CARCASS COMPOSITION IN MATURE HEREFORD COWS:

ESTIMATION AND INFLUENCE ON METABOLIZABLE

ENERGY REQUIREMENTS FOR MAINTENANCE

DURING WINTER

By

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PREFACE

Without a doubt, this is the most difficult section of this entire manuscript to write. I owe the success of my graduate career to many individuals. Several people have touched my life in many ways, significantly influencing my professional and personal development during my stay in Stillwater. I sincerely apologize to anyone who I inadvertently fail to recognize in the succeeding paragraphs.

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

CHAPTER III

CHAPTER IV

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In recent years, increasing emphasis has been placed on improving the efficiency of beef production through improved feeding standards. The bulk of this effort however, has centered on the cattle feeding segment of production. Tremendous increases in the performance of feedlot cattle have been achieved through the application of modern ration formulation programs, namely the California Net Energy system (Lofgreen and Garrett, 1968).

Technological advances in the feeding of mature beef cows have been realized more slowly. Current National Research Council (NRC, 1984) feeding standards compute energy requirements for beef cows factorially. Briefly stated, energy expenditures for maintenance, tissue gain, pregnancy and lactation are summed and their total is considered to be the requirement.

Ferrell et al. (1976) estimated energy deposition in the conceptus of beef heifers. Other data concerning energy retention by the bovine fetus is available (Eley et al., 1978; Silvey and Haydock, 1978; Prior and Laster, 1979). The net energy (NE) requirement for pregnancy ($kcal \cdot d^{-1}$ NE_m equivalent), based on calf birth weight and day of gestation (t), is estimated by the expression: NE_m = calf birth weight $(0.0149 - 0.0000407t)e^{0.05883t-0.0000804t^2}$ (NRC, 1984).

Data from the dairy cow (NRC, 1978) are used to estimate energy requirements for milk production. The expression NE_m(mcal$\cdot$kg^{-1} milk) = 0.1 (percent fat) + 0.35 is used to estimate the energy requirement for lactation in beef cows (NRC, 1984).

The weight increase of thin non-lactating, non-pregnant, mature adult beef cows contains between 5.5 and 7.5 kcal energy per gram (Garrett, 1974; Swingle et al., 1979). The estimated NRC (1984) requirement for tissue gain by mature thin cows is 6.5 mcal$\cdot$kg^{-1} gain.

Cow size, as determined by cow weight, is the major factor determining energy expenditures for maintenance. The NE_m requirement for penned animals in nonstressful environments with minimal activity is estimated by the expression 77 kcal per kilogram body weight$^{.75}$ (Lofgreen and Garrett, 1968). Variations in maintenance requirements based on breed (Blaxter and Wainman, 1966; Garrett, 1971; Frisch and Vercoe, 1977; Webster, 1978), prior plane of nutrition and season of the year (Armstrong and Blaxter, 1984) have been noted. Feed requirements for maintenance can be adjusted for differences in environmental temperature, humidity and wind velocity (NRC, 1981).

Subcutaneous fat cover insulates the animal body from cold environments (Curtis, 1983). Furthermore, the heat production of rats (Webster et al., 1978) and growing livestock (Webster, 1980) was more closely correlated with body protein than with body weight. The maintenance requirement of the fat free body may be higher than that of fat. As a result, cattle with a higher percentage of body fat, may require less energy per unit weight for maintenance than lean cattle. Early research by Klostermann et al. (1968) indicated that fat cows required less energy per unit weight for maintenance than did thin cows.

Energy required for maintenance by the cow has been estimated to range from 70 (Jenkins and Ferrell, 1983) to 91% (Johnson, 1984) of the total dietary energy consumed by a cow for the production year. The cow-calf producer must recover the cost of maintaining the cow through the sale of her calf. Under many production schemes, even a small savings in maintenance costs may improve net returns per cow.

If body condition or degree of fatness has a significant effect on energy expenditures for maintenance, a rapid, reliable, and most importantly, non-destructive method of estimating body fatness must be employed in order to adjust feeding standards. Furthermore, to adequately evaluate the effect of various treatment regimes on individual cows used in research, body composition must be estimated with minimal error. Various subjective scores, linear measures, densitoic methods and dilution techniques have been used as measures of body composition with varying degrees of success.

The objectives of this research were: 1) to evaluate live weight, subjective condition score, weight:height ratio and urea water space as indicators of carcass composition and 2) to investigate the relationship between body condition and winter maintenance energy expenditures in mature Hereford beef cows.

CHAPTER II

REVIEW OF LITERATURE

Subjective Measures of Body Composition

Body Condition Scoring

Murray (1919) defined body condition as "the ratio of the amount of fat to the amount of non-fatty matter in the body of the living animal". Since that time, a number of subjective systems have been developed throughout the world to describe body condition. Relatively few attempts have been made to quantify these scoring systems.

Australian workers assessed body condition in sheep utilizing a 6-point scale representing the amount of tissue cover over the lumbar region of the spine (Jefferies, 1961). Russel et al. (1969), working in Scotland, adapted the Australian system to Scottish Blackface ewes. Lowman et al. (1976) modified the system for use with cattle. The system defines six grades (0 to 5), and describes each one in terms of the amount of tissue cover over the transverse processes of the lumbar vertebrae and around the tail head. Cattle falling into categories 0 to 5 are described as follows:

Score 0. The animal is emaciated. No fatty tissue can be detected and the neural spines and transverse processes feel very sharp.

Score 1. The individual transverse processes are sharp to the touch and easily distinguished.

Score 2. The transverse processes can be identified individually when touched, but feel rounded rather than sharp.

Score 3. The transverse processes can only be felt with firm pressure and the areas on either side of the tail head have some fat cover.

Score 4. Fat around the tail head is easily seen as slight mounds, soft to the touch. The transverse processes cannot be felt.

Score 5. The bone structure of the animal is no longer noticeable and the tail head is almost completely buried in fatty tissue.

Russel et al. (1969) quantified body condition score in Scottish Blackface ewes and showed that it was related closely to the proportion of chemical fat in the body (r=.94, standard error of the estimate = 2.54%). The work of Guerra et al. (1972) also showed a close relationship (r=.77) between body condition score and the proportion of fat in the live sheep.

Wright and Russel (1984a) related body condition score directly to the chemically determined composition of 73 mature, non-pregnant, non-lactating Hereford x Friesian, Blue-Grey, Galloway, Luing and British Friesian cows. Relationships between condition score and body fat were highly significant and considered to be of value for predictive purposes. Condition score accounted for over 90% of the variation in body fat. The residual standard deviation (20.7 kg), when expressed as a proportion of the mean was .205. Each unit change in condition score corresponded to approximately 100 kg live weight, 52.6 kg fat, 7.35 kg protein, 1.18 kg ash, 22.2 kg water and 2242 MJ body energy in the beef breeds studied and 84.1 kg fat, 7.35 kg protein, 1.18 kg ash, 22.2 kg water and 3478 MJ body energy in British Friesian cows. Coefficients of determination and residual standard deviations expressed as a proportion of the mean from the regressions of protein, water and ash were .723 and .082, .644 and .098, and .577 and .111, respectively.

A system of body condition scoring is being utilized at the Oklahoma Agricultural Experiment Station. Dr. Joe V. Whiteman initially applied the system to the station's sheep flock in the late 1950's. In about 1964, the system was applied to the teaching herd of cattle on campus. Dr. Robert Totusek began scoring all beef cows at the Range Cow Research Center at Oklahoma State University in 1969. This system assesses body condition based on a 1 to 9 scale and appraises fat deposits visually and by palpation over the entire body rather than just over the lumbar and tail head region. Several experiment stations throughout the country use a similar 1-9 scale (Warner and Spitzer, 1982; Dunn et al., 1983). Cattle falling into categories 1 through 9 are described as follows:

Score 1. The cow is severely emaciated and physically weak with all ribs and bone structure easily visible.

Score 2. The cow appears emaciated, similar to 1 above but not weakened. Muscle tissue seems severely depleted through the hindquarters and shoulder.

Score 3. The cow is very thin with no fat on ribs or in brisket and the backbone is easily visible. Some muscle depletion appears evident through the hindquarters.

Score 4. The cow appears thin, with ribs easily visible and the backbone showing. Muscle tissue is not depleted through the shoulders and hindquarters.

Score 5. The cow may be described as moderate to thin. The last two or three ribs can be seen and little evidence of fat is present in the brisket, over the ribs or around the tail head.

Score 6. The cow exhibits a good smooth appearance throughout. Some fat deposition is present in the brisket and over the tail head. The back appears rounded and fat can be palpated over the ribs and pin bones.

Score 7. The cow appears in very good flesh. The brisket is full, the tail head shows pockets of fat and the back appears square due to fat. The ribs are very smooth and soft handling due to fat cover.

Score 8. The cow is obese. Her neck is thick and short and her back appears very square due to excessive fat. The brisket is distended and she has heavy fat pockets around tail head.

Score 9. These cows are very obese and rarely seen. They can be described similar to 8's but taken to greater extremes. She also has a heavy deposition of udder fat.

Dunn et al. (1983) studied the relationship between several measurements made on 55 mature beef cows and carcass content of energy determined on the same animals following slaughter. Body condition scores at time of slaughter ranged from 2-9 and fat in the carcass ranged from 4.5 to 30.2%. Body condition score was the live animal measure most closely related to carcass energy content and to carcass fatness (r=.77 to .86). Carcass energy content increased .194 $mcal \cdot kg^{-1}$ hot carcass and .132 $mcal \cdot kg^{-1}$ live weight for each unit increase in condition score. Equations predicting energy content per kilogram hot carcass and energy content per kg live weight accounted for 59 and 66% of the variation, respectively.

Criticisms of Visual Appraisal

Because of the subjective nature of body condition scores, many researchers feel condition scores are subject to intolerable levels of assessor bias and measurement error. Investigations by Russel et al. (1968) and Doney and Russel (1968) showed that repeatability of condition score (0-5 scale) within observers was greater than 80%; less than 15% of observations differed by 0.5 grade, and less than 5% by 1.0 grade. Repeatability between observers showed more than 70% absolute agreement, less than 20% differing by 0.5 grade and less than 10% by 1.0 grade. Condition scores agreed by two or three operators were more than 90% repeatable, the remainder being within 0.5 grade of the first agreed score.

Evans (1978) reported a high correlation (r=.7) between scores (0-5 scale) assigned by different operators to the same animal. Repeat scores by the same operator on each animal were also highly correlated (r=.8). Evans suggested that the accuracy and precision of body condition scoring could be improved through a second, independent assessment of each animal, with a different person scoring the animals the second time. Assessor bias and inconsistency may be calculated from the deviations from a standard score. Evans stated that such bias and inconsistency may be reduced through the careful training of assessors and through periodic standardization of scores.

Wright and Russel (1984a) proposed that subjective condition scores only assess subcutaneous fat reserves and that variations in the partition of fat among the major adipose tissue depots might influence the relationship between condition score and body fat. Factors, such as breed, which have a pronounced effect on the distribution of fat may significantly influence the assignment of body scores. Cattle that have a higher portion of body fat stored in internal depots may be scored lower than cattle with greater proportions of fat in subcutaneous depots even though total energy reserves may be nearly the same. Wright and Russel (1984a) found that the distribution of fat among the major depots was nearly equal for Hereford x Friesian, Blue-Grey, Galloway and Luing cows. British Friesian cows, however, possessed a higher proportion of fat in the intra-abdominal depots and a correspondingly lower proportion of fat in the subcutaneous depots.

Objective Measures of Body Composition

Objective measures employ an instrument or measuring device that attempts to reduce assessor bias and increase repeatability of body composition estimates. Techniques commonly used range in sophistication from simple measurement of live weight to isotope dilution procedures. Through instrumentation, these procedures are generally believed to be more precise (repeatable) than visual estimates. The accuracy of objective measures, however, is a function of the parameter being estimated and the relationship of that parameter to the characteristic in question and are not necessarily limited by the precision associated with instrumentation. Some of the simpler linear measures used to estimate composition are discussed below, followed by brief discussions of densitoic methods and dilution techniques for estimating composition.

Live Weight

When predicting the composition of bodies of animals by indirect methods, equations may be developed to estimate the proportion or absolute weight of components in the body. If prediction equations express body components on an absolute basis, it is possible to develop equations that are completely independent of live weight. Data comparing the efficacy of using live weight or condition score as predictors of body composition have been reported in the literature. In general, if body fat is expressed as an absolute amount, live weight is often the best single predictor of body fat. However, condition score predicts body fat almost as well and is in fact superior to body weight when fat is expressed as a percentage of body weight.

Wright and Russel (1984b) showed that live weight accounted for 91.2% of the variation in body fat in mature cows when expressed on an absolute basis. The residual standard deviation (19.5 kg) when expressed as a proportion of the mean was .193. Condition score (0-5 scale) predicted body fat almost as well as live weight (R^2=.902, coefficient of variation = .205). Using condition score and live weight together in the same model explained 95% of the variation in body fat. The residual standard deviation (15.3 kg) when expressed as a proportion of the mean was reduced to .151 for the two variable model.

Dunn et al. (1983) demonstrated that body condition score (1-9 scale) was more closely related to the percentage carcass fat in mature cows than was live weight (r=.77 and .48, respectively). Likewise, Russel et al. (1969) showed that condition score (0-5 scale) accounted for 88% of the variation in the percentage fat in the fleece-free empty body of sheep while live weight only accounted for 66% of the variation in percent fat. Standard errors of the estimate were 2.54 and 4.45% for the regressions based on condition score and live weight respectivly. Guerra et al. (1972) reported that if animals are of very similar body size, live weight and condition score (0-5 scale) afford similar levels of prediction of body fat (r=.77 and .83, respectively).

Many other data support this relationship between composition and weight. Reid et al. (1968), in agreement with the allometric growth theory (Huxley, 1932), contended that body composition is almost entirely controlled by weight. Berg and Butterfield (1976) pointed out that sexes, breeds and animals fed on widely differing planes of nutrition differ in composition at given weights.

Weight:Height Ratio

Many researchers attempted to improve the utility of live weight as a predictor of body composition by using it in conjunction with various linear measures that essentially estimate body size. One of the most common of these techniques is to measure height at the hooks or withers and estimate composition using a weight:height ratio. Weight:height ratio was only moderately correlated (r=.56) with percent carcass fat in mature beef cows and that regression equations developed to predict body energy from weight:height ratio accounted for only 33% of the variation in energy (Dunn et al., 1983).

Condition Index

Guerra et al. (1972) used a more complicated measure of body size in calculating their "condition index". Body size (cm^3, by the methods of Turner et al., 1953) was calculated as: Wpl•Cd•.5•(Ws + Wh), where Wpl = wither to pinbone length (cm), Cd = chest depth (cm), Ws = shoulder width (cm) and Wh = hip width (cm). Condition index was correlated (r=.78) with the percentage chemical fat in sheep.

