 1986) and ultrasonic measurement of back fat (Temple et al., 1956; Stouffer and Cross, 1985) hold the most promise of being practical and an easily implemented procedure for research and on-farm applications.

Hammond et al. (1990) and Bartle et al. (1987) concluded that slight differences in prediction equations may be needed for various breed types when using UD. Therefore, the objectives of this research were to determine the effects of repeated UD on the performance of feedlot cattle, to determine the consistency of UD measurements over time and to determine if there was a difference between *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) cattle.

Materials and Methods

Forty steers (20 *Bos indicus* cross and 20 *Bos taurus* cross, $341 \pm .97$ kg) were initially randomly assigned to a 2 x 2 factorial design at the Burnett

Center, New Deal, TX after an initial 28 d receiving trial was completed. On d 42 one control steer was removed from the trial due to the animal's extreme difficulty in handling and injury. The steers were sorted into pens of five head each according to breed type, and light and heavy blocks. The effects of breed type was of interest; therefore, it was examined as a block. The steers were also sorted by weight to reduce variation within pens because pen means were used in the data analysis. All steers were fed the same High Plains finishing diet (Table 1). On days 0 and 84, all steers were implanted with one Revalor-S[®] implant (120 mg trenbolone acetate and 24 mg estradiol; Hoechst Roussel Vet, Somerville, NJ). Individual weights were recorded on d 0, 42, 84, 126, and 140, refer to Table 2 for the corresponding periods. Real-time ultrasound images (3.5 MHz transducer; Tokyo Keiki Company, Boulder, CO) of the twelfth rib back fat thickness were captured and the urea dilution procedure was performed on d 0, 42, 84 and 126 (Figure 1).

The urea solution consisted of 20% urea in 0.9% saline solution (w/v) and was infused at a rate of 0.75 ml solution per kilogram of shrunk body weight or 150 mg urea per kilogram of live body weight. Before infusion, the solution was filtered through a 0.8 μ m Milli-Fil[™] PF filter unit (Millipore Corporation, Bedford, MA) using a peristaltic pump to remove any debris

Table 1. Composition of High Plains Finishing Ration fed to the steers.

Feed Stuff	Percent of Diet, as fed
Steam flaked milo	63.50
Corn silage	26.50
Cane molasses	3.70
Animal/vegetable fat	1.50
Cottonseed meal	1.45
Rumensin premix	0.72
Calcium carbonate	0.63
Urea	0.57
Vitamin A premix ^a	0.31
Tylosin premix	0.36
Potassium chloride	0.24
Dicalcium phosphate	0.21
Trace mineral premix ^b	0.18
Sodium chloride	0.10
Vitamin E premix ^c	0.03
Feed Analysis	
Dry matter, %	72.00
Crude Protein, % ^d	12.52
Nitrogen:Sulfur	12.97
Calcium:Phosphorus	1.74
Potassium:Sodium	7.00

^a 333,333 IU/lb

^b Trace mineral premix contained: 13.69 ppm I, 8966 ppm Mn, 9343 ppm Zn, 9.19 ppm Cu, and 57 ppm Co.

^c 8,000 IU/lb

^d Dry matter basis

Table 2. Sampling periods and corresponding dates for steers.

Period	Days	Date
1	0	February 21, 1995
2	42	April 4, 1995
3	84	May 16, 1995
4	126	June 27, 1995
5	140	July 12, 1995

Figure 1. Example of ultrasound image of back fat.

present in the solution. The urea solution was mixed and filtered within 24 h of infusion. The solution was stored at 4°C.

Urea space measurements were determined using the technique described by Preston and Kock (1973). Feed was withheld for 16 h prior to infusion for all steers, including controls. Infusion was accomplished using jugular venipuncture with a 14 gauge, 57 mm I.V. catheter (Critikon, Tampa, FL). The stylus was removed while leaving the catheter in place. Then, approximately a 45 cm length of PE-190, inside diameter 1.19 mm, outside diameter 1.70 mm, non-radiopaque polyethylene tubing (Clay Adams, Parsippany, NJ) was inserted through the I.V. catheter and into the jugular vein. This insured that all of the infusate would immediately go directly into the blood supply; thus, reducing the possibility of injecting the infusion solution subcutaneously. The catheter was flushed with 2-3 ml of heparinized saline (100 units heparin per ml of saline). Before collecting a sample, approximately 5 ml of blood was drawn into a syringe and then reinjected; thus, allowing for all of the blood collected to be fresh and have a homogeneous urea concentration. A 10 ml blood sample was collected (T_0) before injecting any infusate into the steer. Blood samples were stored on ice and in a sterile Vacutainer® (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) which contained EDTA as an anti-coagulant until arrival at the laboratory and centrifugation. The predetermined volume of infusate,

0.75 ml solution per kilogram of shrunk live body weight, was infused within 2 minutes or less by using a 60 ml syringe and a 3-way syringe stopcock valve. Infusion times were recorded on note cards, using the mid-point of infusion as the starting time, along with animal number, weight and quantity of infusate injected. Twelve minutes later (T_{12}), a blood sample was taken using the same collection procedure as above. The accuracy of the volume of infusate injected was gravimetrically determined by infusing into three volumetric flasks, once each at the beginning, mid-point and end of the sampling day.

Blood samples were centrifuged at 3,000 x g for 20 minutes after a small sample was retained for hematocrit determination. Plasma urea nitrogen (PUN) analysis was performed (Fawcett and Scott, 1960; Chaney and Marbach, 1962; Searle, 1984) within 24 h of sampling using a Beckman DU-50 spectrophotometer. Briefly, 400 μ l of a buffered urease solution was added to 20 μ l plasma in a test tube and then incubated at 37°C for 15 minutes. Then, 4 ml of phenol color reagent is added followed immediately with 4 ml of the alkaline hypochlorite reagent. The samples were then thoroughly mixed and again incubated in a 37°C water bath for 15 minutes. This final solution, which was stable for 24 hours if placed in a cool and dark room, was assayed at 625 nm using a spectrophotometer. The value obtained, which was a measure of light absorbance, from the

spectrophotometer directly corresponds to the amount of urea present in the original blood sample. Percent urea space (US) was calculated with the following equation:

$$\frac{\text{mg urea infused}}{\Delta \text{ PUN} \times \text{live weight (kg)} \times 10}$$

where Δ PUN is the change in PUN concentration of the blood between T_0 and T_{12} . Duplicate runs were performed and all samples were analyzed in triplicate within each run. Analysis of samples was accepted if the coefficient of variation was less than 2% within and 5% between runs. Percent empty body water (EBH₂O), percent empty body fat (EBF) and percent carcass protein of each steer were calculated with the following equations (Rule et al., 1986).

$$\% \text{ EBH}_2\text{O} = 59.1 + 0.22 * \text{US\%} - 0.04 * \text{LW}$$

$$\% \text{ UDEBF} = 19.5 - 0.31 * \text{US\%} + 0.05 * \text{LW}$$

$$\% \text{ Carcass Protein} = 16.7 + 0.07 * \text{US\%} + 0.01 * \text{LW},$$

where US% is percent urea space and LW is live weight in kilograms.

Real-time ultrasound images were captured on the right side of each steer at the twelfth rib immediately after it was weighed. Excess hair was shorn to reduce interference from hair and dirt. Mineral oil was then applied to the area to insure proper contact of the probe and conduction of the sound waves. All images were captured on a video monitor before printing. Using the calipers on the monitor, the back fat thickness was marked and

measured. A printed image of each steer's back fat thickness was retained for record.

Before the blood samples were centrifuged and separated for PUN analysis a small amount was retained for hematocrit determination.

Hematocrit (% red blood cells; RBC) was measured on d 0, 42, 84 and 126 to determine the effects of age on red blood cell volume and to determine the effects of UD on RBC post infusion. Blood samples were drawn into a microhematocrit capillary tube and then centrifuged using a Clay Adams Autocrit II Centrifuge (Parsippany, NJ) for 3 minutes. The percent red blood cell volume (RBC) was determined by measuring the amount of red blood cells that were located on the bottom or outer end of the capillary tube.

On d 140 all steers were weighed and taken to the Excel Meat Packing Plant in Plainview, TX. The carcasses were chilled for 48 h. Hot carcass weight, rib eye area (REA), fat thickness, percent kidney, pelvic and heart fat (KPH), and degree of marbling were determined after 48 h.

Data were statistically analyzed using the General Linear Means procedures of SAS (1985). This type of analysis was used at each period to allow for the evaluation of the UD procedure at the specified time intervals. It was also used to determine if there was an optimum time at which to perform this procedure during the feed-out period that would accurately predict final

body composition. Least squares means were used to calculate correlation coefficients.

Results and Discussion

No interactions between treatments and breed types were observed; therefore, only main effects will be discussed. Average daily gain (ADG) data were inconsistent between periods for UD and control steers. Figure 2. Urea dilution (UD) treatment steers had a higher ADG for days 0-42 and 85-126, 2.11 vs. 1.95 and 1.71 vs. 1.51 kg; $P=0.24$ and $P=0.10$, respectively. Control animals had higher ADG values during days 43-84 and 127-140, 1.61 vs. 1.28 and 1.76 vs. 1.53; $P=0.03$ and $P=0.11$, respectively. There was a much higher difference in ADG values when the control animals had higher ADG than there was when the UD steers gained more. Thus, over the entire feeding trial, the control steers only gained a total of 2.8 kg more during the 140 d trial, Figure 3. This is equivalent to a 1.2% decrease in ADG for the UD cattle. The data are in concert with that of Bartle and Preston (1992) in which they noted decreased gains of steers during the week following the UD procedure and an overall 3.1% decrease of ADG for UD steers.

ADG data were also inconsistent for breed type, Figure 4. BIX steers had numerically, but not statistically higher ADG on days 0-42, and 52-126, 2.14 vs. 1.93, and 1.71 vs. 1.51 kg; $P=0.19$, and $P=0.24$, respectively, while

BTX steers only had a numerically higher ADG during days 43-84, (1.50 vs. 1.39, $P=0.28$). Figure 3 graphically illustrates that the BIX steers did not have a higher rate of gain over the entire feeding trial than did the BTX steers, (1.74 vs. 1.64 kg, $P=0.28$).

Gain efficiency data over treatments were also inconsistent between periods (Figure 5). This is reflected in the inconsistency of the ADG of the steers. UD steers had a higher gain efficiency during days 0-42 and 85-126; 292 vs. 218 and 196 vs. 174 G/1000 DM; $P=0.23$ and $P=0.09$, respectively. Control animals had significantly higher gain to DM ratios on days 43-84 and 127-140; 190.44 versus 162 and 197 versus 169; $P=0.07$ and $P=0.06$, respectively. Although; overall, the UD and control steers had the same gain efficiency (209 vs. 207, $P=0.78$ Figure 6).

As with the ADG data, the breed effect data were inconsistent between periods (Figure 7). The BIX cattle had significantly higher gain to DM ratios on days 0-42, 85-126 and 126-140; 311 versus 253, 199 versus 171 and 187 versus 180 G/1000 DM; $P=0.02$, $P=0.05$ and $P=0.52$, respectively. BTX steers only had a numerically higher gain efficiency during days 43-84; 180 versus 171 G/1000 DM; $P=0.43$. Thus, Figure 6 delineates that the BIX cattle significantly had higher gain efficiencies than did the BTX steers (218 vs. 197, $P=0.06$) over the entire feeding trial. The BIX steers started the trial weighing 342.50 kg while the BTX steers weighed 356.12 kg, $P=0.35$, a difference of 13.62 kg.

Figure 2. Period average daily gain (ADG) of control and urea dilution (UD) treatment steers.

Figure 3. Average daily gain (ADG) of control, urea dilution (UD), *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) breed steers over the entire feeding trial.

Figure 4. Period average daily gain (ADG) of *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) breed steers.

Figure 5. Period gain efficiency of control and urea dilution (UD) treatment steers. All P values were greater than 0.05.

Figure 6. Overall gain efficiency of control, urea dilution (UD) treatments and *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) breed steers.

Figure 7. Period gain efficiencies between *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) breed steers.

On the final day of the trial, they weighed 583.90 and 585.32 kg, $P=0.94$, respectively, for BIX and BTX

Bartle and Preston (1992) showed that weighing steers did not appear to affect DMI. There was no significant difference in overall DMI between breed types (7.96 vs. 8.35 kg, $P=0.50$) for the BIX and BTX steers respectively, although, BTX steers consistently had a numerically higher DMI than did the BIX steers (7.66 vs. 6.84, 8.30 vs. 8.14, 8.86 vs. 8.60, 8.97 vs. 8.77, kg; $P=0.34$, $P=0.76$, $P=0.68$, $P=0.54$) during each period.

Tables 3 and 4 list the correlation coefficients for UD determined empty body fat (UDEBF) versus ultrasonic backfat (BF) measurements between periods for the two breed types. In general, the correlation coefficients become stronger for the all of the data, pooled data, -0.78, 0.50, 0.84, 0.84, for each successive period, 1, 2, 3, and 4. These data support the conclusions of Bennett et al. (1982) in which they calculated a correlation coefficient of $r=0.88$ between ultrasound and carcass 12th rib fat thickness and $r=0.75$ between ultrasound and percentage ether extract. Figure 8 illustrates that starting with period 2 through period 4 there is an increasing linear trend for both UDEBF and BF with a steady decrease in the standard error of the mean for the UDEBF measurements. When the data were separated into breed types, the BTX steers (Figure 9 and Table 4) had a

Table 3. Correlation coefficients of various measurements of the steers between periods ^a

Variable	Correlation Coefficients
Day 0 live weight vs. d 0 % UDEBF	0.34
Day 42 live weight vs. d 42% UDEBF	0.99
Day 84 live weight vs. d 84 % UDEBF	0.82
Day 126 live weight vs. d 126 % UDEBF	0.95
Day 0 live weight vs. % ECF ^{bc}	0.53
Day 42 live weight vs. % ECF ^{bc}	0.69
Day 84 live weight vs. % ECF ^{bc}	0.66
Day 126 live weight vs. % ECF ^{bc}	0.72
Day 140 live weight vs. % ECF ^{bc}	0.73
Day 126 BF to ECF ^{bc}	0.61
Day 0 BF vs. % carcass protein ^c	-0.80
Day 42 BF vs. % carcass protein ^c	-0.50
Day 84 BF vs. % carcass protein ^c	-0.80
Day 126 BF vs. % carcass protein ^c	-0.85
Day 0 % UDEBF vs. % carcass protein ^c	-0.999
Day 42 % UDEBF vs. % carcass protein ^c	-0.999
Day 84 % UDEBF vs. % carcass protein ^c	-0.999
Day 126 % UDEBF vs. % carcass protein ^c	-0.999
Day 0 % UDEBF vs. d 0 % BF	-0.78
Day 42 % UDEBF vs. d 42 % BF	0.50
Day 84 % UDEBF vs. d 84 % BF	0.84
Day 126 % UDEBF vs. d 126 % BF	0.84
Day 84 % UDEBF vs. % ECF ^{bc}	0.82
Day 126 % UDEBF vs. % ECF ^{bc}	0.66

^a Correlation coefficients use pen means.

^b Miller et al. (1988) equation; carcass fat=(25.3*BF, .1in) + (.08*HCWT, kg) + (1.7*%KPH) + (-1.8*REA, in²) + 9.7

^c Carcass protein and ECF were determined at 140 d.

Table 4. Correlation coefficients of various measurements of *Bos indicus* cross (BIX) and *Bos taurus* cross (BTX) breed types^a

Variable	Correlation Coefficients
<u><i>Bos indicus</i> cross steers</u>	
Day 0 live weight vs. d 0 % UDEBF	0.76
Day 42 live weight vs. d 42 % UDEBF	0.84
Day 84 live weight vs. d 84 % UDEBF	0.57
Day 126 live weight vs. d 126 % UDEBF	0.79
Day 126 UDEBF vs. carcass fat ^{bc}	0.63
Day 126 BF vs. % carcass protein ^c	-0.78
Day 0 % UDEBF vs. % carcass protein ^c	-0.999
Day 42 % UDEBF vs. % carcass protein ^c	-0.999
Day 84 % UDEBF vs. % carcass protein ^c	-0.998
Day 126 % UDEBF vs. % carcass protein ^c	-0.998
Day 42 % UDEBF vs. d 42 BF	0.69
Day 84 % UDEBF vs. d 84 BF	0.28
Day 126 % UDEBF vs. d 126 BF	0.74
<u><i>Bos taurus</i> cross steers</u>	
Day 0 live weight vs. d 0 % UDEBF	-0.36
Day 42 live weight vs. d 42 % UDEBF	0.83
Day 84 live weight vs. d 84 % UDEBF	0.91
Day 126 live weight vs. d 126 % UDEBF	0.73
Day 126 carcass fat ^{bc} vs. d 126 % UDEBF	-0.14
Day 126 BF vs. % carcass protein ^c	0.01
Day 0 % UDEBF vs. % carcass protein ^c	-0.997
Day 42 % UDEBF vs. % carcass protein ^c	-0.999
Day 84 % UDEBF vs. % carcass protein ^c	-0.999
Day 126 % UDEBF vs. % carcass protein ^c	-0.64
Day 42 % UDEBF vs. d 42 BF	0.73
Day 84 % UDEBF vs. d 84 BF	0.53
Day 126 % UDEBF vs. d 126 BF	0.08

^a Correlation coefficients use all animal values.

^b Miller et al. (1988) yield grade (YG) equation; carcass fat=8.9*YG + 9.7

^c Carcass fat and carcass protein determined at 140 d. periods 2, 3, and 4,

Figure 8. Comparison of urea dilution empty body fat (UDEBF) and ultrasonic back fat (BF) measurements.

Standard error of the mean (SEM) for each data set is listed.

Figure 9. Comparison of urea dilution empty body fat (UDEBF) and ultrasonic back fat (BF) measurements of *Bos taurus* cross (BTX) breed steers. Correlation coefficient for each period is indicated.

trend of lower correlation coefficients as time progressed ($r=0.73$, $r=0.53$, $r=0.08$, respectively). BIX steers had inconsistent correlation coefficients between UDEBF and BF for the last 3 sample periods ($r=0.69$, $r=0.28$, and $r=0.74$, respectively, for periods 2, 3, and 4, Figure 10 and Table 4). BIX steers consistently had lower UDEBF values than did the BTX steers throughout the entire trial (Figure 11). UDEBF, when using BF as a basis of comparison, was a better indicator for the pooled data than it was for the individual breed types. This is in contrast to the results of Bennett et al. (1982) in which US was a better indicator for homogeneous groups of cattle. BIX and BTX steers had similar final BF thickness' and UDEBF values of 16.4 versus 15.0 mm and 30.04 versus 29.77%, $P=0.49$, respectively.

Percent UDEBF was also correlated with the live weight of the UD treatment steers (Tables 3 and 4). Moderate to significant correlations were obtained for periods 2, 3 and 4 for the pooled data and the BIX steers, range from $r=0.57$ to $r=0.99$. Comparisons at the various period were made to determine if reasonable estimates for sorting of the animals could be made during the feeding trial. UDEBF and live weight had the lowest correlation for period 1 for the pooled data and the BTX steers, $r=0.34$ and $r=-0.36$, respectively. As can be seen in Figures 12 and 13, UDEBF accretion followed the same linear trends and with the same slope starting with period 2 and continuing through period 4 as that of live weight. A high correlation between UDEBF and live weight can be partially explained because live

Figure 10. Comparison of urea dilution empty body fat (UDEBF) and ultrasonic back fat (BF) measurements of Bos indicus cross (BIX) breed steers. Correlation coefficient for each period is indicated.

Figure 11. Comparison of urea dilution empty body fat (UDEBF) of *Bos indicus* cross (BIX) and *Bos taurus* cross breed steers. Standard error of the mean (SEM) for each data set is listed.

Figure 12. Comparison of period live weight and urea dilution empty body fat (UDEBF) within the *Bos taurus* cross (BTX) breed steers. Correlation coefficient for each period is indicated.