Circumference of the Heart Girth

Circumference of the heart girth is another linear measure sometimes used as an indication of condition. Dunn et al. (1983) found this measure to be moderately correlated (r=.56) to the percent carcass fat in mature beef cows.

Backfat Thickness

Backfat thickness, determined by surgical incision in live sheep was related (r=.78) to the percent carcass fat (Guerra et al., 1972). Wright and Russel (1984b) predicted body fat in mature cows using ultrasonic estimations of fat depth (R^2 = .804, residual standard deviation expressed as a proportion of the mean = .29). Dunn et al. (1983) determined that backfat thickness measured over the longissimus dorsi muscle is a useful predictor (r=.86) of the percentage fat in the carcass of mature beef cows and suggested that development of an accurate method of measuring fat depth on the live animal may produce an accurate predictor of carcass energy content. Preliminary data of Wagner (unpublished) indicated that thin cattle have little or no backfat, limiting the value of backfat estimates as predictors of carcass energy in thin cows.

Densitoic Methods

Perhaps the most widely studied and certainly the earliest developed technique for determining composition uses the Archimedian principle. While taking a bath, Archimedes, in about 200 B.C., pondered the problem of how to measure the purity of the Emperor's crown and observed that a body displaces a volume equal to its own. He realized that the composition of substances can be compared on a basis of their weight per unit of volume. Robertson (1757) attempted to estimate the density of 10 men, who were paid to submerge themselves in a tank filled with water, and concluded that the subjects were more interested in the bribe than the experiment.

The rationale for estimating fatness or leanness, or both, from density is based on the assumption that the body can be considered a two-component system, with the components being of different but constant densities (Pearson et al., 1968). The two components usually considered are fatty tissue (density app. = .9) and the fat-free body (density app. = 1.2).

Kraybill et al. (1952) first developed a relationship between carcass specific gravity and percent separable fat or percent body water in beef cattle. Garrett and Hinman (1969) re-evaluated the relationship between carcass density and body composition of beef steers. They described in detail the procedures used and reported a series of prediction equations to estimate the chemical components in the carcass from carcass density.

Using carcass density requires the sacrifice of the animals in question. Density of living animals can be used to predict composition as well. Volume measurements via air or water displacement are difficult with living animals. The armed forces and various athletic organizations routinely use body density as an indication of body composition in man. Interesting reading on the subject may be found in the proceedings from a symposium on body composition in animals and man (NRC, 1968).

Dilution Methods

Dilution techniques are based on the assumption that water constitutes a constant fraction of the fat-free body. Usually, total body water is estimated by introducing a "marker" substance in a known quantity which equilibrates with the body water. A sample of body fluid, usually blood, is drawn and the concentration of the marker in a known volume is determined. Total fluid volume can be estimated as:

$$\text{Volume (ml)} = \frac{[\text{g (or counts} \cdot \text{min}^{-1}\text{) added marker}]}{[\text{g (or counts} \cdot \text{min}^{-1}\text{) per ml sample}]}$$

Antipyrine and several of its derivatives (Soberman et al., 1949; Kraybill et al., 1951; Reid et al., 1958), deuterium oxide or tritiated water (Hevesy and Hofer, 1934; Reid et al., 1955; Garrett et al., 1959; Pearson, 1965) and urea (Preston and Koch, 1973) have all been used as markers with varying degrees of success.

The chemical used as a marker substance should be distributed rapidly and uniformly throughout the body, it should be non-toxic, it should remain stable long enough to permit sampling, its excretion from the body should be slow, and convenient methods should be available for its analysis (Berg and Butterfield, 1976). Hansard (1968) listed, as the more important sources of error associated with dilution procedures, nonquantitative injection of marker, accelerated metabolism or loss of label from the system, and inadequate mixing and sampling for analyses.

Another problem with using estimated total body water for estimating body composition relates to the constancy of water in the body. Water in the fat-free tissue decreases with maturity, but for practical purposes this may not be important after six months of age (Berg and Butterfield, 1976). Berson (1956) reported that fat-free water for the various animal species range from 72 to 76% of the body weight. In addition, Farrell and Reardon (1972) found that undernourished sheep had a significantly higher water content in the fat-free empty body than well-nourished sheep. Furthermore, some of the chemicals used equilibrate with the gut water. Water in the gut is subject to great fluctuations and may radically influence total body water estimations.

Byers (1979) described "curve peeling" techniques used to estimate the size of two deuterium oxide pools. Pool A was considered to be related to empty body water space and pool B was considered to be related to gut water space. Ferrell and Jenkins (1984a) used similar computations and estimated empty body weight of mature beef cows from live weight and pool B. Regression of empty body water, fat and fat-free dry matter on the estimated empty body weight resulted in R^2 values and coefficients of variation of .92 and .044, .86 and .092, and .92 and .044, respectively. These findings support the suggestion that empty body weight may be a good index of empty body composition (Reid et al., 1968; Gil et al., 1970).

Urea Dilution Technique

As stated above, one of the markers commonly used in dilution studies of composition is urea. Urea offers a number of advantages over other indicators in that it is a naturally occurring substance found in significant quantities in the animal body and is therefore not a potential hazard if it enters the human food chain, the cost of the required dosage is relatively inexpensive and the method of analysis is rapid and inexpensive compared to other indicators. The remaining portions of this section deal with the distribution, equilibration and elimination of urea within the animal body and the subsequent effectiveness of urea dilution in estimating composition.

Distribution

Urea is highly soluble, easily penetrates cell membranes and has been shown by Marshall and Davis (1914) to be uniformly distributed throughout all tissues of the dog except for fat and the urinary tract. The urea content of the urine and the urinary tract tissue was high while the urea content of fat was low due to the low solubility of urea in fat and the low water content of adipose tissue. This uniform distribution of urea was also found when the urea content of the body was increased, either by urea infusion, by interference with kidney urea excretion, or by both methods simultaneously.

Equilibration

Equilibrium is rapidly achieved between plasma and tissue urea concentrations. Estimates for the dog range from 15 min (Marshall and Davis, 1914) to 1 hr (Painter, 1940). Equilibrium was reached within

15 min in the human (Donovan and Brenner, 1930) and in 12 to 15 min in cattle (Preston and Koch, 1973).

Elimination

In mammals, urea is often considered a waste product of protein metabolism. Excretion in the urine at one time was considered to be the sole fate of urea. In the dog, urinary excretion of urea is directly proportional to the concentration of urea in the blood (Marshall and Davis, 1914). Plasma urea concentration was related to the amount of urea excreted in the urine of cattle (Thornton, 1970a, 1970b; Vercoe, 1971) and sheep (Cocimano and Leng, 1967).

In ruminant animals, urea enters the rumen in saliva (McDonald, 1948; Houpt, 1959) and by diffusion across the rumen wall (Houpt, 1959). Once in the rumen, bacterial urease hydrolyzes urea to ammonia and carbon dioxide. Rumen ammonia serves as as a nitrogen source for microbial protein synthesis. Through this mechanism, dietary urea or urea infused into the blood stream may be retained in body tissues. Bailey and Balch (1961) demonstrated that salivary urea concentrations in cattle were linearly related to plasma urea concentrations. The transfer of urea from the blood across the rumen wall in sheep and goats was by diffusion and was linearly related to the plasma urea concentration (Houpt and Houpt, 1968). Thornton (1970c) reported that the transfer of urea from the blood to the rumen and the urinary excretion of urea are reciprocally related.

Plasma urea concentrations above 15-17 mg nitrogen$\cdot$dl^{-1} did not influence the maximum concentration of nitrogen in the rumen of sheep (Thornton, 1970d). Despite large differences in plasma urea concentrations, the rates of nitrogen accumulation in the rumen were similar (6-7 mmoles·hr^{-1}).

From the previous discussion it is obvious that fluctuations in the endogenous plasma urea concentration may occur. These fluctuations may interfere with the accurate measurement of the disappearance curve of exogenous urea. Preston and Koch (1973) speculated that the short time required for urea equilibration and the concomitant short time interval between infusion and sampling excludes gut water from urea space. Rapid sampling may reduce the potential errors introduced by the recycling of urea.

Water Space and Composition Determinations

Painter (1940) reported that in the dog, urea water space was similar to sulfanilamide water space and the water available for the solution of sulfanilamide is equal to total body water obtained by desiccation of the entire body. Urea water space was found to be similar to deuterium oxide space when both were measured simultaneously in humans (San Pietro and Rittenberg, 1953) and in cats (Kornberg and Davies, 1952).

Preston and Koch (1973) reported that empty body fat percentage as determined by carcass specific gravity was closely related to urea water space (r = -.75 to -.91). The relationship was stronger (r = -.92 to -.97) for heavy weight steers than for light weight steers (r = nearly zero).

Urea space measured 12 min following urea infusion was correlated with the 8-9-10th rib section water (r = .84), protein (r = .73), fat (r = -.84) and ash (r = .58) (Koch and Preston, 1979). Correlations between urea space and fat percentage of the rib were slightly lower for thin (15.3% fat) cattle than for fat (27.7% fat) cattle (r = -.67 vs -.75) and were slightly lower for light (163 kg cold carcass weight) cattle than for heavy (246 kg cold carcass weight) cattle (r = -.65 vs -.87).

Bartle et al. (1983) showed that urea water space accounted for up to 64% of the variation in the percentage fat in the edible carcass of mature beef cows as estimated from the composition of the 9-10-11th rib cut (Hankins and Howe, 1946). In dairy cows, urea space accounted for 41% of the variation in percentage fat. Examination of the data presented in the plot of percentage fat vs. urea space indicates that urea space is not closely related to the percentage fat in thin (<15% fat) cows.

It appears that over a wide range of cattle weights and degrees of fatness, urea water space may be a useful predictor of body composition. However, in thin cows or light weight steers, the value of urea space must be questioned.

The Influence of Body Composition on Maintenance Requirement

Scientists have speculated for many years concerning the role of body composition on heat production and transfer and the resulting effect on energy expenditures for maintenance. Two broad theories are generally proposed. The first theory contends that the amount and distribution of body fat and lean influences the ability of the animal body to dissipate heat and to resist changes in body temperature. The second theory supposes that because fat and lean tissue turn over at differing rates and require differing amounts of energy for maintenance, the ratio of fat to lean influences the amount of energy needed per unit body weight for maintenance.

The succeeding sections of this review address these two possibilities. The first theory is discussed using physical science concepts concerning heat absorption and dissipation and the interaction of these concepts with known physiological responses to environmental stress. The second possibility is addressed on the basis of relative metabolic rate and heat production data for lean and fat tissue presented in the literature.

Heat Dissipation and Absorption

The transformation of chemical energy in feedstuffs into forms of energy which are useful to the animal is not an efficient process. Heat is produced as a result of this inefficiency. Biochemical and physiological reactions occur at rates partially determined by temperature. Stable temperatures enable such reactions to function steadily. Homeothermic animals' vital and productive processes require a relatively constant body temperature. Homeothermic animals resist cool and warm environments by physiologically, anatomically and behaviorally altering the rates of production of metabolic heat and the rate of heat transfer to or from the environment (Curtis, 1983).

The specific heat of a substance is the heat absorbed or released per unit mass per degree rise or fall in temperature. It represents the number of calories of heat required to raise the temperature of 1 g of a given substance by 1 C. The specific heat of water and of the dry matter of an animal's body is 1 and around .4 $cal \cdot g^{-1} \cdot C^{-1}$, respectively.

Heat capacity is the number of calories which will raise the temperature of a whole body of matter by one degree. A homogeneous body's heat capacity equals the product of its specific heat times its mass. If an animal body's ratio of water to dry matter is known, its heat capacity can be estimated. From the data of Wright and Russel (1984a) and Thompson et al. (1983) it appears that the empty bodies of fat beef cows may contain six percentage units less water that thin beef cows. Assuming that water makes up about 70% of an adult animal's body, water content may vary from 67 to 73% for fat and thin cows, respectively. A 400 kg fat cow would have a heat capacity of approximately 320 $kcal \cdot C^{-1}$ while a 400 kg thin cow would have a heat capacity of approximately 335 $kcal \cdot C^{-1}$. Curtis (1983) stated that the high water content of the animal's body is an asset since water physically buffers the body temperature against changes in environmental temperature.

Animal bodies are not homogeneous mixtures of water and dry matter. Furthermore, the dry matter portion of the body is not a homogeneous mixture of protein, fat and ash of constant proportions. Fat is the most variable component of the adult animal body and is distributed throughout the body in various depots. Therefore, heat capacity computations concerning animal bodies may be simply interesting academic exercises that are difficult to apply and interpret. The main contribution of adipose tissue to heat dissipation and absorption is believed to stem from the assumed insulatory properties of subcutaneous fat.

Animals lose heat to and gain it from the environment via three sensible forms of energy transfer--radiation, convection and conduction. Heat also flows between animals and the environment via evaporation and condensation. Because evaporation and condensation occur along a vapor pressure gradient and not along a temperature gradient, they cannot be sensed with a thermometer and are known as latent forms of heat flow.

Radiant heat loss does not require the aid of a material medium. Convection refers to the transfer of heat through the movement of molecules down a temperature gradient. In conduction, heat is transferred from molecule to molecule without material movement.

Conductive heat flow through a substance depends on the thermal conductivity and the thickness of the substance, the area over which conduction occurs, and the temperature gradient from one side of the substance to the other in a line perpendicular to the surface. Thermal conductivity is lowest in gasses and highest in solids reflecting the relative distance between the molecules of each substance. Insulation may be defined as the reciprocal of conduction. Substances with low thermal conductivities are good insulators. The thermal conductivity of vasoconstricted animal fat is about one-third that of normal animal fat (Blaxter, 1967). Thus, the insulatory value of depot fat is increased by around three times by vasoconstriction.

Some heat flows from the visceral organs to the skin of the trunk and extremities via conduction, but most flows via convection through the circulatory system. In a thermoneutral environment, when the rate of blood flow to the surface is unrestricted, subcutaneous fat contributes little to tissue insulation (Curtis, 1983). When environmental temperature decreases below the critical temperature, vasoconstriction occurs and limits convective heat flow through the peripheral blood stream. The magnitude of an animal's adipose tissue insulation is determined largely by the status of its peripheral blood vessels.

Blaxter (1967) contended that the thermal insulations of the tissues of different species were much smaller than the thermal insulations of the surface to air interface of the animal body. Curtis (1983) suggests that the volume associated with the winter hair coat of mammals may be comprised of up to 90% air. Because the thermal conductivity of air is low, its insulatory value is high. When moisture displaces the air associated with an animal's hair coat, the insulatory value of the hair coat is substantially reduced. In addition, wind tends to flatten the hair coat and decreases the amount of air closely associated with hair. During periods of cold stress, particularly if the cold is accompanied by wind, rain or snow, the importance of subcutaneous fat as an insulator may be increased.

Tissue Turnover

Pullar and Webster (1977) showed that the energy cost of fat and protein deposition per gram of dry tissue was nearly equal. Also, they demonstrated that only 8% of the total protein synthesis in the body occurred in the muscle. These workers then calculated that the maintenance requirement of both fatty and lean rats was more closely related to body protein content, or lean body weight, than to total body weight. Protein synthesis, protein mass and body weight accounted for 90, 72 and 59% of the variation in total heat loss, respectively for the rat (Webster et al., 1978). Bulls deposit relatively more energy as protein and less as fat than steers. The heat production of bulls was about 20% higher than that of steers at the same food intake and stage of maturity (Webster et al., 1977). Largely from these data, Webster (1980) proposed that heat production was related more closely to total protein synthesis than to body weight.

Fat cows have proportionately less body protein than thin cows of the same body weight. Consequently, protein turnover and synthesis per unit weight would be less in fat cattle. If maintenance energy expenditures are indeed closely correlated with protein synthesis, fat cows may have a lower requirement per unit weight than thin cows.

Animal Data

Data concerning the influence of composition on maintenance requirement are limited and at times not designed to adequately address the question. In addition, much of the data do not include adequate description of body composition making interpretation and across trial comparisons difficult.

Lambourne and Reardon (1963) found that thin Merino sheep required about 40% more dry organic matter per kilogram body weight for maintenance than did fat sheep. When sheep were exposed to cold in winter, maintenance requirements increased more for thin sheep indicating they were not as well insulated as fat sheep.

Metabolizable energy requirements ($kcal \cdot kg^{-1}$ live weight) for maintenance, calculated from estimated volatile fatty acid production and changes in body energy content, were about 45% greater for thin, adult Merino sheep than for fat sheep (Farrell et al., 1972a). Heat production and energy expenditures of fasted ewes on pasture, calculated from estimates of carbon dioxide entry rate of these sheep, also led to the same conclusions (Farrell et al., 1972b).

Fat Hereford and Charolais cross cows tended to gain weight while thin cows tended to lose weight when fed similar amounts of energy per $kg^{.75}$ body weight (Klosterman et al., 1968). These data indicate that fat cows had a lower maintenance requirement per $kg^{.75}$ than thin cows. Using weight/height (W/H, $kg \cdot cm^{-1}$) as an index of condition, maintenance (kcal DE) was predicted by the equation, $130kg^{.75} - (W/H - 4.0)1716$.

Maintenance energy requirements for nonpregnant, nonlactating, mature Hereford x Friesian or White Shorthorn x Galloway cows were best determined by the expression, M = (0.147 - 0.016C)LW (R^2 = .771, residual s.d. = .47), where M = mega joules ME per day, LW = kg live weight and C = condition score (0 = very thin, 5 = very fat) (Russel and Wright, 1983).

Thompson et al. (1983) demonstrated that thin (app. 9.6% fat) Angus x Hereford cows required more energy for maintenance than fat app. 16.7% fat) cows (132 vs. 124 kcal ME per kilogram live $weight^{.75}$, respectively). The maintenance value of fat tissue was calculated at -1.55 kcal $ME \cdot kg^{-1}$ fat indicating that fat may have acted as an insulator reducing heat losses.

Hohenboken et al. (1972) found partial regressions of TDN required for maintenance on W/H to be mostly negative but not significantly different from zero in lactating Hereford cows. The data of Neville (1971) show no relationship between W/H and kcal $ME \cdot (kg^{.75})^{-1}$ required for maintenance in lactating Hereford cows.

The amount of feed required per unit body weight was not related to composition in Ayrshire cows (Taylor and Young, 1968). Maintenance costs in Angus x Holstein cows were not related to body composition (Thompson et al., 1983). Russel and Wright (1983) found no difference in the effect of condition on maintenance between cattle of partial dairy breeding and those of beef breeding.

Lighter weight, thin sheep lost more weight during undernutrition than heavier, fatter sheep, but these differences could not be accounted for by variations in metabolic rate as measured by closed-circuit indirect calorimetry (Graham, 1967).

Discussion

Data describing body composition of the cows involved in the above trials are inconsistent making a comparison of the magnitude of change in maintenance requirements difficult. Thompson et al. (1983) found that maintenance requirements per kilogram live weight$^{.75}$ appear reduced by .9% for each percentage increase in empty body fat. From the data of Wright and Russel (1984b), one can calculate that the empty body of a cow with a condition score of 1 unit (0 = very thin, 5 = very fat) would contain 3.5% fat while the empty body of a cow with a condition score of 3 would contain 24.4% fat. Maintenance costs per kilogram live weight$^{.75}$ observed by Russel and Wright (1983) appear reduced by 1.5% for each percentage increase in empty body fat. Assuming that each unit WTHT corresponds to 8.4% carcass fat (Wagner et al., 1985), one can calculate from the data of Klosterman et al. (1968) that each percentage increase in carcass fat corresponded to a 1.2% reduction in maintenance requirements per kilogram live weight$^{.75}$. It appears as if maintenance requirements per kilogram live weight$^{.75}$ may be reduced by 1% for each percent increase in empty body fat.

CHAPTER III

BODY CONDITION SCORE, LIVE WEIGHT, WEIGHT:HEIGHT RATIO AND UREA WATER SPACE AS ESTIMATORS OF CARCASS COMPOSITION IN NONPREGNANT, NONLACTATING, MATURE HEREFORD COWS

Summary

Body condition score (CS), live weight (LW), weight:height ratio (WTHT) and urea water space (US) were evaluated and compared as estimators of carcass composition in beef cows. Seventy-one mature, nonpregnant, nonlactating Hereford cows ranging in LW, CS and WTHT from 275 to 595 kg, 2.0 to 8.0 units and 2.29 to 4.62 $kg \cdot cm^{-1}$ respectively, were slaughtered. Live weight, CS or WTHT predicted total carcass energy (TMCAL, mcal; r^2 = .81 vs .85 or .83; $Sy \cdot x$ = 89.06 vs 79.14 or 85.16), carcass fat (FAT, kg; r^2 = .78 vs .82 or .80; $Sy \cdot x$ = 8.56 vs 7.72 or 8.14), carcass protein (PRO, kg; r^2 = .71 vs .74 or .70; $Sy \cdot x$ = 3.47 vs 3.29 or 3.51) and carcass water (WAT, kg; r^2 = .78 vs .71 or .77; $Sy \cdot x$ = 9.74 vs 11.14 or 9.97) with similar accuracy, respectively. When composition was expressed on a per unit weight basis, CS was superior to LW or WTHT as predictors of $TMCAL \cdot kg^{-1}$ hot carcass weight (ECCW), $TMCAL \cdot kg^{-1}$ LW (ECLW) and $FAT \cdot kg^{-1}$ hot carcass weight$\cdot$100% (FATPR) (r^2 = .82 vs .60 and .64, .83 vs .58 and .62, and .82 vs .64 and .68, respectively). Standard error of the regressions were .242 vs .355 or .338, .143 vs .223 or .213 and

2.46 vs 3.52 or 3.32 for ECCW, ECLW and FATPR, respectively. Correlation coefficients between predictor variables and WAT$\cdot kg^{-1}$ hot carcass weight (WATPR) or PRO$\cdot kg^{-1}$ hot carcass weight (PROPR) were low and regression equations developed to predict WATPR or PROPR were of limited value. Urea water space, determined 24 min post-infusion (US24) was more closely related to carcass composition than was US determined at other times. Correlations of carcass composition with US were low ($r<.4$) and regression equations developed to predict composition from US24 were of limited value (r^2 = .17, .18, .14, .17, .18, .12, .0008, .09 and .07 for TMCAL, ECCW, ECLW, FAT, FATPR, PRO, PROPR, WAT and WATPR, respectively). These data indicate that CS was the more useful predictor of carcass composition in mature cows.

Introduction

The relationship between weight, body condition and reproduction in beef cows has been well established (Dunn and Kaltenbach, 1980). For many years animal scientists and producers have been searching for accurate, precise and nondestructive methods to estimate carcass energy stores in beef cows for research and management. Objective techniques range in sophistication from simple measurements of live weight (LW) to complex double isotope dilution procedures. In addition, a number of subjective scoring systems have been developed to describe body condition. Relatively few attempts have been made to quantify these scoring systems.

Live weight and condition score (0 = very thin, 5 = very fat) accounted for 91.2 and 90.2% of the variation in kilograms body fat in mature cows, respectively (Wright and Russel, 1984b). Using condition score and LW together in the same model explained 95% of the variation in body fat. Residual standard deviations when expressed as proportions of the means were .193, .205 and .151 for LW, condition score and the two variable model, respectively.

Dunn et al. (1983) demonstrated that body condition score (CS; 1 = very thin, 9 = very fat) was more closely related to the percentage carcass fat in mature cows than was LW (r = .77 vs .48). Likewise, Russel et al. (1969) showed that condition score (0-5 scale) accounted for 88% of the variation in the percentage fat in the fleece-free empty body of sheep while LW only accounted for 66% of the variation in percent fat.

Weight:height ratio (WTHT) was only moderately correlated (r = .56) with percent fat in mature beef cows and regression equations predicting body energy from WTHT accounted for only 33% of the variation in energy (Dunn et al., 1983).

Preston and Koch (1973) reported that percentage fat in the empty body as determined by carcass specific gravity was closely related to urea water space (r = -.75 to -.91). Koch and Preston (1979) demonstrated that urea water space (US) measured 12 min following urea infusion was correlated with the 8-9-10th rib section water (r = .84), protein (r = .73), fat (r = -.84) and ash (r = .58). US accounted for up to 64% of the variation in the percentage fat in the edible carcass of mature beef cows (Bartle et al., 1983).

The objective of this research was to evaluate and compare CS, LW, WTHT and US as estimators of carcass composition in mature, nonpregnant, nonlactating Hereford cows.

Materials and Methods

Seventy-one mature, nonpregnant, nonlactating Hereford cows were slaughtered as part of a regression study investigating the effects of carcass composition on energy requirements for maintenance during winter. Prior to slaughter and after an overnight (16h) withdrawal of feed and water, each cow was weighed and evaluated visually and by palpation and assigned a body condition score (table 1) by two independent observers. Hip height (HPHT) was determined on all cows prior to the initiation of the trial. WTHT was computed by dividing LW(kg) by HPHT(cm).

On the morning prior to slaughter, US was estimated as described by Bartle et al. (1983). A cannula (polyvinyl; 2.08 mm od) was placed in the jugular vein. Cows were maintained in individual stalls with free access to water and fed 5 kg of a complete ration[1] daily. A time 0 sample was withdrawn from the cannulae. Cows were then infused with a 20% (w:v) urea dissolved in .9% saline solution at the rate of .66 ml per kilogram LW. Cannulae were rinsed with 10 ml .9% saline and removed. Blood samples (15 ml) were collected by puncture of the opposite jugular vein. Samples were withdrawn at 6, 12, 18 and 24 min after infusion with urea. Oxalate (.634 $mg \cdot ml^{-1}$ sample) was used as an anticoagulant and plasma was retained and stored at -20C for urea analysis (Fawcett and Scott, 1960; Searcy et al., 1961). US expressed as a percentage of LW at 6, 12, 18 and 24 min post infusion (US6, US12, US18 and US24, respectively), was calculated by the equation: US% =

[1] Ration consisted of 40% rolled corn, 35% alfalfa pellets, 21.7% cottonseed hulls, 3% cane molasses and .3% salt on an as fed basis.

urea nitrogen infused (mg)/change in plasma urea nitrogen $(mg \cdot dl^{-1})$/LW/10.

Cows were slaughtered at a commercial slaughter plant. Hot carcass weight (HCW) was measured. Kidney, heart and pelvic fat were removed, weighed and sampled within 30 min of death. Carcasses were cooled for two days and the right side of each carcass was delivered to the Oklahoma State University meat laboratory where the chemical composition of the edible carcass tissue was determined.

Bones were removed from the edible carcass and weighed. Edible tissue was ground, mixed and sampled in a manner similar to that described by Munson et al. (1966). Carcass soft tissue was ground through a coarse (1.25 cm) plate, thoroughly mixed and reground through the coarse plate. Following another thorough mixing, tissue was ground through a fine (.3 cm) plate. Nine 50 g "grab" samples were obtained at random and composited into three 150 g samples. Each composite sample was mixed and 50 g was frozen (-20C) for subsequent determination of dry matter, protein, fat and ash.

Samples were thawed at 5C and homogenized using a household food processor. Dry matter was determined by drying duplicate 3 g samples for 48 h at 100C in a vacuum oven. Dry samples were weighed then extracted with ethyl ether (B.P. 35C) in a Soxhlet apparatus for 48 h (AOAC, 1975). Ash content was estimated by combusting the remaining residue at 600C for 8 h. Total nitrogen was determined on duplicate 2 g samples by the Kjeldahl procedure (AOAC, 1975). Percent protein was calculated as Kjeldahl nitrogen x 6.25.

Total carcass energy (TMCAL, mcal) was estimated by the equation: TMCAL = carcass fat (FAT, kg)$\cdot$9.4 mcal/kg + carcass protein (PRO, kg)·5.6 mcal/kg (NRC, 1984). Kidney, heart and pelvic fat was included in the calculation of FAT. Energy content per kilogram HCW (ECCW) and per kilogram LW (ECLW) was computed by dividing TMCAL by HCW or LW, respectively. Proportion FAT (FATPR), PRO (PROPR) and carcass water (WATPR) were computed by dividing FAT, PRO and carcass water (WAT) respectively, by HCW. Contribution of carcass bone to carcass fat, protein and water was not accounted for.

Data were analyzed and prediction equations developed by correlation and regression techniques outlined by Barr et al. (1979).

Results and Discussion

The mean and standard deviation of each of the variables in the data set are summarized in table 2. Cows varied widely in LW (275 to 595 kg) and CS (2.0 to 8.0 units). Hip height and WTHT ranged from 111 to 129 cm and from 2.29 to 4.62 $kg \cdot cm^{-1}$, respectively.

Simple correlation coefficients between LW, CS, WTHT, HPHT, US and estimates of composition are displayed in table 3. These data were obtained from cows utilized in a regression study and large ranges in body condition and LW were purposely created prior to the initiation of the trial. Increasing the range of these data may increase the magnitude of correlation coefficients.

The measurements of LW, CS or WTHT show a similar degree of association with TMCAL (r = .90, .92 and .91), FAT (r = .88, .91 and .90), PRO (r = .84, .86 and .84) and WAT (r = .88, .84 and .88), respectively. When energy and fat are expressed on a percentage basis, however, CS (r = .90, .91 and .91) appeared to be more closely related to ECCW, ECLW and FATPR respectively, than LW (r = .76, .76 and .80) or WTHT (r

= .80, .77 and .83).

The correlation between WTHT and LW in this study was greater than .98. Consequently, the degree of relationship between WTHT or LW and the other variables measured is likely to be similar. Correlation coefficients between HPHT and other variables were low (r = .30, .19, .14, .28, .19, .36, -.03, .38 and -.17 for TMCAL, ECCW, ECLW, FAT, FATPR, PRO, PROPR, WAT and WATPR, respectively). There appeared to be little relationship between PROPR and LW, CS, HPHT or WTHT (r = nearly zero).