Figure 13. Comparison of period live weight and urea dilution empty body fat (UDEBF) within the *Bos indicus* cross (BIX) breed steers. Correlation coefficient for each period is indicated.

weight is used to determine the amount of urea infusate to infuse, is used to calculate percent US and it is a variable in the equation by Rule et al. (1986) which is used to calculate UDEBF.

Percent UDEBF was compared with several other derived equations. UDEBF for the period data was compared to two equations derived by Miller et al. (1988) that uses several carcass measurements to obtain percent carcass fat. The first equation is as follows:

$$\text{Percent Estimated Carcass Fat (ECF)} = (25.3 * \text{BF}, .1\text{in}) + (0.08 * \text{HCWT}, \text{kg}) + (1.7 * \% \text{KPH}) + (-1.8 * \text{REA}, \text{in}^2) + 9.7.$$

Moderate to high correlation coefficients between pooled UDEBF data and ECF were obtained for periods 3 and 4, $r=0.82$ and $r=0.66$, respectively.

Figure 14 shows UDEBF at 126 d consistently produced a value that was lower than the 140 d ECF equation ($30.4\% \pm 0.17$ vs. $36.9\% \pm 1.4$). A possible explanation for the higher standard error of the mean (SEM) for the ECF equation is that it contains 4 variable compared to the 2 that the UDEBF equation uses. Three of the four variables in the ECF equation are more subjective in which they are estimated rather than being made by quantitative measurements. The coefficient of determination was higher for UDEBF than it was for ECF ($R^2=0.99$ vs. $R^2=0.72$). The calculated coefficient of determination of ECF ($R^2=0.72$) was only slightly lower than that determined by Miller et al. (1986) ($R^2=0.77$). BIX and BTX steers had similar ECF values (38.9% vs. 36.6% , $P=0.48$). Using the pooled data, a moderate correlation,

Figure 14. 126 d urea dilution empty body fat (UDEBF) versus 140 d Empty Carcass Fat (ECF).

$r=0.61$, was obtained between BF and ECF. A general increasing trend of correlation coefficients was noticed between shrunk live weight and ECF, $r=0.53$, $r=0.69$, $r=0.66$, $r=0.72$ and $r=0.73$ for periods 1, 2, 3, 4, and 5; respectively (Table 3).

The second equation that was compared to UDEBF was an equation obtained from Miller et al. (1988) which uses carcass yield grade (YG) to calculate carcass fat; carcass fat = $8.9 \times \text{YG} + 9.7$. Using this equation, a moderate correlation was obtained for the BIX steers, $r=0.63$, while a low negative correlation of $r=-0.14$ was calculated for BTX steers (Table 4).

Correlations using percent carcass protein were used to check the accuracy of various measurements (Tables 3 and 4). A negative correlation is expected between percent carcass protein and UDEBF and BF, because as the animal approaches maturity a greater percentage of the live weight will be in the form of fat. Thus, the data reported here seems reasonable since significantly high negative correlations were calculated for percent carcass protein verses percent UDEBF for the pooled data and both breed types. Carcass protein was also negatively correlated with BF. The pooled data of both breeds and the BIX data yielded moderate to high negative correlations with a range of $r=-0.50$ to $r=-0.78$. The BIX cattle showed little correlation of percent carcass protein to BF, $r=0.01$.

An increase in the mean of both breed types of T_0 red blood cell (RBC) can be seen as the steers became older, 40.5, 40, 43.1, 42.6 % RBC, respectively for periods 1, 2, 3, and 4. Doornenbal and Martin (1965) observed in pigs that the percent RBC increased as the animal became older and gained weight. Percent carcass protein had a high correlation with T_0 RBC for period 4. This conclusion is supported by the work of Doornenbal and Martin (1965) in which they determined that there is a high correlation between the lean tissue mass, oxygen consumer, and the RBC mass. Correlation coefficients between T_0 and T_{12} for period 3 and 4 are $r=0.95$ and $r=0.40$, respectively. Period 4 percent carcass protein has a negative correlation, $r=-0.11$, with the T_{12} RBC value. A possible explanation for the low negative correlation is that the volume of infusate was high enough to cause a dilution effect of the RBC in the blood. The T_{12} RBC concentration was higher than the T_0 concentration because the volume of fluid in which the RBC was diluted by the volume of infusate. When comparing both breed types, T_0 RBC values are higher for periods 3 and 4 (Figures 15 and 16). The T_0 and T_{12} RBC are not different at the first sampling period for both breeds. This could be because the volume of infusate was relatively small when compared to the volumes of subsequent sampling dates. In contrast to BIX steers the BTX steers had a higher T_0 RBC than T_{12} for period 2.

Figure 15. *Bos taurus* cross (BTX) T0 and T12 percent red blood cell (RBC). Standard error of the mean (SEM) for each data set is listed.

Figure 16. *Bos indicus* cross (BIX) T0 and T12 percent red blood cell (RBC). Standard error of the mean (SEM) for each data set is listed.

Conclusions

The urea dilution technique for live animal carcass composition determination is a valid and useful procedure that can be used over a wide range of body condition and breed types. UD had no overall effect on average daily gain, dry matter intake, gain efficiency, empty carcass, and live weight for control and UD treatment steers. The slight, but not statistically significant, higher ADG for the control steers only results in a 1.2% decrease in rate of gain or a 2.8 kg reduction in final body weight of the UD steers when compared to the control animals. UDEBF had moderate to high correlations, ranging from $r=0.73$ to $r=0.84$, with ultrasonic back fat over the pooled data and within the breed types.

There were no differences observed using the general breed type specification of *Bos indicus* steers and *Bos taurus* cross steers for ADG, DMI, BF and ECF. The ADG of the BIX steers was 1.74 kg compared to 1.64 kg for the BTX steers, $P=0.28$. BIX and BTX steers had similar DMI of 7.96 versus 8.30 kg, $P=0.50$. The BIX steers did have a higher gain efficiency over the BTX steers (218 vs. 197, $P=0.06$). BF and ECF measurements for the BIX and BTX steers were also similar (16.4 vs. 15.0 mm, $P=0.30$ and 39.9 vs. 36.6%, $P=0.48$, respectively).

Based on these observations the UD procedure is a viable method of body composition determination. The best time to implement this procedure

is d 84 because this is at a time when re-implantation may occur and 60 to 90 d are left for time-on-feed for the steers.

A draw-back to this procedure is the amount of time required for sampling, 12 minutes, and the amount of time required for plasma urea nitrogen (PUN) analysis, about 30 to 45 minutes per sample. Thus, this procedure would be more valuable for researchers than for on-farm or in feedlot uses. Geneticists and bull evaluation stations could use this procedure as part of a set of bull selection criteria. It would be valuable because there is no need to sacrifice the animal or its progeny to be able to predict body composition and develop EPD values. Thus, selection of better cattle could be sped up which will help the cattle industry to catch-up with the changing desires of the consumers preference of type and quality of meat.

CHAPTER IV

EXPERIMENT 2: EFFECTS OF CRUDE PROTEIN LEVEL OF DIET ON UREA SPACE MEASUREMENTS IN LAMBS

Abstract

Eight cross-breed wethers (39.73 ± 2.23 kg) were used in a 2 x 2 factorial design experiment to study the effects of level of protein and energy in the diet on the results of the urea dilution procedure in the metabolism facilities of the Texas Tech University Research Center, New Deal, TX. The UD procedure was performed once every 72 hours for three sampling periods. Two levels, high and low, of protein and energy were randomly assigned to eight lambs; with two lambs on each treatment. Actual protein and energy levels fed to the lambs were 10.01%, 12.95%, 10.49%, and 13.44% crude protein, and 0.40, 0.40, 0.31, and 0.32 NE_m Mcal/kg of the diet, respectively, for diets 1, 2, 3, and 4. No interactions between the level of protein and level of energy in the diet were observed. Treatment means were used in the analysis of data. The level of protein in the diet had a significant effect on percent UDEBF, UDH₂O and carcass protein (high vs. low protein, 8.81 vs. -2.78%, 64.19 vs. 76.72%, and 18.53 vs. 22.45%; $P=0.02$, 0.001 and 0.0001, respectively). Protein levels did not affect T₀ or T₁₂ RBC counts (29.5 vs. 29.13% and 27.38 vs. 28.17, respectively) for high

and low levels. The energy level of the diet did not have a significant effect on UDEBF, UDH₂O, carcass protein, T₀ or T₁₂ RBC (4.26 vs. 1.77%, 69.4 vs. 71.5%, 20.2 vs. 20.8%, 29.98 vs. 28.85% and 28.68 vs. 26.9%, respectively for high and low levels). T₀ and T₁₂ RBC levels decreased between period 1 and period 2 and then leveled off between period 2 and period 3 (35.9% vs. 34.0%, 26.1% vs. 25.4%, and 25.9% vs. 23.9%, respectively, for T₀ vs. T₁₂) and periods 1, 2, and 3.

Introduction

Much work has been conducted to validate the US concept for determining live animal carcass composition. US was first proposed for use on cattle and found to have moderate correlations with carcass specific gravity (Preston and Kock, 1973; Kock and Preston, 1979) . Other researchers have used cattle to compare US to chemical composition (Kock and Preston, 1979; Bartle et al., 1983; Hammond et al., 1984, 1988; Rule et al., 1986); and ultrasound (Jones et al., 1982). Hammond et al. (1990) and Bartle et al. (1987) concluded that slight differences in prediction equations may be needed for various breed types of cattle when using UD. No research has been specifically performed to determine if a difference in prediction will occur for animals on various diets. Therefore, this experiment will try to answer this question.

Materials and Methods

Eight cross-breed wethers were used in a 2 x 2 factorial design experiment to study the effects of level of protein and energy in the diet on the results of the urea dilution procedure in the metabolism facilities of the Texas Tech University Research Center, New Deal, TX. The weights of the lambs ranged from 34.8 to 42.0 kg. All eight lambs were part of a corresponding research project in which urea dynamics in the rumen and blood were to be studied (Dettle and Preston, 1996, unpublished research). For this additional project, all wethers were fitted with rumen cannulas and jugular vein catheters. Each lamb was allotted to treatments randomly and placed in metabolism stalls one week prior to the initiation of both studies to allow for acclimation to their new environment and diets. Two wethers were placed on each diet for a total of four treatments (Table 5). Lambs were weighed one day prior to infusion of a 99.1% ¹⁵N enriched urea infusate solution. No feed was withheld from the lambs prior weighing and to infusion. Refer to Table 6 for the amount of infusate and the weight for each lamb.

The procedure of the placement of the jugular catheter was the same as that for experiment 3 with a few minor exceptions. The first exception was that about 30 cm of the catheter remained outside of the animal and was attached to the skin of the lamb at three or four locations along the length of

Table 5. Composition of rations fed to lambs.

Feed Stuff	Percent of Diet, as fed			
	Treatment 1 High Energy/ Low Protein	Treatment 2 High Energy/ High Protein	Treatment 3 Low Energy/ Low Protein	Treatment 4 Low Energy/ High Protein
Cracked Corn	76.99	75.80	29.96	29.98
Cottonseed Hulls	10.13	10.13	50.57	49.43
Cottonseed Meal	4.38	4.38	10.39	10.38
Cane Molasses	4.31	4.30	4.24	4.24
Calcium Carbonate	1.33	1.33	1.01	1.04
Animal/Vegetable Fat	1.11	1.15	2.07	2.07
Dicalcium Phosphate			0.21	0.18
Salt	0.35	0.35	0.38	0.38
Trace Mineral Premix ^a	0.30	0.30	0.29	0.29
Vitamin A Premix	0.38	0.38	0.37	0.37
Vitamin E Premix	0.10	0.10	0.10	0.10
Vitamin D Premix	0.35	0.35	0.35	0.35
Ammonium Sulfate	0.06	0.26	0.04	0.24
Urea		0.96		0.94
Potassium Chloride	0.22	0.22		
Feed Analysis				
Dry matter, %	89.42	89.51	90.77	90.83
Crude Protein, % ^b	10.01	12.95	10.49	13.44
NEm, Mcal/kg	0.40	0.40	0.32	0.31
Supplemented Vitamins,IU				
Vitamin A	1261	1259	1242	1241
Vitamin D	176	176	174	173
Vitamin E	8	8	8	8

^a Trace mineral premix contained: 13.69 ppm I, 8966 ppm Mn, 9343 ppm Zn, 9.19 ppm Cu, and 57 ppm Co.

^b Dry matter basis.

Table 6. Weight, diet and infusate doses of each lamb.

Lamb	Diet	Weight	Infusate 1			Infusate 2			Infusate 3		
			ml	g Urea-N	ml	g Urea-N	ml	g Urea-N	ml	g Urea-N	g Urea-N
942	1	41.2	25.93	0.58	25.93	0.58	25.93	0.58	25.93	0.58	0.58
131	1	40.8	25.68	0.58	25.68	0.58	25.68	0.58	25.63	0.58	0.58
128	2	39.6	24.92	0.56	24.92	0.56	24.92	0.56	24.92	0.56	0.56
946	2	39.2	24.67	0.55	24.67	0.55	24.67	0.55	24.67	0.55	0.55
130	3	34.8	21.90	0.49	21.90	0.49	21.90	0.49	21.90	0.49	0.49
949	3	41.0	25.80	0.58	24.67	0.58	24.67	0.55	25.80	0.58	0.58
129	4	39.2	24.67	0.55	25.80	0.55	25.80	0.58	24.67	0.55	0.55
945	4	42.0	26.43	0.59	26.43	0.59	26.43	0.59	26.43	0.59	0.59
Mean		39.73		0.56		0.56		0.56		0.56	0.56

the catheter via a suturing of the catheter to the skin and then covering the area and excess length of the catheter with athletic tape. The end of an 18-gauge needle was plugged with hematocrit clay and then used as a stopper for the catheter after the stem was cut to about 1.25 cm and dulled to prevent cutting of the catheter wall. Secondly, the chronic catheter was maintained by flushing with 2-3 ml of 0.9% saline prior to and then flushed with 2-3 ml of heparinized saline (100 units heparin per ml of saline) after the infusion of the urea solution and blood letting

The urea dilution procedure was conducted three times according to the procedure in Chapter III over the course of seven days. Instead of using a three-way stopcock and 60 ml syringe, a 30 ml syringe was used since smaller volumes were being infused. This also allowed for greater accuracy of infusing the target dose. In addition to blood samples being taken at T_0 and T_{12} , samples were also collected at .5, 1.5, 4, 8, 16, 24, 48 and 72 hours. The 72 hour sample was used as the T_0 sample when the second and third dilution procedures were performed.

All blood samples were immediately placed in a refrigerator until transport to the on campus laboratory where hematocrit determinations were made prior to centrifugation and separation of plasma. Samples were stored in Vacutainer® vials and transported on ice to the laboratory. They were then centrifuged at 3,000 x g for 20 minutes (Rule et al., 1986). Hematocrit

samples and measurements were conducted according to the procedure in Chapter III. PUN determination and calculation of US, UDEBF, UDH₂O and carcass protein were the same as outlined in Chapter III.

All data were statistically analyzed using the General Linear Means procedures of SAS (1985).

Results and Discussion

No interactions between protein and energy levels were observed; therefore, only main effects will be discussed. Treatment means were used in the analysis of data. Percent protein in the diet had a significant effect on UD calculated body composition measurements; percent UDEBF, UDH₂O and carcass protein, high vs. low protein (8.8 vs. -2.8%, 64.2 vs. 76.7%, and 18.5 vs. 22.5%; $P=0.02$, 0.001 and 0.0001, respectively, Table 7). As can be seen in Table 7, all four diets resulted in percent US values that were too high for the actual body condition of the lambs. The same equations used to calculate body composition for steers were used in this trial (Rule et al., 1986). The diets with the higher level of protein resulted in percent US values that were not as high which allowed for UDEBF values what are slightly more logical, but still too low. The low protein diets drastically underestimated the UDEBF values of the sheep by having extremely high US values and in two cases calculated values were negative. This is biologically

Table 7. Percent US%, UDEBF, UDH ₂ O, and carcass protein of each lamb on each diet ^{ab}					
Diet	Lamb	US%	UDEBF	UDH ₂ O	Carcass Protein
2	128	52.77	5.12	69.13	20.00
2	946	29.70	12.25	64.07	18.39
4	129	-13.15	25.54	54.64	15.39
4	945	36.86	10.17	65.53	18.86
1	942	83.49	-4.32	75.82	22.13
1	131	67.22	0.70	72.26	21.00
3	130	78.45	-3.08	74.97	21.84
3	949	52.73	5.21	69.06	19.98

^a Refer to table 5 for description of diets.

^b Equations used are from Rule et al. (1986).

impossible for a living animal to express a negative percent fat content. With all diets, the UDH₂O and carcass protein values were also high. Bartle et al. (1988) also found that lambs fed 70 and 50% roughage diets tended to overestimate EBH₂O. This is to be expected since both equations utilize percent US in their calculations. One possible explanation for the values observed here is that the change in PUN concentration was not large enough to be able to adequately predict the animal's total urea space. The delta PUN values were only 2-3 mg/dl. This is 3-4 times lower than what is normally expected. The reason that the delta PUN is so low is because an extremely low amount of urea as ¹⁵N-urea was injected into each animal, approximately 56 mg urea per kilogram of body weight. This is in contrast to the 150 mg of urea per kilogram of body weight that was used in chapter 3. These data support the work by Bartle et al. (1988) from which they concluded that infusing a greater amount of urea per kilogram of live weight may improve the composition relationships in lambs. Although, one must consider the possibility of hemolysis if the infusion concentration is elevated too high (>22%; Preston, unpublished data). When the ¹⁵N analysis from the corresponding research becomes available better estimates of body composition may result. Bartle et al. also stated that procedural errors may have a large role in determining the amount of PUN of the sample. If there is

a large coefficient of variation in the determination of PUN and/or if the delta PUN is small, then the delta PUN value will not be accurate.

The energy level of the diet did not have a significant effect on UDEBF, UDH₂O, carcass protein T₀ or T₁₂ (4.3 vs. 1.8%, 69.4 vs. 71.5%, 20.2 vs. 20.8%, 29.9 vs. 28.8% and 28.6 vs. 26.9%, respectively, for high and low energy levels). UDEBF values were extremely low for both levels of energy. Again the range of the UDH₂O and carcass protein were too high for the condition of the lambs in the trial.

Protein levels did not affect T₀ or T₁₂ RBC counts (29.5 vs. 29.1% and 27.4 vs. 28.2, respectively for high and low levels, Figures 17 and 18). The pooled T₀ and T₁₂ RBC levels decreased between period 1 and period 2 and then leveled off between period 2 and period 3 (35.9% vs. 34.0%, 26.1% vs. 25.4%, and 25.9% vs. 23.9%, respectively for T₀ vs. T₁₂ and periods 1, 2, and 3). During all times, the T₁₂ RBC value was lower than the T₀ which is what is to be expected due to the dilution effect of the infusate. The sharp decline in RBC between T₀ of period 1 and T₀ of period 2 may be due to the numerous blood samples that were collected during this period.

Figure 17. Percent red blood cell (RBC) of the high protein diet fed to the lambs. Standard error of the mean (SEM) for each data set is listed.

Figure 18. Percent red blood cell (RBC) of the low protein diet fed to the lambs. Standard error of the mean (SEM) for each data set is listed.

Conclusions

A significant difference in PUN and calculated UDEBF values between the two levels of protein in the diet was detected. These data have limited use because the urea concentration of the infusate was too low to yield a large enough delta PUN to accurately predict body composition. UDEBF calculated values were too low and in some cases a negative percentage was obtained. Lambs on the high roughage, low protein diets exhibited an overestimation of percent US, UDH₂O and carcass protein for all lambs. Protein and energy levels had no effect on RBC counts. No significant differences in US, UDEBF, UDH₂O or carcass protein were detected when the data was analyzed in regards to the level of energy in the ration. RBC levels drastically dropped between period 1 and 2 but reached a plateau between periods 2 and 3. The next step in this research would be to feed high and low levels of protein and energy to sheep and cattle and conduct the US procedure using the typical concentration of urea for the cattle and possibly a slightly higher concentration for the sheep, although the concentration of the urea should not be too high in order to prevent hemolysis.