Correlation coefficients between US and the other variables were low indicating US may be of limited value in estimating carcass composition in live cows. Urea space measured at 24 min following urea infusion was more closely correlated with body composition and energy content. Koch and Preston (1979) demonstrated that US12 was most closely correlated with the composition of the 8-9-10th rib section in steers (r = .84, .73, -.84 and .58 for carcass water, protein, fat and ash, respectively).

Figure 1 illustrates the close relationship (r = .84) between LW and CS. A quadratic function of CS (table 4) accounts for more variation in LW than the linear model (r^2 = .76 vs .70, respectively). Changes in condition for thinner cows may reflect less weight changes than do condition changes for fatter cows. Wright and Russel (1984b) demonstrated that for each unit increase in body condition (0 = very thin, 5 = very fat), LW increased nearly 94 kg for cows of primarily beef breeding (r^2 = .78). In this study, with condition scores from 0 to 9, a weight increase of 38 kg was associated with a one unit change in CS.

Prediction equations for estimating carcass energy from LW, CS, WTHT or US are displayed in table 5. When carcass energy was expressed on an absolute basis (TMCAL), CS, LW and WTHT predicted energy with a similar degree of accuracy (r^2 = .85, .81 and .83, respectively). However, when carcass energy was expressed on a per unit weight basis, CS (r^2 = .82 and .83) accounted for more of the variation in ECCW and ECLW, respectively than LW (r^2 = .60 and .58) or WTHT (r^2 = .64 and .62). Equations predicting carcass energy from US24 accounted for only 17, 18 and 14 % of the variation in TMCAL, ECCW and ECLW, respectively.

Dunn et al. (1983) found that CS and WTHT of post-partum beef cows accounted for 59 and 30% of the variation in ECCW and 66 and 33% of the variation in ECLW, respectively. Our values were 82, 64, 83 and 58%, respectively. Likewise, Wright and Russel (1984b) demonstrated that body condition (0-5 scale) was a useful predictor of total carcass energy in beef cows (r^2 = .91) and in dairy cows (r^2 = .86) compared with an r^2 in this study of .85.

Equations for estimating carcass fat from LW, CS, WTHT or US are shown in table 6. When carcass fat was expressed on a total kilogram basis, CS, LW and WTHT predicted FAT with similar accuracy (r^2 = .82, .78 and .80, respectively). Including CS and LW in the model accounted for more variation in FAT (r^2 = .88) than either CS or LW alone. When carcass fat is expressed as a percentage of hot carcass weight, CS accounted for more variation in FATPR than LW or WTHT (r^2 = .82 vs. .64 and .68, respectively). The quadratic function of CS accounted for slightly more of the variation in FATPR than the linear function (r^2 = .84 vs. .82).

Dunn et al. (1983) reported that correlation coefficients between FATPR and CS, LW and WTHT were .77, .48 and .56. Wright and Russel

(1984b) showed that LW and body condition (0-5 scale) accounted for 91 and 90% of the variation in FAT.

Only 17% of the variation in FAT and 18% of the variation in FATPR could be explained by equations using US, indicating US was a poor estimator of carcass fat. Bartle et al. (1983) reported that equations that included change in plasma urea nitrogen and LW accounted for 66% of the variation in fat percentage. However, including US24 and initial plasma urea concentration as additional factors in multiple regression with LW in our study did not significantly improve the estimation of FATPR (table 6).

Examination of the plot published by Bartle et al. (1983) indicates that the degree of association between percentage fat and urea water space may be lower in cows with less than 23% fat. This observation appears confirmed by figure 2. Figures 3 and 4 illustrate the relationship between FATPR and CS or LW, respectively. Condition score and LW appear to be more useful estimators of carcass fat than US.

Equations estimating carcass protein from LW, CS, WTHT and US24 are summarized in table 7. Similar amounts of variation in PRO are explained by CS (r^2 = .74), LW (r^2 = .71) and WTHT (r^2 = .70). The inclusion of CS and LW in the model improves the accuracy of the regression (r^2 = .79). Only 12% of the variation in PRO was accounted for by US. The relationship between PROPR and the predictor variables, CS, LW, WTHT and US24 was low (table 4 and figure 5). Regression equations estimating PROPR from CS, LW or WTHT (table 7) were of little predictive value (r^2 = .005, .007 and .07, respectively). A quadratic function of CS accounted for 29% of the variation in PROPR.

Dunn et al. (1983) found that the correlation coefficients between percent carcass crude protein and LW, CS and WTHT in post-partum beef cows were -.37, -.51 and -.43, respectively compared with -.08, .07 and -.08 in this trial. Wright and Russel (1984b) demonstrated that LW was the best single predictor of kilograms carcass protein and that a quadratic function of LW accounted for 92% of the variation in protein.

Equations for predicting carcass water from LW, CS, WTHT or US are shown in table 8 and accounted for 78, 71, 77 and 9% of the variation in WAT and 19, 16, 19 and 7% of the variation in WATPR, respectively. Using CS and LW in the same model enables one to predict WAT with slightly more accuracy ($r^2 = .81$). Figure 6 indicates that the relationship between WATPR and CS or LW may not be linear. A quadratic function of CS or LW accounts for 33 or 23% of the variation in WATPR, respectively. Including US to the model predicting WATPR from the quadratic function of LW only increased r^2 from .23 to .26.

Discussion

The close relationship between CS and the estimates of carcass energy and composition indicate that CS can be used to estimate carcass body composition in cows. When estimates of carcass components are expressed on an absolute basis (kg or mcal), LW and CS predict composition with about equal accuracy. However, when carcass components are expressed on a percentage basis, CS is superior to LW as a predictor of composition.

Because of the subjective nature of CS, many researchers feel that CS estimates are subject to intolerable levels of assessor bias and measurement error. Investigations by Russel et al. (1968) and Doney and Russel (1968) showed that in sheep, repeatability of CS (0 = very thin, 5 = very fat) within observers was greater than 80%, less than 15% of the observations differed by 0.5 grade, and less than 5% by 1.0 grade. Repeatability between observers showed more than 70% absolute agreement, less than 20% differing by 0.5 grade and less than 10% by 1.0 grade. Condition scores agreed by two or three operators were more than 90% repeatable, the remainder being within 0.5 grade of the first agreed score.

Evans (1978) reported a large correlation (r = .7) between scores (0-5 scale) assigned by different operators to the same animal. Repeat scores by the same operator on each animal were also correlated (r = .8). Evans suggested that the precision of body condition scoring could be improved through a second, independent assessment of each animal, with a different person scoring the animals the second time, strict criteria categorizing each score, careful training of assessors and periodic standardization of scores.

Body condition scoring appears to be a useful predictor of composition in cows. Although subjective in nature, CS offers sufficient accuracy for many research and management situations. Data from this study indicate that 76% of the variation in LW, 85% of the variation in carcass energy and 82% of the variation in carcass fat was explained by CS.

TABLE 1. CONDITION SCORING SYSTEM

Score	Description
1	-- Severely emaciated. Physically weak. All ribs and bone structure easily visible.
2	-- Emaciated but not physically weakened. Muscle tissue seems severely depleted through hindquarters and shoulders.
3	-- Very thin. No visible or palpable fat on ribs, over the backbone or in the brisket. Muscle appears depleted.
4	-- Thin. Ribs easily visible and backbone showing. Muscling through the shoulders and hindquarters does not appear depleted.
5	-- Moderate to thin. Last two or three ribs can be seen and little evidence of fat in brisket, over ribs or around tail head.
6	-- Moderate, smooth appearance throughout. Palpable fat over ribs and around tail head.
7	-- Very good flesh. Brisket is full, tail head shows pockets of fat and the back appears square due to fat. Ribs handle very soft.
8	-- Obese. Neck is thick and short. Back is very square due to fat. Brisket is distended and heavy fat pockets are visible around tail head.
9	-- Extremely obese. Description of 8's taken to greater extremes. Heavy deposition of udder fat.

TABLE 2. SUMMARY OF SLAUGHTER DATA USED TO GENERATE CORRELATION COEFFICIENTS AND PREDICTION EQUATIONS

Live weight, kg	398.1	66.50
Condition score, units	5.1	1.45
Hip height, cm	121.4	3.17
Weight:height, $kg \cdot cm^{-1}$	3.3	.51
Carcass fat, kg	27.2	18.23
Carcass protein, kg	30.6	6.39
Carcass water, kg	113.0	20.44
Hot carcass weight, kg	214.4	46.22
Total carcass energy, mcal	426.7	202.15
Carcass energy$\cdot kg^{-1}$ HCW[a]	1.9	.56
Carcass energy$\cdot kg^{-1}$ LW[b]	1.0	.34
Carcass fat, %	11.7	5.83
Carcass protein, %	14.3	1.48
Carcass water, %	53.1	3.63
Urea space - 6 min, %	41.0	6.61
Urea space - 12 min, %	52.8	8.63
Urea space - 18 min, %	57.8	9.33
Urea space - 24 min, %	61.6	9.34

[a] Hot carcass weight.
[b] Live weight.

TABLE 3. CORRELATION COEFFICIENTS BETWEEN LIVE WEIGHT, CONDITION SCORE, HIP HEIGHT, WEIGHT:HEIGHT RATIO, UREA WATER SPACE AND ESTIMATES OF CARCASS COMPOSITION[a]

	TMCAL	ECCW	ECLW	FAT	FATPR	PRO	PROPR	WAT	WATPR
LW	.90	.76	.76	.88	.80	.84	-.08[b]	.88	-.43
CS	.92	.90	.91	.91	.91	.86	.07[b]	.84	-.40
HPHT	.30	.19[b]	.14[b]	.28	.19[b]	.36	-.03[b]	.38	-.17[b]
WTHT	.91	.80	.77	.90	.83	.84	-.08[b]	.88	-.44
US6	-.29	-.33	-.26	-.29	-.33	-.25	-.07[b]	-.18[b]	.21[b]
US12	-.27	-.30	-.24[b]	-.27	-.29	-.22[b]	-.09[b]	-.15[b]	.18[b]
US18	-.22[b]	-.25	-.17[b]	-.23[b]	-.25	-.17[b]	-.03[b]	-.08[b]	.27
US24	-.37	-.40	-.36	-.38	-.40	-.29	-.03[b]	-.26	.22[b]

[a]LW = live weight; CS = condition score; HPHT = hip height; WTHT = weight:height ratio; US6, US12, US18 and US24 = urea water space 6, 12, 18 and 24 min post-infusion, respectively; TMCAL = total carcass energy; ECCW = TMCAL x kg^{-1} hot carcass weight; ECLW = TMCAL x kg^{-1} LW; FAT = carcass fat; FATPR = percentage carcass fat; PRO = carcass protein; PROPR = percentage carcass protein; WAT = carcass water; WATPR = percentage carcass water.

[b]Probability > .05.

TABLE 4. EQUATIONS FOR ESTIMATING LIVE WEIGHT FROM CONDITION SCORE

Equations	Sy·x[a]	R^2
LW[b] = 204.35 + 38.31 CS[c]	36.65	.70***
LW = 368.59 - 33.05 CS + 7.11 CS^2	33.07	.76***

[a]Standard error of the regression.
[b]Live weight.
[c]Condition score.
***$P < .001$.

TABLE 5. EQUATIONS FOR ESTIMATING CARCASS ENERGY FROM LIVE WEIGHT, CONDITION SCORE, WEIGHT:HEIGHT RATIO OR UREA WATER SPACE

Equations		$Sy \cdot x$[a]	R^2
TMCAL[b]	= -221.5 + 128.19 CS[c]	79.14	.85***
	= -661.5 + 2.73 LW[d]	89.06	.81***
	= -756.7 + 361.52 WTHT[e]	85.16	.83***
	= -487.2 + 78.38 CS + 1.30 LW	63.65	.90***
	= 570.1 + 18.84 U0[f] - 517.20 US24[g]	180.91	.17**
ECCW[h]	= .147 + .3465 CS	.242	.82***
	= -.689 + .0065 LW	.355	.60***
	= -.973 + .8774 WTHT	.338	.64***
	= .035 + .3254 CS + .0006 LW	.243	.82***
	= 2.686 + .0381 U0 - 1.839 US24	.507	.18**
ECLW[i]	= -.053 + .2140 CS	.143	.83***
	= -.531 + .0039 LW	.223	.58***
	= -.703 + .5292 WTHT	.213	.62***
	= -.057 + .2134 CS + .000017 LW	.144	.83***
	= 1.496 + .0184 U0 - 1.032 US24	.312	.14**

[a] Standard error of the regression.
[b] Total carcass energy, mcal.
[c] Condition score, units.
[d] Live weight, kg.
[e] Weight:height ratio, $kg \cdot cm^{-1}$.
[f] Initial plasma urea concentration, $mg \cdot dl^{-1}$.
[g] Urea water space determined 24 min post urea infusion, %.
[h] $TMCAL \cdot hot\ carcass\ weight^{-1}$.
[i] $TMCAL \cdot LW^{-1}$.
** $P < .01$.
*** $P < .001$.

TABLE 6. EQUATIONS FOR ESTIMATING CARCASS FAT FROM LIVE WEIGHT, CONDITION SCORE, WEIGHT:HEIGHT RATIO OR UREA WATER SPACE

Equations		Sy·x[a]	R^2
FAT[b]	= −30.38 + 11.385 CS[c]	7.72	.82***
	= −69.38 + .243 LW[d]	8.56	.78***
	= −78.14 + 32.176 WTHT[e]	8.14	.80***
	= −53.84 + 6.987 CS + .115 LW	6.52	.88***
	= 15.71 − 8.641 CS + 1.995 CS^2	6.27	.89***
	= 42.20 + 1.627 U0[f] − 49.08 US24[g]	16.41	.17**
FATPR[h]	= −6.75 + 3.645 CS	2.46	.82***
	= −16.30 + .070 LW	3.52	.64***
	= −19.34 + 9.477 WTHT	3.32	.68***
	= −9.22 + 3.181 CS + .012 LW	2.44	.83***
	= −.12 + .767 CS + .287 CS^2	2.39	.84***
	= 19.91 + .402 U0 − 19.36 US24	5.31	.18**
	= −6.17 − .248 U0 − 11.66 US24 + .0688 LW	3.45	.66***

[a] Standard error of the regression.
[b] Total carcass fat, kg.
[c] Condition score, units.
[d] Live weight, kg.
[e] Weight:height ratio, $kg \cdot cm^{-1}$.
[f] Initial plasma urea concentration, $mg \cdot dl^{-1}$.
[g] Urea water space determined 24 min post urea infusion, %.
[h] FAT·hot carcass weight^{-1}·100%.
** P < .01.
*** P < .001.