CHAPTER V

INTEGRATED CONCLUSIONS

Based on the observations from Experiment 1, the UD procedure is a viable method of body composition determination. The best time to implement the procedure is d 84 because this is at a time when re-implantation may occur and 60 to 90 d are left for time-on-feed for the steers.

A draw-back to this procedure is the amount of time required for sampling, 12 minutes, and the amount of time required for plasma urea nitrogen (PUN) analysis, about 30 to 45 minutes per sample. Thus, this procedure would be more valuable for researchers than for on-farm or in feedlot uses. Geneticists and bull evaluation stations could use this procedure as part of a set of bull selection criteria. It would be valuable because there is no need to grow the animal and its progeny to be able to predict body composition from chemical analysis. Thus, selection of better cattle can be sped up which will help the cattle industry to catch-up with the changing desires of the consumers preference of type and quality of meat.

Based on Experiment 2, the UD procedure more accurately predicts body composition of lambs when they are on a high protein diet, <10% crude protein. No differences in body composition determination were detected when energy levels were evaluated. Thus, this procedure would have limited

use for determining body composition of cattle which are being fed a protein diet. Therefore, if this procedure is to be used as a bull selection criteria, the type and quality of protein source must be evaluated and the protein level must be kept high enough to allow for an accurate estimation of body composition.

LITERATURE CITED

- Aschbacher, P. W., T. H. Kamal, and R. G. Cragle. 1965. Total body water estimation in dairy cattle using tritiated water. *J. Anim. Sci.* 24:430.
- Ashworth, C. T., E. E. Muirhead, O. F. Thomas, and J. M. Hill. 1943. An analysis of the thiocynate method for determining the distribution of the body fluids. *Am. J. Physiol.* 139:255.
- Bartle, S. J., S. W. Kock, R. L. Preston, T. L. Wheeler, and G. W. Davis, 1987. Validation of urea dilution to estimate in vivo body composition in cattle. *J. Anim. Sci.* 64:1024.
- Bartle, S. J., J. R. Males, and R. L. Preston. 1983. Evaluation of urea dilution as an estimator of body composition in mature cows. *J. Anim. Sci.* 56:410.
- Bartle, S. J., and R. L. Preston. 1992. Effects of experimental weighing, blood sampling and estimation of body composition (urea dilution) on performance of feedlot cattle. Texas Tech univ. Agric. Sci. Tech. Rep. No. T-5-317.
- Bartle, S. J., O. A. Turgeon, Jr., R. L. Preston, and D. R. Brink. 1988. Procedural and mathematical considerations in urea dilution estimation of body composition in lambs. *J. Anim. Sci.* 66:1920.
- Bennett, G. L., L. A. Swiger, R. L. Preston, and V. R. Cahill. 1982. Evaluation of urea space and ultrasonic measurement as selection criteria for beef animal composition. *J. Anim. Sci.* 54:553.
- Breidenstein, B. C., T. G. Lohman, G. S. Smith, and H. W. Norton. 1965. 40K and other indices of carcass lean muscle mass in pigs. *J. Anim. Sci.* 24:860.
- Byers, F. M. 1979a. Extraction and measurement of deuterium oxide at tracer levels in biological fluids. *Anal. Biochem.* 98:208.
- Byers, F. M. 1979b. Measurement of protein and fat accretion in cattle via isotopic dilution. *J. Anim. Sci.* 47:409.

- Carlson, G. P. , D. Harrold, and G. E. Rumbaugh. 1979. Volume dilution of sodium thiocyanate as a measure of extracellular fluid volume in the horse. *Am. J. Vet. Res.* 40:587.
- Carnegie, A. B., and N. M. Tulloh. 1968. The in vivo determination of body water space in cattle using the tritium dilution technique. *Proc. Aust. Soc. Anim. Prod.* 7:308.
- Caster, W. O. and A. B. Simon. 1980. A comparison of sodium, chloride, thiocyanate and sucrose spaces as estimates of extracellular fluid volume. *Physiol. Chem. Phys.* 12:205.
- Chaney, A. L., and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. *Clin. Chem.* 8:130.
- Cornett, Steve. 1994. Fast-track sorting. *Beef* 31:16.
- Cross, H. R. 1982. Proceedings of the 35th Annual Reciprocal Meat Conference of the American Meat Science Association. 35:1.
- Crouse, John D., and Michael E. Dikeman. 1974. Methods of estimating beef carcass chemical composition. *J. Anim. Sci.* 38:1190.
- Dalton, R. G. 1964. Measurement of extracellular fluid volume in cattle with sodium thiosulfate. *Br. Vet. J.* 120:117.
- Doornenbal, H., and A. H. Martin. 1965. The evaluation of blood volume and total red cell mass as predictors of gross body composition in the pig. *Can. J. Animal. Sci.* 45:203.
- Edelman, I. S. 1952. Exchange of water between blood and tissues. Characteristics of deuterium oxide equilibration in body water. *Amer. J. Physiol.* 171:279.
- Eder, H. A. 1951. Determinations of thiocyanate space. *Methods Med. Res.* 4:48.
- Fawcett, J. K., and J. E. Scott. 1960. A rapid and precise method for the determination of urea. *J. Clin. Path.* 13:56.

- Faulkner, D. B., D. F. Parrett, F. K McKeith, and L. L. Berger. 1990. Prediction of fat cover and carcass composition from live and carcass measurements. *J. Anim. Sci.* 68:604.
- Foot, J. Z., and J. F. D. Greenhalgh. 1970. The use of deuterium oxide space to determine the amount of body fat in pregnant Blackface ewes. *Brit. J. Nutr.* 24:815.
- Gad, Soheir M., and R. L. Preston. 1990. In vivo prediction of extracellular and intracellular water in cattle and sheep using thiocynate and urea. *J. Anim. Sci.* 68:3649.
- Garrett, W. N., and N. Hinman, 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. *J. Anim. Sci.* 28:1.
- Groeneveld, E., E. Kallweit, H. Henning, and A. Pfau. 1984. Evaluation of body composition of live animals by X-Ray and nuclear magnetic resonance computed tomography. In: *In vivo measurement of body composition in meat animals.* Elsevier Applied Science Publishers.
- Hamlin, K. E., R. D. Green, T. L. Perkins, L. V. Cundiff, and M. F. Miller. 1995. Real-time ultrasonic measurement of fat thickness and longissimus muscle area: I. Description of age and weight effects. *J. Anim. Sci.* 73:1713.
- Hammond, A. C., T. S. Rumsey, and G. L. Haaland. 1984. Estimation of empty body water in steers by urea dilution. *Growth.* 48:29.
- Hammond, A. C., T. S. Rumsey, and G. L. Haaland. 1988. Prediction of empty body components in steers by urea dilution. *J. Anim. Sci.* 66:354.
- Hammond, A. C., D. R. Waldo, and T. S. Rumsey. 1990. Prediction of body composition in Holstein steer using urea space. *J. Dairy Sc.* 73:3145.
- Hankins, O. G., and P. E. Howe, 1946. Estimation of the composition of beef carcasses and cuts. *U.S.D.A. Tech. Bull.* 926.
- Hedrick, H. B., W. E. Meyer, M. A. Alexander, S. E. Zobrisky, and H. D. Naumann. 1962. Estimation of rib-eye area and fat thickness of beef cattle with ultrasonics. *J. Anim. Sci.* 21:362.

- Heymsfield, Steven B., and Masako Waki. 1991. Body composition in Humans: Advances in the development of multicompartment chemical models. *Nutr. Rev.* 49:97.
- Hopper, T. H., 1944. Methods of estimating the physical and chemical composition of cattle. *J. of Agri. Res.* 68:239.
- Hix, E. L, G. K. L. Underbjerg, and L. S. Hughes. 1959. The body fluids of ruminants and their simultaneous determination. *Am. J. Vet. Res.* 20:184.
- Houghton, P. L., and L. M. Turlington. 1992. Application of ultrasound for feeding and finishing animals: A review. *J. Anim. Sci.* 70:930.
- Jones, S. D. M., J. S Walton, J. W. Wilton, and J. E. Szkotnicki. 1982. The use of urea dilution and ultrasonic back fat thickness to predict the carcass composition of live lambs and cattle. *Can. J. Anim. Sci.* 62:371.
- Kock, S. W., and R. L. Preston. 1979. Estimation of bovine carcass composition by the urea dilution technique. *J. Anim. Sci.* 48:319.
- Lawes John B., and J. H. Gilbert. 1859. Experimental inquiry into the composition of the animals fed and slaughtered as human food. *Trans. Roy. Soc.* 149:493.
- Leymaster, K. A., H. J. Mersmann, and T. G. Jenkins. 1985. Prediction of the chemical composition of sheep by use of ultrasound. *J. Anim. Sci.* 61:165.
- Lohman, T. G., B. C. Breidenstein, A. R. Twardock, G. S. Smith, and H. W. Horton. 1966. Symposium on atomic energy in animal science. II. Estimation of carcass lean muscle mass in steers by 40K measurement. *J. Anim. Sci.* 25:1218.
- Lunt, D. K., G. C. Smith, F. K. McKeith, J. W. Savell, M. E. Riewe, F. P. Horn, and S. W. Coleman. 1985. Techniques for predicting beef carcass composition. *J. Anim. Sci.* 60:1201.
- Martin, T. G., W. V. Kessler, E. G. Stant, Jr., J. E. Christian, and F. N. Andrews. 1963. Body composition of calves and pigs measured by large volume liquid scintillation counting and conventional chemical analysis. *Ann. N. Y. Acad. Sci.* 110:213.

- Maynard, Leonard A., John K. Loosli, Harold F. Hintz, and Richard G. Warner. 1979. *Animal Nutrition*, Seventh Edition. McGraw-Hill, Inc., New York.
- Meissner, H. M. 1976. Urea space versus tritiated water space as an *in vivo* predictor of body water and body fat. *S. Afr. J. Anim. Sci.* 6:171.
- Meissner, H. M., J. H. van Staden, and E. Pretorius, 1980. *In vivo* estimation of body composition in cattle with tritium and urea dilution. I. Accuracy of prediction equations for the whole body. *S. Afr. J. Anim. Sci.* 10:165.
- Miller, M. F., H. R. Cross, J. F. Baker, and F. M. Byers. 1988. Evaluation of live and carcass techniques for predicting beef carcass composition. *Meat Sci.* 23:111.
- Mitchell, A. D., P. C. Wang, R. W. Rosebrough, T. H. Elsasser, and W. F. Schmidt. 1991. Assessment of body composition of poultry by nuclear magnetic resonance imaging and spectroscopy. *Poultry Sci.* 70:2494.
- Moulton, C. R., 1923. Age and chemical development in mammals. *J. Biol. Chem.* 57:79.
- Nour, A. Y. M., and M. L. Thonney. 1994. Technical Note: Chemical composition of Angus and Holstein carcasses predicted from rib section composition. *J. Anim. Sci.* 72:1239.
- Park, B., A. D. Whittaker, R. K. Miller, and D. S. Hale. 1994. Predicting intramuscular fat in beef longissimus muscle from the speed of sound. *J. Anim. Sci.* 72:109.
- Perkins, T. L., R. D. Green, and K. E. Hamlin. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus muscle area in beef cattle. *J. Anim. Sci.* 70:1002.
- Perkins, T. L., R. D. Green, K. E. Hamlin, H. H. Shepard, and M. F. Miller. 1992. Ultrasonic prediction of carcass merit in beef cattle: Evaluation of technician effects on ultrasonic estimates of carcass fat thickness and longissimus muscle area. *J. Anim. Sci.* 70:2758.

- Preston, R. L. 1969. Influence of diethylstilbestrol on body water space in ruminants. *Proc. Soc. Exp. Biol. and Med.* 132:401.
- Preston, R. L., D. P. Hutcheson, H. B. Hedrick, L. E. Jeremiah, S. E. Zobrisky, and G. F. Krause. 1968. Indices of chemical composition in live ovines and their carcasses. In: *Body composition in animals and man*. National Academy of Science Publication number 1598, p. 413.
- Preston, R. L., and S. W. Kock. 1973. In vivo prediction of body composition in cattle from urea space measurements. *Proc. Soc. Exp. Biol. and Med.* 143:1057.
- Preston, R. L., R. D. Vance, V. R. Cahill, and S. W. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. *J. Anim. Sci.* 38:47.
- Recio, H. A., J. W. Savell, H. R. Cross, and M. J. Harris. 1986. Use of real-time ultrasound for predicting beef cutability. *J. Anim. Sci.* 63:(Suppl. 1):260.
- Reid, J. T., A. Bensadoun, L. S. Bull, J. H. Burton, P. A. Gleeson, I. K. Han, Y. D. Joo, D. E. Johnson, W. R. McManus, O. L. Paladines, J. W. Stroud, H. F. Tyrrell, B. D. H. Van Niekerk, and G. W. Wellington. 1968. Some peculiarities in the body composition of animals, In: *Body composition of animals and man*. National Academy of Science Publication number 1598, p. 19-41.
- Reid, J. T., A. Bensadoun, O. L. Paladines, and B. D. H. Van Nierkerk. 1963. Body water estimations in relation to body composition and indirect calorimetry in ruminants. *Ann. New York Acad. Sci.* 110:327.
- Reid, J. T., G. H. Wellington, and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigations. *J. Dairy Sci.* 38:1344.
- Robelin, J. 1977. Estimation in vivo de la composition corporelle des agneaux a partir de l'espace de diffusion de l'eau lourde. *Ann. Biol. Anim. Biochim. Biophys.* 17:95.
- Robelin, J. 1982. Relation entre l'espace de diffusion de l'eau lorde mesuree in vivo et le volume hydrique corporel des bovins en croissance. *Reprod. Nutri. Dev.* 22:(1A):65.

- Robelin, J. 1984. Prediction of body composition in vivo by dilution technique, In: In vivo measurement of body composition in meat animals. Elsevier Applied Science Publishers, New York.
- Robinson, D. L., C. A. McDonald, k. Hammond, and J. W. Turner. 1992. Live animal measurement of carcass traits by ultrasound: Assessment and accuracy of sonographers. J. Anim. Sci. 70:1667.
- Ross, J. G., R. L. Preston, and S. J. Bartle. 1992. Evaluation of sodium thiosulfate as an extracellular water marker in cattle. J. Anim. Sci. 70:434.
- Rule, D. C., R. N. Arnold, E. J. Hentges, and D. C. Beitz. 1986. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: Validation of published equation and comparison with chemical composition. J. Anim. Sci. 63:1935.
- San Pietro A., and D. Rittenberg. 1953. A study of the rate of protein synthesis in humans. I. Measurement of the urea pool and urea space. J. Biol. Chem. 201:445.
- SAS. 1985. SAS user's guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary, NC.
- Searle, P. L., 1984. The Berthelot or indophenol reaction and its use in the analytical chemistry of nitrogen: A review. Analyst 109:549.
- Smith, M. T., J. W. Oltjen, H. G. Dolezal, D. R. Gill, and B. D. Behrens. 1990. Evaluation of real-time ultrasound for predicting carcass traits of feedlot steers. Oklahoma Agric. Exp. Sta. Anim. Sci. Res. Rep. MP-129:374.
- Soberman, R., B. B. Brodie, B. B. Levy, J. Axelrod, V. Hollander, and J. M. Steele. 1949. The use of antipyrine in the measurement of total body water in man. J. Biol. Chem. 179:31.
- Stouffer, J. R. 1966. Objective technical methods for determining carcass value in live animals with special emphasis on ultrasonics. World Rev. Anim. Prod. 1:59.
- Stouffer, J. R., and H. R. Cross. 1985. Evaluation of beef cattle with real time linear array ultrasound. J. Anim. Sci. 61(Suppl. 1):144.

- Stouffer, J. R., M. V. Wallentine, G. H. Wellington, and A. Dikeman. 1961. Development and application of ultrasonic methods for measuring fat thickness and rib-eye area in cattle and hogs. *J. Anim. Sci.* 20:759.
- Temple, R. S., H. H. Stonaker, and D. Howry. 1956. Ultrasonic and conductivity methods for estimating fat thickness in live cattle. *Am. Soc. Anim. Prod. West. Sec. Proc.* 7:477.
- Topel D., and R. Kauffman. 1988. Live animal and carcass composition measurement. In: *Designing Foods: Animal product options in the market place.* National Academy Press. P. 258.
- Waldner, D. N., m. E. Dikeman, R. R. Schalles, W. G. Olson P. L. Houghton, J. A. Unruh, and L. R. Corah. 1992. Validation of real-time ultrasound technology for predicting fat thickness, longissimuss muscle areas, and composition of brangus bulls from 4 months to 2 years of age. *J. Anim. Sci.* 70:3044.
- Ward, G. M., 1968. Introduction to whole-body counting. In: *Body composition in animals and man.* National Academy of Sciences. Pub. 1598:263.
- Wellington, G. H., J. T. Reid, L. J. Bratzler, and J. I. Miller. 1956. Use of antipyrine in nutritional and meat studies with cattle. *J. Anim. Sci.* 15:76.
- Wrenn, T. R., H. C. Cecil, M. R. Connolly, R. W. Miller, M. Okamoto and J. Bitman. 1962. Extracellular body water in growing calves as measured by thiocynate space. *J. Dairy Sci.* 45:205.

APPENDIX A
DATA FOR EXPERIMENT 1

Table A.1. Period weights and ADG data for all steers.

ID	PEN	TRT.	Breed	Weights					ADG				Overall
				2/21/95	4/4/95	5/16/95	6/27/95	7/12/95	4/4/95	5/16/95	6/27/95	7/12/95	
871	31	CTRL	BIX	753	984	1154	1331	1399	5.50	4.05	4.21	4.86	4.59
910	31	CTRL	BIX	758	972	1143	1305	1376	5.10	4.07	3.86	5.07	4.34
911	31	CTRL	BIX	730	905	1040	1200	1257	4.17	3.21	3.81	4.07	3.73
924	31	CTRL	BIX	719	929	1034	1172	1215	5.00	2.50	3.29	3.07	3.60
934	31	CTRL	BIX	772	949	1119	1283	1327	4.21	4.05	3.90	3.14	3.65
798	32	US	BIX	749	868	926	1048	1095	2.83	1.38	2.90	3.36	2.22
823	32	US	BIX	722	927	1069	1214	1272	4.88	3.38	3.45	4.14	3.90
838	32	US	BIX	798	1030	1133	1336	1415	5.52	2.45	4.83	5.64	4.27
852	32	US	BIX	759	954	1062	1220	1255	4.64	2.57	3.76	2.50	3.66
927	32	US	BIX	746	958	1084	1269	1317	5.05	3.00	4.40	3.43	4.15
869	33	US	BIX	655	862	986	1167	1217	4.93	2.95	4.31	3.57	4.06
883	33	US	BIX	705	922	1048	1245	1307	5.17	3.00	4.69	4.43	4.29
959	33	US	BIX	706	933	1072	1253	1277	5.40	3.31	4.31	1.71	4.34
965	33	US	BIX	712	871	990	1154	1197	3.79	2.83	3.90	3.07	3.51
989	33	US	BIX	700	858	942	1072	1105	3.76	2.00	3.10	2.36	2.95
827	34	US	BTX	710	845	999	1164	1204	3.21	3.67	3.93	2.86	3.60
884	34	US	BTX	743	936	1019	1154	1212	4.60	1.98	3.21	4.14	3.26
898	34	US	BTX	706	869	992	1132	1193	3.88	2.93	3.33	4.36	3.38
907	34	US	BTX	793	930	1058	1221	1277	3.26	3.05	3.88	4.00	3.40
984	34	US	BTX	820	978	1087	1250	1293	3.76	2.60	3.88	3.07	3.41
802	35	US	BTX	810	997	1139	1300	1348	4.45	3.38	3.83	3.43	3.89
819	35	US	BTX	794	961	1062	1216	1254	3.98	2.40	3.67	2.71	3.35
915	35	US	BTX	830	1084	1230	1226	1430	6.05	3.48	3.48	3.86	4.33
944	35	US	BTX	858	1106	1224	1357	1382	5.90	2.81	3.17	1.79	3.96
971	35	US	BTX	787	980	1119	1265	1311	4.60	3.31	3.48	3.29	3.79
841	36	CTRL	BTX	659									
848	36	CTRL	BTX	791	898	1032	1120	1191	2.55	3.19	2.10	5.07	2.61
861	36	CTRL	BTX	795	1047	1234	1395	1464	6.00	4.45	3.83	4.93	4.76
879	36	CTRL	BTX	729	900	1071	1215	1244	4.07	4.07	3.43	2.07	3.86
946	36	CTRL	BTX	798	946	1106	1259	1325	3.52	3.81	3.64	4.71	3.66
901	37	CTRL	BTX	856	1031	1166	1304	1303	4.17	3.21	3.29	-0.07	3.56
925	37	CTRL	BTX	853	1018	1189	1332	1391	3.93	4.07	3.40	4.21	3.80
935	37	CTRL	BTX	800	1007	1135	1240	1304	4.93	3.05	2.50	4.57	3.49
955	37	CTRL	BTX	834	986	1152	1258	1318	3.62	3.95	2.52	4.29	3.37
986	37	CTRL	BTX	778	964	1093	1224	1274	4.43	3.07	3.12	3.57	3.54
855	38	CTRL	BIX	647	798	922	1041	1102	3.60	2.95	2.83	4.36	3.13
930	38	CTRL	BIX	699	907	1042	1167	1257	4.95	3.21	2.98	6.43	3.71
932	38	CTRL	BIX	703	892	1020	1171	1210	4.50	3.05	3.60	2.79	3.71
939	38	CTRL	BIX	677	850	996	1150	1208	4.12	3.48	3.67	4.14	3.75
973	38	CTRL	BIX	646	807	972	1117	1156	3.83	3.93	3.45	2.79	3.74