TABLE 7. EQUATIONS FOR ESTIMATING CARCASS PROTEIN FROM LIVE WEIGHT, CONDITION SCORE, WEIGHT:HEIGHT RATIO OR UREA WATER SPACE

Equations		$Sy \cdot x$[a]	R^2
PRO[b]	= 11.44 + 3.78 CS[c]	3.29	.74***
	= -1.67 + .08 LW[d]	3.47	.71***
	= -3.97 + 10.55 WTHT[e]	3.51	.70***
	= 3.37 + 2.27 CS + LW	2.98	.79***
	= 30.96 + .634 UO[f] - 9.97 US24[g]	5.84	.12**
PROPR[h]	= 13.95 + .0696 CS	1.48	.005
	= 15.05 - .0019 LW	1.48	.007
	= 15.08 - .2380 WTHT	1.48	.007
	= 16.10 - .4720 CS - .0105 LW	1.44	.07
	= 5.94 + 3.5497 CS - .3467 CS^2	1.26	.29***
	= 14.55 + .0062 UO - .3373 US24	1.52	.0008

[a] Standard error of the regression.
[b] Total carcass protein, kg.
[c] Condition score, units.
[d] Live weight, kg.
[e] Weight:height ratio, $kg \cdot cm^{-1}$.
[f] Initial plasma urea concentration, $mg \cdot dl^{-1}$.
[g] Urea water space determined 24 min post urea infusion, %.
[h] PRO·hot carcass weight^{-1}·100%.
** P < .01.
*** P < .001.

TABLE 8. EQUATIONS FOR ESTIMATING CARCASS WATER FROM LIVE WEIGHT, CONDITION SCORE, WEIGHT:HEIGHT RATIO OR UREA WATER SPACE

Equations		$Sy \cdot x$[a]	R^2
WAT[b]	= 53.15 + 11.833 CS[c]	11.14	.71***
	= 5.17 + .271 LW[d]	9.74	.78***
	= −2.32 + 35.226 WTHT[e]	9.97	.77***
	= 15.99 + 4.866 CS + 1.819 LW	9.00	.81***
	= 117.03 + 1.576 UO[f] − 30.215 US24[g]	18.18	.09
WATPR[h]	= 58.22 − 1.008 CS	3.34	.16***
	= 62.57 − .024 LW	3.29	.19***
	= 63.31 − 3.112 WTHT	3.29	.19***
	= $43.07 + 5.573\ CS - .656\ CS^2$	3.01	.33***
	= 53.97 − .332 UO + 3.861 US24	3.61	.07
	= $40.16 + .086\ LW - .00013\ LW^2$	3.23	.23***
	= $39.07 + .087\ LW - .00013\ LW^2$ −.102 UO + 2.863 US24	3.28	.26***

[a] Standard error of the regression.
[b] Total carcass water, kg.
[c] Condition score, units.
[d] Live weight, kg.
[e] Weight:height ratio, $kg \cdot cm^{-1}$.
[f] Initial plasma urea concentration, $mg \cdot dl^{-1}$.
[g] Urea water space determined 24 min post urea infusion, %.
[h] $WAT \cdot$ hot carcass weight$^{-1} \cdot 100\%$.
** $P < .01$.
*** $P < .001$.

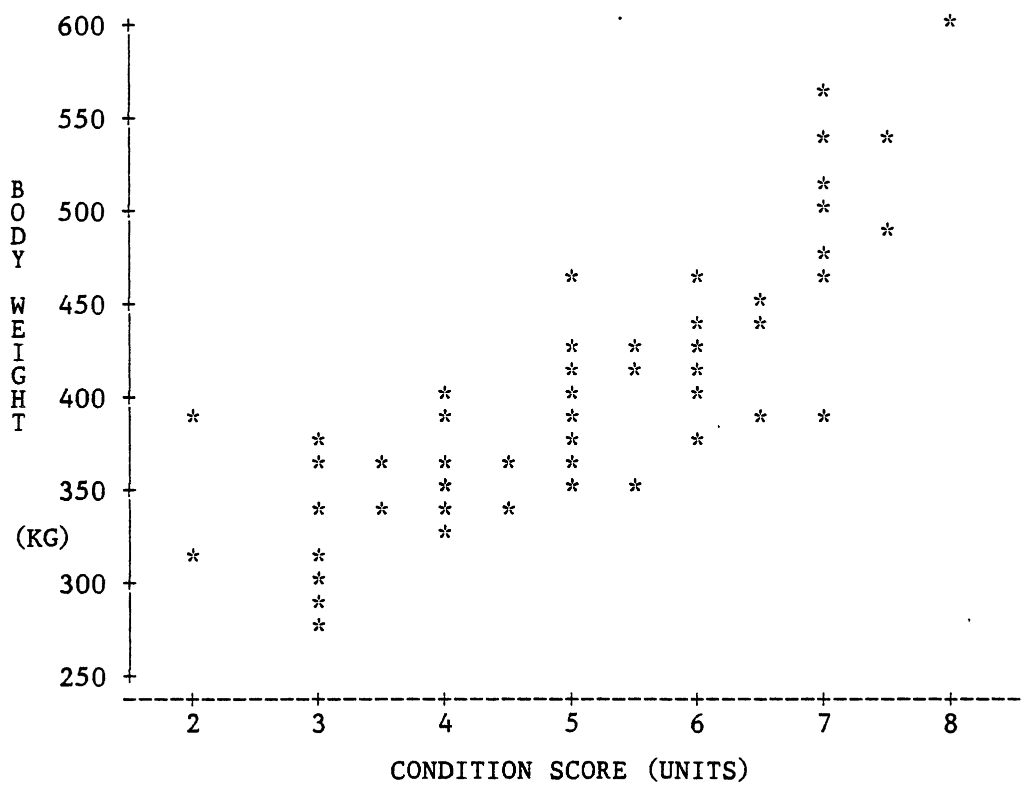

Figure 1. Relationship Between Body Weight and Condition Score

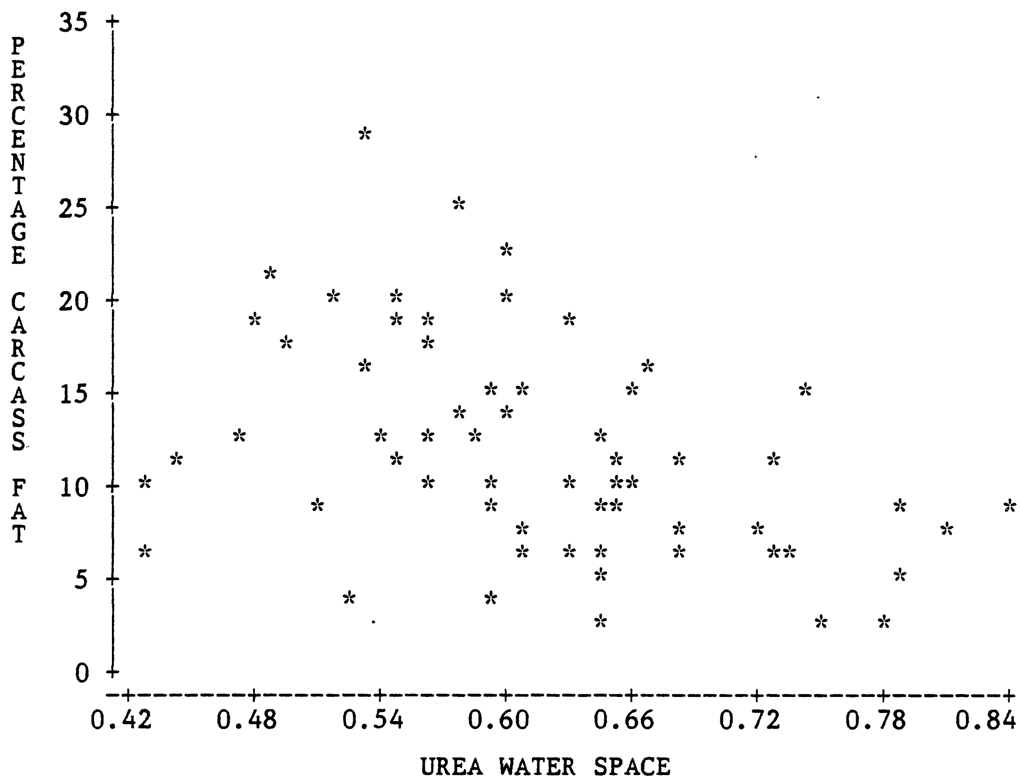

Figure 2. Relationship Between Percentage Carcass Fat and Urea Water Space Estimated 24 Minutes Post-Infusion