Table A.2. Back fat, carcass fat using the yield grade equation and empty carcass fat (ECF).

ID	PEN	TRT.	Breed	BACKFAT (mm)				YIELD GRADE	ECF
				2/21/95	4/4/95	5/16/95	6/27/95		
871	31	CTRL	BIX	3	7	9	15		
910	31	CTRL	BIX	2	4	5	12	42.81	48.99
911	31	CTRL	BIX	2	5	5	8	34.27	43.64
924	31	CTRL	BIX	2	5	6	15	39.35	44.92
934	31	CTRL	BIX	4	7	8	13	40.83	48.03
798	32	US	BIX	5	5	6	7	39.43	43.49
823	32	US	BIX	3	8	9	9	36.48	44.35
838	32	US	BIX	3	5	6	10	41.86	48.07
852	32	US	BIX	1	6	6	9	39.47	45.64
927	32	US	BIX	1	4	5	7	41.68	50.00
869	33	US	BIX	3	4	4	5	30.77	44.30
883	33	US	BIX	2	5	6	9	38.11	46.88
959	33	US	BIX	3	6	8	13	34.60	44.76
965	33	US	BIX	3	5	6	7	28.52	40.64
989	33	US	BIX	4	7	6	11	39.60	43.79
827	34	US	BTX	2	3	6	12	34.71	41.82
884	34	US	BTX	5	6	8	8	37.85	43.66
898	34	US	BTX	4	5	10	9	42.37	46.50
907	34	US	BTX	1	3	4	6	30.59	42.11
984	34	US	BTX	1	5	9	8	31.07	40.98
802	35	US	BTX	1	3	4	5	29.66	42.95
819	35	US	BTX	4	6	9	13	36.38	42.93
915	35	US	BTX	2	4	5	4	30.07	42.07
944	35	US	BTX	2	4	6	11	38.63	45.24
971	35	US	BTX	4	5	6	6	23.77	39.07
841	36	CTRL	BTX	1	5	9	8	28.25	42.26
848	36	CTRL	BTX	5	7	11	12	39.27	45.95
861	36	CTRL	BTX	3	5	11	11	40.06	48.81
879	36	CTRL	BTX	5	9	9	8	39.55	48.44
946	36	CTRL	BTX	1	4	7	8	28.75	41.65
925	37	CTRL	BTX	4	6	7	7	30.53	42.32
935	37	CTRL	BTX	2	4	9	8	30.28	43.50
955	37	CTRL	BTX	5	6	8	7	33.04	43.73
986	37	CTRL	BTX	5	7	12	11	39.14	47.75
855	38	CTRL	BIX	3	5	9	8	35.21	45.15
930	38	CTRL	BIX	5	6	11	15	44.92	50.62
932	38	CTRL	BIX	3	5	6	7	38.50	46.78
939	38	CTRL	BIX	3	4	10	10	39.56	46.37
973	38	CTRL	BIX	1	5	8	8	31.74	42.15

Table A.3. T0 and T12 Pun values.

ID	PEN	TRT.	Breed	'2/21/95		'4/4/95		'5/16/95		'6/27/95	
				T0	T12	T0	T12	T0	T12	T0	T12
798	32	US	BIX	7.14	16.96	5.62	16.13	6.07	17.45	4.60	17.22
823	32	US	BIX	4.97	16.72	5.52	17.75	8.56	20.00	3.18	16.44
838	32	US	BIX	4.17	15.51	4.50	7.16	6.24	19.52	6.71	19.43
852	32	US	BIX	5.82	17.06	6.04	17.57	8.39	19.30	7.60	20.52
927	32	US	BIX	7.29	17.52	2.63	15.03	6.96	18.84	3.81	15.15
869	33	US	BIX	6.51	15.54	4.12	14.38	6.70	16.81	5.73	17.04
883	33	US	BIX	8.47	13.80	3.58	14.66	6.94	17.49	5.08	18.57
959	33	US	BIX	4.19	15.47	3.90	14.48	7.52	19.02	6.32	20.00
965	33	US	BIX	5.46	14.94	3.16	14.14	5.23	16.78	3.91	14.17
989	33	US	BIX	7.61	13.24	14.49	25.69	8.93	24.74	6.27	20.99
827	34	US	BTX	4.73	15.38	3.61	14.41	4.43	15.23	4.31	15.15
884	34	US	BTX	6.09	18.46	5.08	17.23	8.44	18.51	4.72	16.88
898	34	US	BTX	7.07	19.90	4.40	13.01	3.73	12.65	4.49	15.28
907	34	US	BTX	5.87	14.45	3.35	13.58	9.31	20.06	4.87	15.10
984	34	US	BTX	19.32	18.15	5.89	18.56	9.27	19.17	8.26	20.88
802	35	US	BTX	7.56	15.34	4.58	14.63	5.56	16.00	6.05	18.56
819	35	US	BTX	0.00	0.00	4.74	18.30	6.35	17.32	8.55	18.58
915	35	US	BTX	5.07	16.84	4.67	16.04	7.65	18.87	6.60	19.96
944	35	US	BTX	7.26	17.11	9.57	23.69	9.87	23.58	8.31	27.23
971	35	US	BTX	9.49	14.34	4.91	18.07	3.64	15.99	7.76	21.25

Table A.4. Percentage of US, EBF, EBH2O and carcass protein.

ID	PEN	% US			US % EBF			% EBH2O			% CARCASS PROTEIN		
		2/21/95	4/4/95	5/16/95	6/27/95	2/21/95	4/4/95	5/16/95	6/27/95	2/21/95	4/4/95	5/16/95	6/27/95
798	32	66.92	62.42	55.81	53.65	15.74	19.84	23.2	26.64	60.23	57.08	54.58	51.89
823	32	55.74	53.63	55.72	51.53	18.6	23.9	26.47	31.06	58.26	54.08	51.96	48.41
838	32	57.59		47.77	53.52	19.75		30.39	33.21	57.29		49.05	46.63
852	32	58.83	57.03	58.01	52.63	18.48	23.46	25.6	30.85	58.27	54.34	52.59	48.54
927	32	64.50		53.63	59.73	16.42		27.46	29.76	59.75		51.23	49.22
869	33	73.43	64.38	62.73	60.58	11.59	19.09	22.42	27.19	63.37	57.62	55.01	51.25
883	33		59.52	59.95	50.58		21.96	24.68	32.06	73.43	55.47	53.27	47.64
959	33	77.56	62.57	55.25	49.56	11.47	21.26	26.69	32.55	63.35	55.94	51.8	47.27
965	33	84.36	59.54	54.68	58.24	9.5	20.8	25	27.62	64.74	56.4	53.17	50.97
989	33		59.26	40.11	46.23		20.59	28.43	29.48	72.26	56.57	50.83	49.82
827	34	74.03	61.34	58.82	54.65	12.65	19.65	23.92	28.96	62.5	57.26	53.91	50
884	34	67.21	54.31	62.76	56.26	15.52	23.89	23.15	28.23	60.41	54.07	54.42	50.54
898	34	62.86	76.10	71.72	63.00	16.03	15.62	19.76	25.64	60.12	60.08	56.88	52.42
907	34	81.31	64.92	59.05	58.41	12.28	20.47	25.19	29.08	62.6	56.51	52.89	49.8
984	34		52.18	64.18	53.85		25.5	24.26	31.16		52.84	53.5	48.27
802	35	84.23	65.50	61.21	54.69	11.76	21.81	26.36	32.03	62.93	55.42	51.9	47.54
819	35		48.88	57.69	68.01		28.14	25.7	26		52.42	52.52	52
915	35	73.11	57.95	56.79	51.10	15.66	26.12	29.79	34.87	60.12	52.18	49.28	45.38
944	35	85.65	46.35	46.15	35.81	12.41	30.22	32.95	29.18	62.38	49.23	47.05	42.36
971	35	32.58		50.14	51.33		26.18	28.97	28.97	50.37	74.86	52.35	50.09
										47.23	22.69	15.76	15.22

Table A.5. T0 and T12 percent red blood cell.