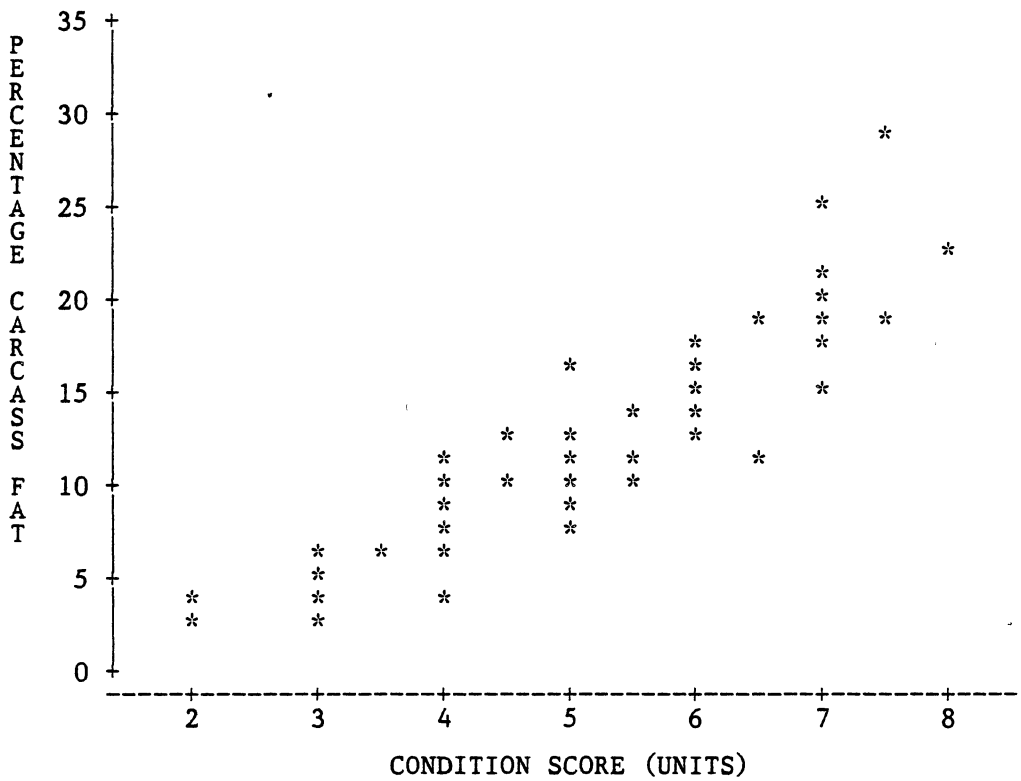

Figure 3. Relationship Between Percentage Carcass Fat and Condition Score

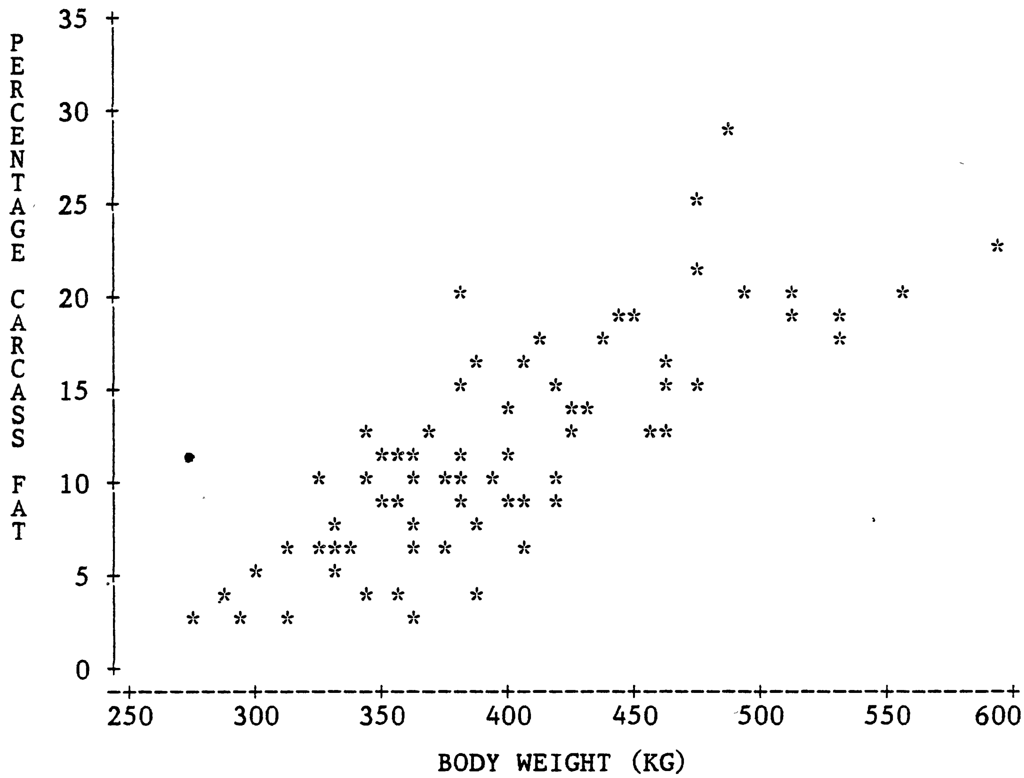

Figure 4. Relationship Between Percentage Carcass Fat and Body Weight

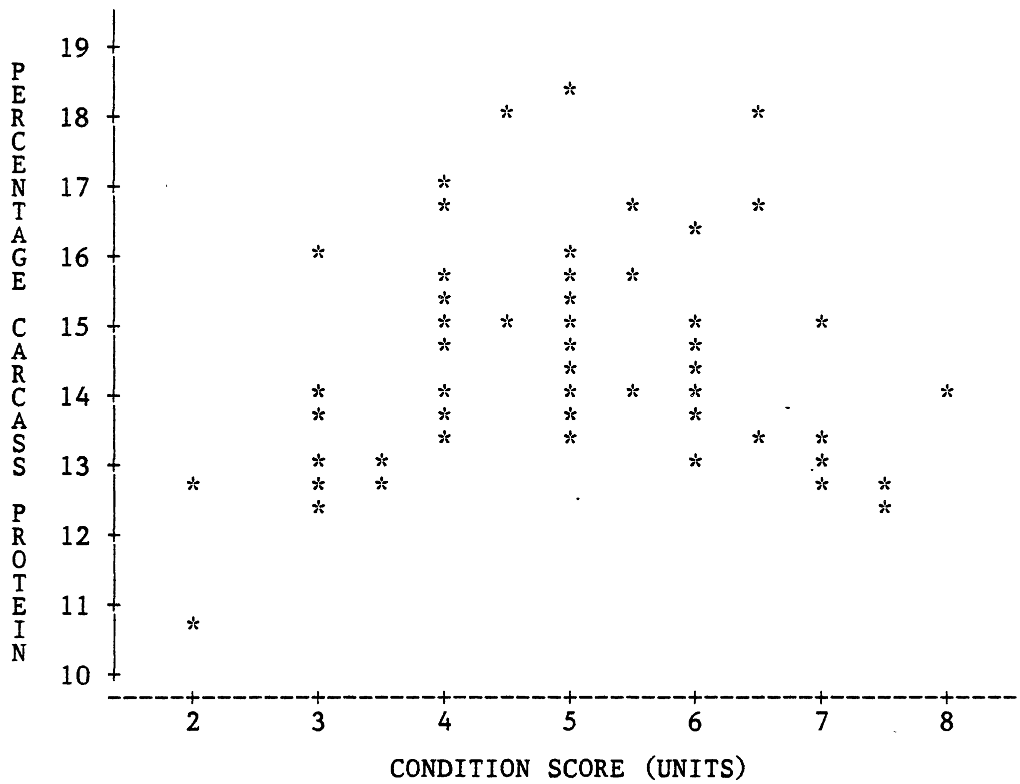

Figure 5. Relationship Between Percentage Carcass Protein and Condition Score

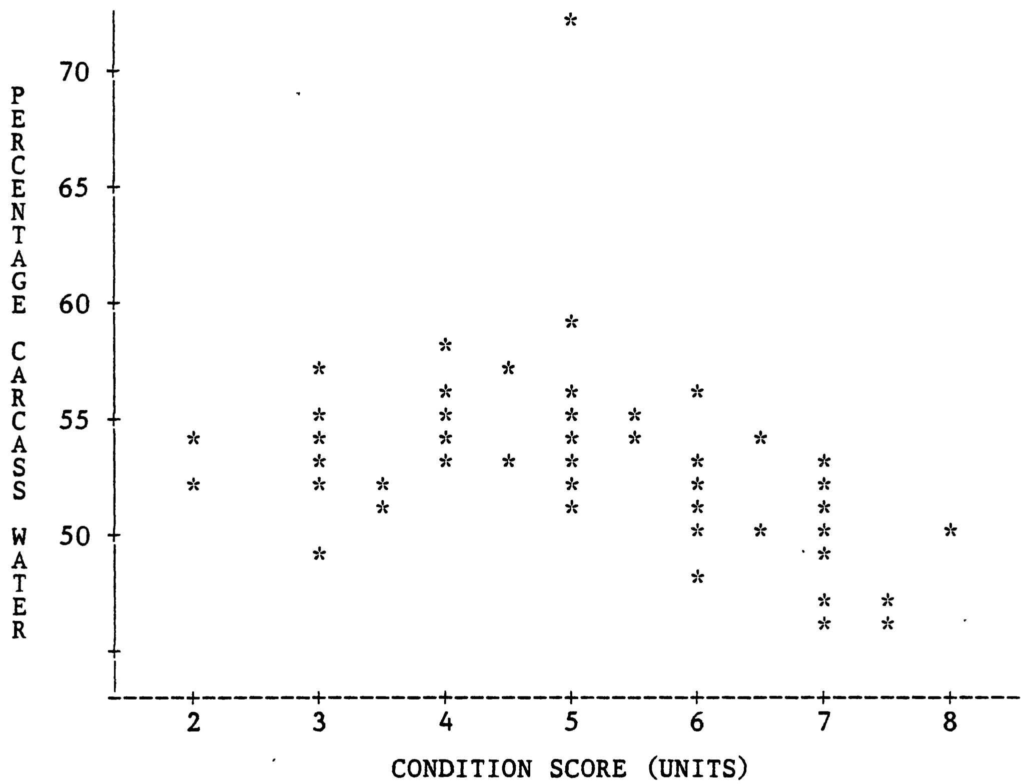

Figure 6. Relationship Between Percentage Carcass Water and Condition Score

CHAPTER IV

RELATIONSHIP BETWEEN CARCASS COMPOSITION AND DAILY METABOLIZABLE ENERGY REQUIREMENT OF MATURE, NONPREGNANT, NONLACTATING HEREFORD COWS DURING WINTER

Summary

Thirty-five cows in 1982-83 and 36 cows in 1983-84 were utilized in a comparative slaughter trial to investigate the effects of carcass composition on winter metabolizable energy (ME) requirements for maintenance. Prior to initiation of the study, all cows were randomly assigned to one of 3 feeding regimes to either lose, maintain or gain weight and condition. By the start of the trials, live weight (LW) ranged from 275 to 595 kg and condition score (CS) ranged from 2 to 8 units (1 = very thin, 9 = very fat). In December of each year, 12 cows representing the entire range of CS were slaughtered. Regression equations based on CS and LW were developed from the initial slaughter groups to predict the initial composition of the remaining cows. Remaining cows were individually fed a complete diet (2.50 mcal ME per kilogram dry matter) in drylot for 115 d. Daily feed intakes were adjusted each week to maintain LW throughout the winter. In March, all cows were slaughtered and final composition was determined. Data were analyzed by fitting the model, ME intake = k^{-1}(carcass energy change) + f(CS)$LW^{.75}$, where k = efficiency of ME use for carcass energy change and f(CS) = function of condition score. The expression, .1028

+ .0234(CS) - .0025(CS)^2, accounted for 41% of the variation in ME (mcal) for maintenance per kilogram LW$^{.75}$. The efficiency of ME utilization for carcass energy change (LW$^{.75}$ basis) was 1.09. The efficiency of fat accretion was 9.11(±3.63) mcal ME per kilogram carcass fat and the energy content of gain for years 1 and 2 were 46.6 and 9.7 mcal per kilogram, respectively. The energetic efficiency of protein synthesis was not significantly different from zero. Maintenance of carcass protein and fat tissue required .531 (±.025) and -.084 (±.021) mcal ME per kilogram, respectively. These data suggest that cows in thin (CS = 3) condition and cows in fat (CS = 7) condition require 4.4 and 8.9% less ME per kilogram metabolic weight, respectively than cows in moderate (CS = 5) condition.

Introduction

In recent years, improving the efficiency of beef production has received increased emphasis. Tremendous improvement in understanding and predicting the performance of feedlot cattle has been achieved with the application of modern ration formulation programs such as the California Net Energy system (Lofgreen and Garrett, 1968).

Current National Research Council (NRC, 1984) feeding standards compute energy requirements for beef cattle factorially. Energy expenditures for maintenance, tissue gain, and in the case of cows, pregnancy and lactation are summed and their total is considered to equal the requirement.

Cow size, as determined by cow weight, is the major factor determining energy expenditures for maintenance. The NE_m requirement for penned cattle in nonstressful environments with minimal activity is estimated by the expression 77 $kcal \cdot W^{.75}$, where W is body weight in kilograms. Energy requirements for maintenance can be adjusted for differences in environmental temperature, humidity and wind velocity (NRC, 1981). Variations in maintenance requirements due to breed have been noted (Blaxter and Wainman, 1966; Garrett, 1971; Frisch and Vercoe, 1977; Webster, 1978; Ferrel and Jenkins, 1984b). Besides breed effects, energy expenditures appear to vary with season of the year (Blaxter and Boyne, 1982), previous plane of nutrition (Koong et al., 1982) or body composition as related to feed intake and stage of production (Armstrong and Blaxter, 1984).

Subcutaneous fat cover is widely believed to insulate the animal body from the cold (Curtis, 1983). Furthermore, the heat production of rats (Webster et al., 1978) and growing livestock (Webster, 1980) was more highly correlated with body protein than with body weight. The maintenance requirement of the fat free body may be higher than that of fat. Cattle with a higher degree of fat, may require less energy per unit weight for maintenance than lean cattle.

The objectives of this research were: 1) to evaluate the relationship between carcass composition and winter maintenance energy expenditures in mature Hereford cows and 2) to develop equations based on weight and/or body condition score representing energy requirements for maintenance.

Materials and Methods

Exp 1

Thirty-five non-pregnant, nonlactating, mature Hereford cows with a condition score (CS) of 5(±.20) units (Wagner et al., 1985) and a weight of 400(±30) kg were randomly assigned to three feeding regimes in July 1982 to alter weights and CS. Twelve cows were allowed to consume wheat straw ad libitum and lost weight (about 80 kg) and body condition (about 2 units). Twelve cows were fed .5 kg cottonseed meal plus 7 kg prairie hay$\cdot hd^{-1}\cdot d^{-1}$ to maintain weight and CS. The remaining cows gained weight (about 80 kg) and body condition (about 2 units) as they were fed 2 kg cottonseed meal$\cdot hd^{-1}\cdot d^{-1}$ and allowed to consume prairie hay ad libitum. By November, weight ranged from 312 to 576 kg and CS ranged from 2 to 8 units. During November, each group of cows was fed a complete diet (table 1) in an amount designed to maintain November weight and CS and to minimize differences in fill.

In the second year, from June through September 1983, 12 cows designated to gain weight and condition were fed 1.5 kg$\cdot hd^{-1}\cdot d^{-1}$ of cottonseed meal and allowed to graze 115 ha of native tall grass range. From September to November, these cows were fed 2 kg$\cdot hd^{-1}\cdot d^{-1}$ cottonseed meal and allowed ad libitum access to prairie hay. From July to October, 12 cows, destined to lose weight and condition, were allowed to consume wheat straw ad libitum and 12 cows, destined to maintain weight and condition, were fed .5 kg$\cdot hd^{-1}\cdot d^{-1}$ cottonseed meal and 7 kg$\cdot hd^{-1}\cdot d^{-1}$ prairie hay. By October, weight ranged from 275 to 595 kg and CS ranged from 2 to 8 units. From

October to December, each group of cows was fed a complete diet (table 1) in an amount designed to maintain weight and CS and to reduce differences in fill.

In December of each year, 12 cows representing the entire range of CS were weighed after withdrawal from water and feed overnight (16 h) and slaughtered at a commercial slaughter plant. The right side of each carcass was delivered to the Oklahoma State University meat laboratory where the chemical composition of the edible carcass tissue was determined as described by Wagner et al. (1985).

Total energy of the boneless carcass (TMCAL, mcal) was estimated by the equation: TMCAL = carcass fat (FAT, kg)$\cdot$9.4 mcal$\cdot$kg^{-1} + carcass protein (PRO, kg)$\cdot$5.6 mcal$\cdot$kg^{-1} (NRC, 1984). Kidney, heart and pelvic fat were included in the calculation of FAT. Energy content of the boneless carcass per kilogram of live weight (ECLW) was computed by dividing TMCAL by live weight (LW).

Regression equations relating carcass energy to LW and CS of the initial slaughter cows were used to predict the initial energy content of the remaining cows each year. The remaining 23 cows in year 1 and 24 in year 2 were maintained in drylot and individually fed precise quantities of a complete diet (table 1) for an average of 114 d in year 1 and 115 d in year 2. Cows were weighed weekly after an overnight shrink (16 h) and daily feed intake was adjusted each week to maintain LW throughout the winter. Feed intakes and refusals were carefully monitored. Upon completion of the trial, the remaining cows were slaughtered and carcass composition was determined.

Daily weather data were obtained during each winter from the Oklahoma State University Agronomy Weather Station. Average daily temperature, rainfall and snow were computed for each week of the feeding trial. The effects of temperature and precipitation on metabolizable energy required for maintenance were examined.

Data were analyzed by using the general linear models procedure (Barr et al., 1979) to fit the models, ME intake = k_e^{-1}(carcass energy change) + f(CS)$LW^{.75}$ or ME intake = k_w^{-1}(weight change each week) + [f(CS) + f(ENV) + CSxENV interactions]$LW^{.75}$, where k_e = efficiency of ME use for carcass energy change, f(CS) = function of condition score, k_w = efficiency of ME use for LW change and f(ENV) = function of average daily temperature and precipitation for the week.

Exp 2

A trial utilizing 64 Hereford and Angus cows (410 kg, CS = 5.5 units), bred to calve in the spring of 1984 was conducted to determine the effect of CS on winter weight and condition change. Cows were stratified by breed, weight, CS and expected calving date and assigned to three feeding regimes in August of 1983. From August through mid-November, 22 cows were group fed 1 $kg \cdot hd^{-1} \cdot d^{-1}$ soybean meal, 21 were group fed .4 $kg \cdot hd^{-1} \cdot d^{-1}$ soybean meal and the remaining cows were fed no supplemental protein. By November, CS ranged from 4 to 7 units. All cows were individually fed 1.4 $kg \cdot hd^{-1} \cdot d^{-1}$ soybean meal from mid-November until calving (March) and 1.8 $kg \cdot hd^{-1} \cdot d^{-1}$ soybean meal from calving through May.

From August through mid-November, each group of cows grazed similar pastures (100 ha) of native tallgrass range in North Central Oklahoma. From mid-November through May all cows grazed together in two common pastures (200 ha). The predominant forage species were little bluestem (Andropogan scoparius), big bluestem (Andropogan gerardii), switchgrass (Panicum virgatum) and Indian grass (Sorghastrum nutans). Large round bales of prairie hay were offered ad libitum on days when snow or ice covered native grass. Cows were weighed and assigned CS after an overnight withdrawal of feed and water initially, and at 28 day intervals throughout the trial.

The effects of cow condition on winter weight and condition change were analyzed by regressing winter weight and condition change on cow breed, December cow weight and CS, calving date, calf birth weight and calf sex.

Results and Discussion

Exp 1

Initial slaughter data from year 1 are shown in table 2. Cows varied in LW (343 to 489 kg), CS (2.0 to 7.5 units), FAT (4.9 to 74.0 kg), PRO (17.6 to 34.7 kg) and TMCAL (145 to 894 mcal). Figure 1 shows the relationship between ECLW and CS. The expression: $-1.712 + 1.664(CS) - .379(CS)^2 + .029(CS)^3$ (table 3) best predicted ECLW. initial energy of the 23 cows fed through the winter averaged 379 mcal and was estimated by multiplying ECLW by LW.

In year 2, initial slaughter cows ranged in LW from 285 to 559 kg, CS from 2.0 to 7.0 units, FAT from 3.7 to 64.7 kg, PRO from 15.9 to 41.4 kg and TMCAL from 124 to 840 mcal (table 4). Figure 2 depicts the relationship between ECLW and CS. Initial energy of the 24 cows fed throughout the winter averaged 381 mcal and was computed by multiplying LW by the expression: $.333 - .028(CS) + .027(CS)^2$ (table 5).