ID	PEN	T0 RBC				T12 RBC			
		2/21/95	4/4/95	5/16/95	6/27/95	2/21/95	4/4/95	5/16/95	6/27/95
798	32	43	34	44	44	46.5	47	41	43
823	32	45	45	45	42	45	42	40	41
838	32	35	31	37	35	32.5	32	33	32.5
852	32	38.5	43	48	45	44	45	44.0	44.0
927	32	40	43.5	46.0	44	36	46.0	45	43
869	33	44	39.5	45	41	45	42	42	42
883	33	38	38	48	43	41	42	40	42
959	33	37	33.5	41.5	39	33	41.5	39.5	37
965	33		40	38	40	37	39	36	38
989	33	42.5	43	50	48.0	40.5	45	46	44
827	34	40	44	44	45	40.5	40	38	42
884	34	37	40	40	40	36	43	40	39
898	34	28.5	27	40	40	33	33	39.5	36.5
907	34	45	47	48.0	45	45	45.0	46	42
984	34	34.5	39	38	40	34	41	37	37
802	35	39	40.5	41	41.5	40	40	40	37
819	35		43	43	49		38	39	
915	35	44.5	44	46.5	40.5	40	45.5	46	46
944	35	42.5	40.5	42	41	40.5	40	39	39
971	35	37	38	39	43		35	36	39

Table A.6. Gain efficiency by pen and period.

PEN BREED		PERIOD 1 (G/1000)	PERIOD 2 (G/1000)	PERIOD 3 (G/1000)	PERIOD 4 (G/1000)	OVERALL (G/1000)
31	BIX	312.31	117.67	185.94	202.13	215.97
32	BIX	285.64	145.14	199.04	192.02	205.64
33	BIX	311.20	171.69	224.72	169.28	226.16
34	BTX	258.72	162.02	189.21	196.88	199.23
35	BTX	283.12	173.08	175.83	152.66	203.09
36	BTX	205.68	198.05	157.51	205.73	188.53
37	BTX	266.60	189.91	162.92	163.57	199.1
38	BIX	302.93	196.14	190.34	217.18	223.91

Table A.7. Carcass measurements of all steers.

ID	PEN	MARBLING	QUALITY GRADE	BF .1 in	ADJUSTED PYG/FT	REA (in2)	REA (cm2)	KPH %	CALCULATED		
									BACKFAT (mm)	YIELD GRADE	DRESSING PERCENT
910	31	MT 10	CHOICE	0.7	3.8	11.7	75.47	2.0	18	4.17	61.85
911	31	SM 20	CHOICE	0.6	3.6	13.3	85.79	2.0	16	3.21	62.45
924	31	SL 0	SELECT	0.7	3.8	11.4	73.53	2.0	18	3.78	59.59
934	31	SL 20	SELECT	0.6	3.6	11.2	72.24	2.0	16	3.95	60.44
798	32	SL 80	SELECT	0.8	4.0	11.7	75.47	2.5	20	3.79	61.55
823	32	SM 10	CHOICE	0.7	3.7	12.7	81.92	2.0	17	3.46	60.85
838	32	SM 60	CHOICE	0.7	3.8	11.7	75.47	1.5	18	4.06	60.00
852	32	SM 80	CHOICE	0.7	3.8	11.8	76.11	1.5	18	3.79	62.71
927	32	SL 10	SELECT	0.5	3.3	9.9	63.86	2.0	13	4.04	60.36
869	33	SL 20	SELECT	0.3	2.8	11.1	71.60	2.0	8	2.82	57.76
883	33	SM 10	CHOICE	0.6	3.4	11.1	71.60	1.5	14	3.64	60.52
959	33	SL 70	SELECT	0.6	3.5	13.2	85.14	2.0	15	3.25	63.59
965	33	SM 30	CHOICE	0.5	3.3	13.6	87.72	1.5	13	2.56	62.16
989	33	SL 50	SELECT	0.7	3.8	10.2	65.79	1.5	18	3.81	59.46
827	34	SL 30	SELECT	0.4	3.0	12.4	79.98	2.0	10	2.69	60.47
884	34	SL 30	SELECT	0.7	3.9	13.0	83.85	1.5	19	3.45	63.61
898	34	SM 10	CHOICE	0.5	3.2	12.7	81.92	1.5	12	2.74	62.03
907	34	SL 0	SELECT	0.7	3.8	12.2	78.69	1.5	18	3.70	62.33
984	34	SL 30	SELECT	0.5	3.2	15.7	101.27	1.5	12	2.03	62.34
802	35	SL 50	SELECT	0.5	3.2	14.5	93.53	2.0	12	2.53	60.16
819	35	MT 50	CHOICE	0.7	3.8	12.3	79.34	2.0	18	3.77	63.56
915	35	SL 70	SELECT	0.6	3.6	12.4	79.98	1.5	16	3.86	63.36
944	35	SL 90	SELECT	0.6	3.6	12.7	81.92	2.5	16	3.80	62.52
971	35	SL 90	SELECT	0.5	3.2	13.5	87.08	1.5	12	2.59	58.58
848	36	SM 50	CHOICE	0.5	3.3	13.3	85.79	2.0	13	2.79	63.14
861	36	SM 0	CHOICE	0.6	3.5	15.9	102.56	2.0	15	2.76	62.23
879	36	SL 80	SELECT	0.6	3.4	13.0	83.85	2.0	14	3.07	62.30
946	36	SL 80	SELECT	0.6	3.5	11.7	75.47	2.0	15	3.76	61.89
901	37	SM 0	CHOICE	0.6	3.5	13.0	83.85	2.0	15	3.32	62.39
925	37	SL 80	SELECT	0.7	3.8	11.2	72.24	2.0	18	4.41	62.62
935	37	SL 70	SELECT	0.6	3.5	11.4	73.53	1.5	15	3.69	61.50
955	37	SM 30	CHOICE	0.7	3.9	13.1	84.50	2.0	19	3.81	64.26
986	37	SL 0	SELECT	0.6	3.6	14.2	91.59	1.5	16	2.93	63.74
855	38	SL 40	SELECT	0.7	3.7	12.1	78.05	1.5	17	3.26	63.34
930	38	SL 60	SELECT	0.7	3.9	12.4	79.98	2.0	19	3.61	58.71
932	38	MD 10	CHOICE	0.8	4.0	11.6	74.82	2.5	20	4.12	62.15
939	38	SL 20	SELECT	0.6	3.4	13.8	89.01	2.0	14	2.80	63.74
973	38	SL 30	SELECT	0.6	3.5	13.2	85.14	2.0	15	2.85	61.25

APPENDIX B
DATA FOR EXPERIMENT 2

Table B.1. Lamb weights and carcass composition

1/21/96						
ID	PERCENT UREA SPACE	LIVE WEIGHT Kg	EMPTY BODY WATER	CARCASS PROTEIN	EMPTY BODY FAT	TOTAL
942	83.49	41.20	75.82	22.13	-4.32	93.63
131	67.22	40.80	72.26	21.00	0.70	93.96
128	52.77	39.60	69.13	20.00	5.12	94.24
946	29.70	39.20	64.07	18.39	12.25	94.71
130	78.45	34.80	74.97	21.84	-3.08	93.73
949	52.73	41.00	69.06	19.98	5.20	94.25
129	-13.15	39.20	54.64	15.39	25.54	95.56
945	36.86	42.00	65.53	18.86	10.17	94.56

1/24/96						
ID	PERCENT UREA SPACE	LIVE WEIGHT Kg	EMPTY BODY WATER	CARCASS PROTEIN	EMPTY BODY FAT	TOTAL
942	42.75	41.20	66.86	19.28	8.31	94.45
131	43.89	40.80	67.12	19.36	7.93	94.42
128	54.61	39.60	69.53	20.13	4.55	94.21
946	49.78	39.20	68.48	19.79	6.03	94.30
130	86.95	34.80	76.84	22.44	-5.71	93.56
949	165.09	41.00	93.78	27.85	-29.63	92.00
129	36.12	39.20	65.48	18.84	10.26	94.58
945	36.28	42.00	65.40	18.82	10.35	94.57

1/27/96						
ID	PERCENT UREA SPACE	LIVE WEIGHT Kg	EMPTY BODY WATER	CARCASS PROTEIN	EMPTY BODY FAT	TOTAL
942	93.19	41.20	77.95	22.81	-7.33	93.44
131	107.62	40.80	81.14	23.83	-11.82	93.15
128	33.29	39.60	64.84	18.63	11.16	94.63
946	9.44	39.20	59.61	16.97	18.53	95.11
130	112.11	34.80	82.37	24.20	-13.51	93.06
949	113.44	41.00	82.42	24.23	-13.62	93.03
129	28.93	39.20	63.90	18.33	12.49	94.72
945	28.30	42.00	63.65	18.26	12.83	94.73

Table B.2. Lamb T0 and T12 RBC.

1/21/9	T0		T12	
942	39	39	37	37
131	34	34	37	37
128	34	34	28	
946	32	32	32	33
130	36	36	35	35
949	34	34	29	29
129	42	42		
945	37	36	31	31

1/24/9	T0		T12	
942	30	29	29	30
131	28		26	27
128	24	24	24	24
946	28	28	28	28
130	25	24	27	27
949	21		18	18
129	27	27	27	26
945	25	24	24	24

1/27/9	T0		T12	
942	25	25	25	25
131	31	31	26	26
128	27	27	23	23
946	27	27	27	26
130	25	25	23	23
949	20	20	22	22
129	25	25	21	21
945	27	27	25	25

Table B.3. T0 and T12 PUN values.

Lamb	'1/21/96		'1/24/96		'1/27/96	
	T0	T12	T0	T12	T0	T12
942	5.536	7.110	3.927	6.779	4.484	5.805
131	5.619	7.574	4.248	7.026	6.403	7.547
128	7.640	10.130	6.091	8.323	9.802	13.500
946	8.275	12.700	8.981	11.430	9.844	22.880
130	5.353	7.028	4.480	5.882	5.978	7.076
949	5.445	7.937	4.876	5.582	5.265	6.350
129	9.994		8.550	12.080	11.545	15.800
945	6.565	10.130	10.090	13.450	9.911	14.260

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