Throughout year 1 (table 6), cows gained a mean of 1.7 kg LW and .2 units CS while cows in year 2 (table 7) gained a mean of 4.4 kg LW and .1 units CS. Cows in year 1 consumed from 10.24 to 16.77 $mcal \cdot d^{-1}$ and gained a mean of 2.5 kg carcass fat, 5.7 kg carcass protein and 79 mcal carcass energy while cows in year 2 consumed from 10.14 to 17.76 $mcal \cdot d^{-1}$ and gained a mean of 3.0 kg carcass fat, 2.6 kg carcass protein and 43 mcal carcass energy. Average daily ME intake was 13.4 mcal in year 1 and 14.5 mcal in year 2. The ME required for maintenance was estimated by solving the following multiple regression equation for zero energy retention, ME intake = $k^{-1} \cdot$ retained energy + $f(CS) \cdot LW^{.75}$, where k = the efficiency of ME utilization for carcass energy change and f(CS) = function of CS.

The efficiency of ME utilization for carcass energy gain was assumed to equal the ME sparing effect (mcal ME spared$\cdot$$mcal^{-1}$ tissue lost) of body tissue loss. Although the validity of this assumption is subject to debate, only 2 cows each year lost carcass energy during the winter. Since the trial procedure limited changes in tissue energy, the standard errors associated with any efficiency or sparing estimates are likely to be large.

The efficiency of ME use for carcass energy retention was 1.24 in year 1 and 1.03 in year 2 with large but undeterminable standard errors (table 8). When data from both years were pooled, the inverse of the efficiency of ME use for carcass energy retention was .9181. Application of the standard error (±.4078) to this estimate indicates that the estimate of the efficiency of ME utilization for carcass energy retention per kilogram $LW^{.75}$ would likely be contained in the interval .75 to 1.96 ($P>.68$). Thompson et al. (1983) reported a partial efficiency of ME use for empty body energy gain of 78.8% and a ME sparing estimate of .70 mcal ME·$mcal^{-1}$ tissue energy for Angus-Hereford cows.

The energy content of LW gain was 46.6 mcal per kilogram in year 1 and 9.7 mcal per kilogram in year 2. The energy content of empty body weight gain in thin beef cows is approximately 6.5 mcal per kilogram (NRC, 1984). The large estimate obtained in year 1 (46.6 mcal) may reflect differences in fill.

In year 1, daily maintenance energy requirement (zero energy retention) was best fit by the equation: ME (mcal) = (.0308 + .0474 CS - .0046 CS^2)$LW^{.75}$ (table 8). Daily carcass energy change and the quadratic function of CS accounted for 29% of the variation in ME intake per kilogram $LW^{.75}$. In year 2, 34% of the variation in ME intake per kilogram $LW^{.75}$ was explained by daily carcass energy change and the quadratic function of CS (table 8). Daily maintenance energy requirement was estimated by the expression: ME (mcal) = (.1324 + .0151 CS - .0017 CS^2) ·$LW^{.75}$.

Figure 3 shows the relationship between Mcal ME·$(W^{.75})^{-1}$ required for maintenance and CS for years 1 and 2. Energy required for maintenance averaged 12% higher in year 2 than year 1. The winter of 1983-84 was more severe than the winter of 1982-83. Average daily temperature ranged from -1.4 to 10.7C in year 1 and from -11.8 to 11.2C in year 2. When data from both years were combined, the regression, ME intake per kilogram $LW^{.75}$ = $\beta_0 + \beta_1(CS) + \beta_2(CS)^2$, was nonsignificant ($P<.18$) and only accounted for 11% of the observed variation in maintenance. When year was included as a class variable, the expression, .1028 + .0234 (CS) - .0025$(CS)^2$ accounted for 41% of the variation in maintenance per kilogram $LW^{.75}$ (table 8).

Diet NEg content was .95 mcal per kilogram diet dry matter (NRC, 1984). Energy required for maintenance was also estimated by adjusting daily energy intake based on average daily live weight change, energy density of the diet (2.5 $mcal \cdot kg^{-1}$), ration NEg and energy content of gain by cows (6.5 $mcal \cdot kg^{-1}$; NRC, 1984). Daily ME required for maintenance per kilogram $LW^{.75}$ was regressed on the function of CS. The quadratic function of CS accounted for only 5.9% (year 1) and 4.6% (year 2) of the variation in maintenance energy requirements if feed intake was adjusted to maintenance (zero weight change) based on tabular values for NEg and caloric content of gain. Using carcass energy retention and energetic efficiency figures generated by these data to describe energy required for maintenance, dramatically improved the accuracy of our prediction (R^2 = .29 and .34 vs .059 and .046 for years 1 and 2, respectively).

Klosterman et al. (1968) reported that fat Hereford and Charolais cross cows tended to gain weight while thin cows tended to lose weight when fed similar amounts of energy per $kg^{.75}$ body weight. Using weight:height ratio (W/H, $kg \cdot cm^{-1}$) as an index of condition, maintenance (kcal DE) was predicted by the equation, 130 $kg^{.75}$ - (W/H - 4.0)1716. Russel and Wright (1983) reported that maintenance energy requirements for nonpregnant, nonlactating, mature Hereford x Friesian or White Shorthorn x Galloway cows were best determined by the expression, M = (0.147 - 0.016C)LW (R^2 = .771, residual s.d. = .47), where M = megajoules ME per day, LW = kilograms live weight and C = condition score (0 = very thin, 5 = very fat). Thompson et al. (1983) demonstrated that thin (app. 9.6% fat; Which would correspond to a CS of 4 units.) Angus x Hereford cows required more energy for maintenance than fat (app. 16.7% fat; CS = approximately 6 units) cows (132 vs. 124 kcal $ME \cdot (kg^{.75})^{-1}$, respectively).

Hohenboken et al. (1972) found partial regressions of TDN required for maintenance on W/H to be mostly negative but not significantly different from zero in lactating Hereford cows. Neville (1971) found no relationship between W/H and kcal $ME \cdot (kg^{.75})^{-1}$ required for maintenance in lactating Hereford cows.

Taylor and Young (1968) reported that the amount of feed required per unit body weight was not related to composition in Ayrshire cows. Maintenance costs in Angus x Holstein cows were not related to body composition (Thompson et al., 1983). Russel and Wright (1983) found no difference in the effect of condition on maintenance between cattle of partial dairy breeding and those of beef breeding.

The interactions between year and carcass energy change, CS or CS^2 were not significant ($P>.20$). Examination of figure 3 indicates that differences in energy required for maintenance by moderate and fat cows (CS = 4.5-7.0) were consistent between years 1 and 2. However, energy required for maintenance by thin ($CS<4$) cows was more variable and in year 1 appeared substantially less than that required by similar cows in year 2. This discrepancy may be the result of differences in the pre-trial plane of nutrition between years 1 and 2. Thin cows in year 2 achieved their respective degrees of body condition 2 mo prior to initiation of the trial and had more time to adjust their metabolism to realimentation than cows in year 1.

Farrell et al. (1972b) demonstrated that the fasting heat production (kcal per kilogram live weight) of sheep normally kept at pasture decreased from 31 kcal$\cdot$kg^{-1} to 24 kcal$\cdot$kg^{-1} during a period of 4 mo when their live weight was declining due to low availability of pasture. Koong et al. (1982), as cited by Johnson (1984), showed that sheep switched from a high to a low plane of nutrition had 30% lower rates of fasting heat production than sheep switched from a low to a high plane of nutrition. Turner and Taylor (1983) suggested that the length of time required to stabilize metabolism after a change in diet was 28 d. Wainman et al. (1972) reported that 98% of the maximum change in heat production associated with change in diet occurs in 6.3 to 8.9 d in sheep, while Schydner et al. (1982), as cited by Armstrong and Blaxter (1984), estimated the response in 300 kg cattle to be complete in 5 d.

The variation between cows in ME required for maintenance appeared greater for thin cows than for fat cows (figure 3). This difference may indicate that the physiological effects of body fat on maintenance requirements may vary with differing degrees of body fatness. Less variation in maintenance requirements by moderate to fat cows may indicate a relatively consistent insulatory effect of fat tissue. Greater variation in maintenance requirements by thin cows may reflect variation in the ability of individual cows to adapt to environmental stress. Physiological adaptation by thin cows may be a more variable response than the physical effect of fat tissue acting as an insulator.

Equating the first derivative of the maintenance function of CS, .0234 - .005 CS, to zero and solving for CS indicates that maximum mcal ME$\cdot$(LW$^{.75}$)$^{-1}$ occurs at CS = 4.68. Cows in thin condition (CS = 3) required 95.6% of the maximum mcal ME$\cdot$(LW$^{.75}$)$^{-1}$ while cows in fat condition (CS = 7) required 91.1% of the maximum mcal

$ME \cdot (W^{.75})^{-1}$ (table 9).

Lower maintenance requirements by cows in thin (CS = 3 units) condition compared to cows in moderate (CS = 5 units) condition may reflect the pre-trial plane of nutrition as previously discussed. Perhaps if the cows attained their respective degrees of body condition 6 mo prior to initiating the trial, as compared to 1 mo in year 1 and 2 mo in year 2, maintenance energy requirements per kilogram $LW^{.75}$ would be similar for thin and moderate cows. Lower maintenance requirements by cows in fat (CS = 7 units) condition compared to cows in moderate condition may reflect an insulatory effect of subcutaneous fat (Curtis, 1983) or differences in tissue turnover rate as a reflection of the proportion of fat and protein in the body. Cows in CS = 5 and 7 units have approximately .25 and 1.02 cm fat over the loin eye muscle at the 12th rib, respectively (Wagner, unpublished data). Webster (1980) proposed that heat production was related more closely to protein synthesis and turnover than to body weight. In addition, fat cows required 9.6% more feed to maintain LW throughout the winter than moderate cows. Because of their greater feed intake, fat cows may have benefitted from increased heat production due to digestive and fermentative processes. Higher heat increment in fat cows may have reduced the need to generate additional heat to maintain temperature of the body core.

Initial carcass protein (27.2 kg) and fat (23.6 kg) of cows fed in year 1 was predicted by multiplying carcass protein per kilogram LW (PCLW) and carcass fat per kilogram LW (FCLW) by LW, respectively (table 3). The equations used to predict initial carcass protein (28.0 kg) and fat (23.8 kg) of cows fed in year 2 are shown in table 5.

Two models were used to estimate the efficiency of changes in carcass protein and fat (table 10). Model I regresses daily ME intake on $LW^{.75}$ and changes in carcass protein and fat. Model II adjusts the coefficient applied to $LW^{.75}$ using the quadratic function of CS to improve the estimate of maintenance. Efficiency coefficients (table 10) reported for years 1 and 2 indicate a difference due to year may occur in the efficiency of carcass protein change. The influence of year on daily ME intake was assumed to result from environmental effects on maintenance requirements. Consequently, year effects were included in models Iy and IIy by calculating separate maintenance coefficients for years 1 and 2.

The inclusion of the quadratic function of condition score to estimate the maintenance coefficient (Model II), consistently increased R^2 and reduced the standard error of the regression for all data sets examined. Estimates for the conversion of dietary ME to carcass fat were in most cases significantly different than zero and ranged from 7.5 to 13.6 $mcal \cdot kg^{-1}$. Model IIy estimated that 9.11 (±3.63) mcal ME were required to deposit 1 kg carcass fat. Estimates for the conversion of dietary ME to carcass protein were not different than zero and highly variable ranging from -17.12 to 10.42 $mcal \cdot kg^{-1}$. Swingle et al. (1979) demonstrated that the boneless carcass gain in cull range cows was comprised of 51% fat, 14% protein and 35% moisture. This corresponds to a gain in carcass energy of approximately 5.6 $mcal \cdot kg^{-1}$. The requirement for body weight gain by thin, non-lactating beef cows is approximately 6.5 $mcal \cdot kg^{-1}$ (NRC, 1984).

Relative maintenance energy requirements for protein and fat tissues are shown in table 11. Estimated maintenance costs per kilogram of tissue for fat are near zero. A negative energy requirement for fat (-.084 $mcal \cdot kg^{-1}$) would suggest that fat cows of the same lean body mass may have lower winter maintenance requirements. When only FAT and carcass energy change were used in a model to predict ME intake, the standard error of the regression was three fold higher than for the model using carcass energy change and PRO and four fold higher than for the model using carcass energy change and LW. Pullar and Webster (1977) demonstrated that the maintenance requirement of both fatty and lean rats is more closely associated with body protein content. Thompson et al. (1983) proposed that the maintenance requirement for fat tissue in Hereford-Angus cows was -1.55 kcal ME per kilogram empty body fat. The maintenance requirement of fat tissue in Angus-Holstein cows was +51.11 kcal ME per kilogram empty body fat. Beef cattle deposit a greater proportion of fat in subcutaneous depots than Holstein cattle (Charles and Johnson, 1976). Negative maintenance requirements for fat tissue in beef cows, may indicate that fat insulates the body from cold reducing the energy needed to maintain body temperature.

The effects of environment on daily metabolizable energy required for maintenance were evaluated by fitting the model, ME intake = $k^{-1} \cdot$LW change each week + [f(CS) + f(ENV)] $LW^{.75}$, where k = the efficiency of LW change, f(CS) = the maintenance function of CS and f(ENV) = the function of average daily temperature and precipitation for each week. The interactions between environment and CS were also examined. The full model accounted for 41.2% of the variation in ME intake per kilogram $LW^{.75}$. Rainfall, snow, CS x rain and CS x snow were not significant (P>.10) sources of variation in ME intake per kilogram $LW^{.75}$ and were removed from the model. The reduced model (table 12) explained 39.7% of the variation in maintenance. The inverse of the efficiency of LW change per kilogram $LW^{.75}$ was .313 (±.058). The influence of temperature and the interaction between temperature and CS were highly significant ($P<.0001$) indicating that the effect of temperature on ME required for maintenance was dependent on CS. The interaction between average daily temperature for the week and CS is illustrated in figure 4. For each °C decrease in average temperature, ME required per kilogram $LW^{.75}$ for maintenance was increased .0055, .0039 and .0025 mcal for cows with CS 3, 5 and 7 units, respectively. These data indicate that the effect of temperature on ME required for maintenance may be more significant in thin cows than in moderate or fat cows.

Regression coefficients for CS (.0295±.0082) and CS^2 (-.0034± .0008) appeared similar to the regression coefficients reported earlier for CS (.0234±.0116) and CS^2 (.0025±.0011) when year was included in the model as a class variable (table 8). This indicates that most of the variation associated with year could be attributed to differences in environmental temperature.

Exp 2

The effects of cow condition on winter (November 15, 1983 to May 25,1984) weight and condition change were analyzed by regressing winter weight (table 13) and condition (table 14) change on cow breed, December cow weight and CS, calving date, calf birth weight and calf sex. Cow breed, December weight, calf sex and calf birth weight did not significantly influence winter weight loss (42.4 kg) by spring calving cows. Cows calving early in the season lost more weight (P<.015) than cows calving late in the season (.58 kg per day). Cows which were fat when entering the winter tended to lose more weight (P<.10) during the winter than cows entering the winter thin (10.99 kg per unit CS). Winter CS losses by spring calving cows (.94 units) were not influenced by cow breed or calving date. Cows nursing bull or steer calves tended to lose .394 or .312 units more condition (P<.10) than cows nursing heifer calves. Cows that gave birth to heavier calves tended to lose more condition (P<.10) than those giving birth to lighter calves (.033 units CS per kilogram birth weight). Cows with more condition in December lost significantly more condition (P<.001) than thinner conditioned cows (1.062 units per unit CS).

Discussion

Data reported in this study suggest that cows in fatter body condition (CS = 7 units) have a lower ME requirement per kilogram body weight than cows with a moderate degree of fat (CS = 5 units). Johnson (1984) suggested that 91% of the energy intake by mature cows is partitioned to maintenance. Consequently, even a small savings in maintenance could significantly improve net returns per cow. Thompson et al. (1983) concluded that a cow must be maintained in fat condition over a period of 10 years in order for the savings in maintenance to be realized.

Wagner et al. (1985) demonstrated that a moderate cow (CS = 5 units) would weigh approximately 381 kg, while a fat cow at (CS = 7 units) would weigh approximately 486 kg. Data from the present study indicate that the 381 kg, CS 5 cow would require 13.6 mcal ME per day.

The same cow at 486 kg and CS 7 units would require 14.9 mcal ME per day for maintenance. Hence, no energy savings of maintaining a cow in fat condition would be realized. But a cow with a higher fat content (CS = 7) than one with lower fat (CS = 5) both having the same weight, the fatter cow would require 8.3% less energy for maintenance.

Weight and body condition of spring calving cows can be efficiently increased prior to winter (Wagner et al., 1984). Cows grazing native tallgrass range during late lactation in August through October required 2.4 kg supplement per kilogram LW gain. Differences in forage intake were not apparent. Moe et al. (1971) proposed that the efficiency of body weight gain in dairy cows was greater during lactation than during the dry period.

Data from experiment 2 demonstrate that winter weight loss in spring calving cows is related to CS. Cows with more fat lost more weight and body condition than thinner cows. Rakestraw (1984) observed similar results for fall calving cows. Perhaps under conditions where higher quality pasture or harvested forages are utilized to winter cows, fat condition can be maintained. It appears that under range conditions, however, cows with greater CS tend to lose more weight and condition than thinner cows. Whether this is a response to forage intake or nutrient utilization is unknown. Wagner et al. (1984) was unable to detect a difference in winter forage intake by spring calving cows due to body condition.

Cows in thin condition (CS = 3) required 4.4% less ME per kilogram metabolic weight than moderate cows (CS = 5). As previously discussed, part of this response may be due to the effects of previous plane of nutrition on maintenance. In addition, Wagner et al. (1985) showed that cows of CS 3 would weigh approximately 333 kg. Data from the present study indicate that a 333 kg, CS 3 cow would require 11.7 mcal ME for maintenance. A 14.0% savings in feed costs, primarily due to lower LW, could be realized by maintaining cows in thin condition than at CS 5.

The relationship between reproduction and cow weight and condition is well established (Dunn and Kaltenbach, 1980). At present, it is not feasible to keep cows in thin condition and maintain satisfactory reproductive performance. If factors initiating estrus and maintaining pregnancy could be identified and managed in a manner promoting satisfactory reproduction under adverse conditions, maintaining cows in thin condition may become a viable option for cattlemen.

The results obtained from the current study are most useful as a tool to help budget feed requirements more precisely. Data from this study demonstrate that maintenance requirements per unit metabolic weight are not static and vary with body condition and environmental conditions. Metabolizable energy per kilogram $LW^{.75}$ required for maintenance was best described by the expression, $.1028 + .0234\ CS - .0025\ CS^2$.

TABLE 1. COMPOSITION OF DIET FED TO COWS

Ingredient	Int. feed no.	Percentage[a]
Rolled corn	4-02-931	39.5
Alfalfa pellets	1-00-023	36.0
Cottonseed hulls	1-01-599	21.7
Cane molasses	4-04-696	2.5
Salt		.3
Dry matter, %		90.2
Crude protein		12.0
Metabolizable energy[b]		2.50

[a]Dry matter basis.
[b]$Mcal \cdot kg^{-1}$ dry matter.

TABLE 2. INITIAL SLAUGHTER DATA USED TO DERIVE EQUATIONS ESTIMATING INITIAL COMPOSITION OF COWS FED IN YEAR ONE

Item	Mean	Standard deviation
Live weight, kg	358.8	43.33
Condition score, units	5.0	1.77
Carcass fat, kg	25.9	38.28
Carcass protein, kg	27.4	5.14
Total carcass energy, mcal	396.8	225.65

TABLE 3. EQUATIONS USED TO ESTIMATE INITIAL ENERGY, PROTEIN AND FAT CONTENT OF COWS FED DURING YEAR ONE

Equation	Sy·x	R^2
$ECLW^a = -1.712 + 1.664\ CS^d - .379\ CS^2 + .029^3$	.122	$.95^{***}$
$PCLW^b = 9.308 + .587\ CS - .013\ LW^e$	.702	$.62^{*}$
$FCLW^c = -18.784 + 16.030\ CS - 3.780\ CS^2 + .300\ CS^3$	1.441	$.92^{***}$

[a] Total mcal carcass energy per kilogram live weight.
[b] Total kilograms carcass protein per kilogram live weight.
[c] Total kilograms carcass fat per kilogram live weight.
[d] Condition score, units.
[e] Live weight, kilograms.
[*] $P \leq .05$.
[***] $P < .001$.

TABLE 4. INITIAL SLAUGHTER DATA USED TO DERIVE EQUATIONS ESTIMATING INITIAL COMPOSITION OF COWS FED IN YEAR TWO

Item	Mean	Standard deviation
Live weight, kg	408.6	81.48
Condition score, units	4.9	1.72
Carcass fat, kg	25.4	21.76
Carcass protein, kg	29.2	8.70
Total carcass energy, mcal	402.3	249.92

TABLE 5. EQUATIONS USED TO ESTIMATE INITIAL ENERGY, PROTEIN AND FAT CONTENT OF COWS FED DURING YEAR TWO

Equation	Sy•x	R^2
$ECLW^a = .333 - .028\ CS^d + .027\ CS^2$	.130	.92***
$PCLW^b = 6.933 - 2.315\ CS + .867\ CS^2 - .075\ CS^3$	.478	.86***
$FCLW^c = 2.964 - 1.639\ CS + .396\ CS^2$	1.246	.92***

[a] Total mcal carcass energy per kilogram live weight.
[b] Total kilograms carcass protein per kilogram live weight.
[c] Total kilograms carcass fat per kilogram live weight.
[d] Condition score, units.
*** $P < .001$.

TABLE 6. DATA USED TO ESTIMATE MAINTENANCE REQUIREMENTS OF COWS FED DURING YEAR ONE

Item	Mean	Standard deviation
Live weight, kg		
Initial	395.9	62.92
Final	397.6	65.29
Condition score, units		
Initial	5.0	1.33
Final	5.2	1.18
Carcass energy, mcal		
Initial[a]	378.7	177.1
Final	458.0	174.7
Carcass fat, kg		
Initial[a]	23.6	15.68
Final	29.1	15.91
Carcass protein, kg		
Initial[a]	27.2	3.75
Final	32.9	5.36
Daily energy intake, mcal	13.4	1.64

[a] Estimated using equations developed from initial kill data.

TABLE 7. DATA USED TO ESTIMATE MAINTENANCE REQUIREMENTS OF COWS FED DURING YEAR TWO

Item	Mean	Standard deviation
Live weight, kg		
Initial	390.0	72.50
Final	394.4	72.34
Condition score, units		
Initial	5.0	1.59
Final	5.1	1.47
Carcass energy, mcal		
Initial[a]	381.2	207.5
Final	423.8	198.0
Carcass fat, kg		
Initial[a]	23.8	18.01
Final	26.8	17.71
Carcass protein, kg		
Initial[a]	28.0	7.94
Final	30.6	6.05
Daily energy intake, mcal	14.5	1.77

[a]Estimated using equations developed from initial kill data.

TABLE 8. REGRESSION OF METABOLIZABLE ENERGY INTAKE ON ENERGY RETAINED AND CONDITION SCORE

Year	Equation[e]	Sy·x	R^2
1	ME intake[a] = .0308(±.0664)+.8056(±.5945)ECH[b] +.0474(±.0262)CS[c]−.0046(±.0024)CS^2	.0153	.29*
2	ME intake = .1324(±.0264)+.9728(±.5858)ECH +.0151(±.0114)CS−.0017(±.0012)CS^2	.0093	.34**
Both[d]	ME intake = .1028(±.0286)+.9181(±.4078)ECH +.0234(±.0116)CS−.0025(±.0011)CS^2	.0115	.41***

[a]Daily metabolizable energy intake, mcal per kg live weight $^{.75}$.
[b]Daily tissue energy change, mcal per kg live weight $^{.75}$.
[c]Condition score, units.
[d]Model includes year as a class variable.
[e]Regression coefficients ± standard error.
*P<.10.
**P<.05.
***P<.0001.

TABLE 9. METABOLIZABLE ENERGY REQUIRED FOR MAINTENANCE BY COWS OF VARIOUS CONDITION SCORES

Condition score	Maintenance[a]	% of maximum[b]
3	.151	95.6
4	.156	98.7
5	.157	99.4
6	.153	96.8
7	.144	91.1

[a]Daily metabolizable energy required, mcal per kg live weight$^{.75}$.

[b]Maximum = .158 mcal metabolizable energy per kg live weight$^{.75}$ at condition score 4.7.

TABLE 10. REGRESSION OF METABOLIZABLE ENERGY INTAKE ON MAINTENANCE AND CHANGES IN CARCASS PROTEIN AND FAT

Year	Model[a]	b_1[b]	b_2[c]	R^2	$Sy \cdot x$[d]
Both	I	-13.56(±5.934)	9.31(±4.235)	.992	1.278
	II	-17.12(±6.091)	7.56(±4.093)	.994	1.186
Both	Iy	-3.19(±5.957)	12.28(±3.827)	.994	1.129
	IIy	-3.63(±6.584)	9.11(±3.631)	.996	1.031
One	I	-15.68(±9.541)	13.64(±5.271)	.992	1.309
	II	-9.76(±9.818)	10.91(±5.248)	.993	1.246
Two	I	10.42(±6.347)	10.98(±5.233)	.997	.826
	II	7.28(±9.051)	7.50(±5.364)	.998	.786

[a] Model I: $\text{Mcal} = a(\text{LW})^{.75} + \beta_1(\text{protein change}) + \beta_2(\text{fat change})$. Model II: $\text{Mcal} = (a + \beta'_1\text{CS} + \beta'_2\text{CS}^2)\text{LW}^{.75} + \beta_1(\text{protein change}) + \beta_2(\text{fat change})$. Model Iy: same as model I except year effects were included in the maintenance coefficient. Model IIy: same as model II except year effects were included in the maintenance coefficient. LW = live weight and CS=condition score.

[b] Protein change, $\text{kg} \cdot \text{d}^{-1}$. Regression coefficient ± standard error.

[c] Fat change, $\text{kg} \cdot \text{d}^{-1}$. Regression coefficient ± standard error.

[d] Standard error of the regression.

TABLE 11. REGRESSION OF METABOLIZABLE ENERGY INTAKE ON LIVE WEIGHT, CARCASS FAT, CARCASS PROTEIN AND CHANGES IN CARCASS ENERGY

Model[a]	R^2	Sy·x[b]
ME[c] = .155(±.0034)W$^{.75}$[d] +.577(±.4319)DECH[e]	.991	1.357
ME = .441(±.0136)PRO[f]+1.266(±.5862)DECH	.983	1.881
ME = .304(±.0325)FAT[g]+7.368(±1.4209)DECH	.856	5.420
ME = .531(±.0247)PRO-.084(±.0205)FAT +.629(±.5272)DECH	.988	1.616

[a]Year was included in the model as an additive effect. Cows in year 2 consumed approximately 14% more metabolizable energy than cows in year 1.
[b]Standard error of the regression.
[c]Daily metabolizable energy intake, mcal
[d]Live weight, kilograms.
[e]Daily carcass energy change, mcal.
[f]Carcass protein, kilograms.
[g]Carcass fat, kilograms.

TABLE 12. REGRESSION OF DAILY METABOLIZABLE ENERGY INTAKE PER KILOGRAM LIVE WEIGHT$^{.75}$ ON LIVE WEIGHT CHANGE PER KILOGRAM LIVE WEIGHT$^{.75}$ AND THE MAINTENANCE FUNCTION OF CONDITION SCORE AND ON THE FUNCTION OF ENVIRONMENT

Variable	Regression Coefficient	P[a]	Standard Error
Intercept	.1151	.0001	.0199
Weight change[b]	.3127	.0001	.0581
Condition score, units	.0295	.0004	.0082
Condition score^2	-.0034	.0001	.0008
Temperature, °C	-.0076	.0001	.0008
CS x temperature[c]	.0007	.0001	.0002

[a]Probability of a greater T for the hypothesis, H_o: parameter = 0.
[b]Kilograms$\cdot$(live weight$^{.75}$)$^{-1}$.
[c]Condition score x temperature interaction, units$\cdot$°C.

TABLE 13. REGRESSIONS OF WINTER (NOVEMBER 15, 1983 TO MAY 25, 1984) WEIGHT CHANGE ON COW BREED, DECEMBER COW WEIGHT, DECEMBER CONDITION, CALVING DATE, CALF BIRTH WEIGHT AND CALF SEX

Variable		Regression Coefficient	P[a]	Standard Error
Intercept		13.48	.765	44.544
Breed[b]	1	1.71	.873	10.684
	2	0.00		
Sex[c]	1	-8.37	.373	9.317
	2	-9.85	.407	11.781
	3	0.00		
December weight, kg		-0.05	.617	.104
December CS[d], units		-10.99	.099	6.553
Calving date, days		0.58	.015	.232
Calf birth weight, kg		-0.43	.638	.917

[a]Probability of a greater T for the hypothesis, H_o: parameter = 0.
[b]1 = Angus, 2 = Hereford.
[c]1 = bull calf, 2 = heifer calf, 3 = steer calf.
[d]Condition score.

TABLE 14. REGRESSIONS OF WINTER (NOVEMBER 15, 1983 TO MAY 25, 1984) CONDITION CHANGE ON COW BREED, DECEMBER COW WEIGHT, DECEMBER CONDITION, CALVING DATE, CALF BIRTH WEIGHT AND CALF SEX

Variable		Regression Coefficient	P[a]	Standard Error
Intercept		3.710	.001	.847
Breed[b]	1	0.075	.714	.203
	2	0.000		
Sex[c]	1	-0.394	.030	.177
	2	-0.312	.169	.224
	3	0.000		
December weight, kg		0.007	.001	.002
December CS[d], units		-1.062	.001	.125
Calving date, days		0.001	.880	.004
Calf birth weight, kg		-0.033	.065	.017

[a]Probability of a greater T for the hypothesis, H_o: parameter = 0.
[b]1 = Angus, 2 = Hereford.
[c]1 = bull calf, 2 = heifer calf, 3 = steer calf.
[d]Condition score.

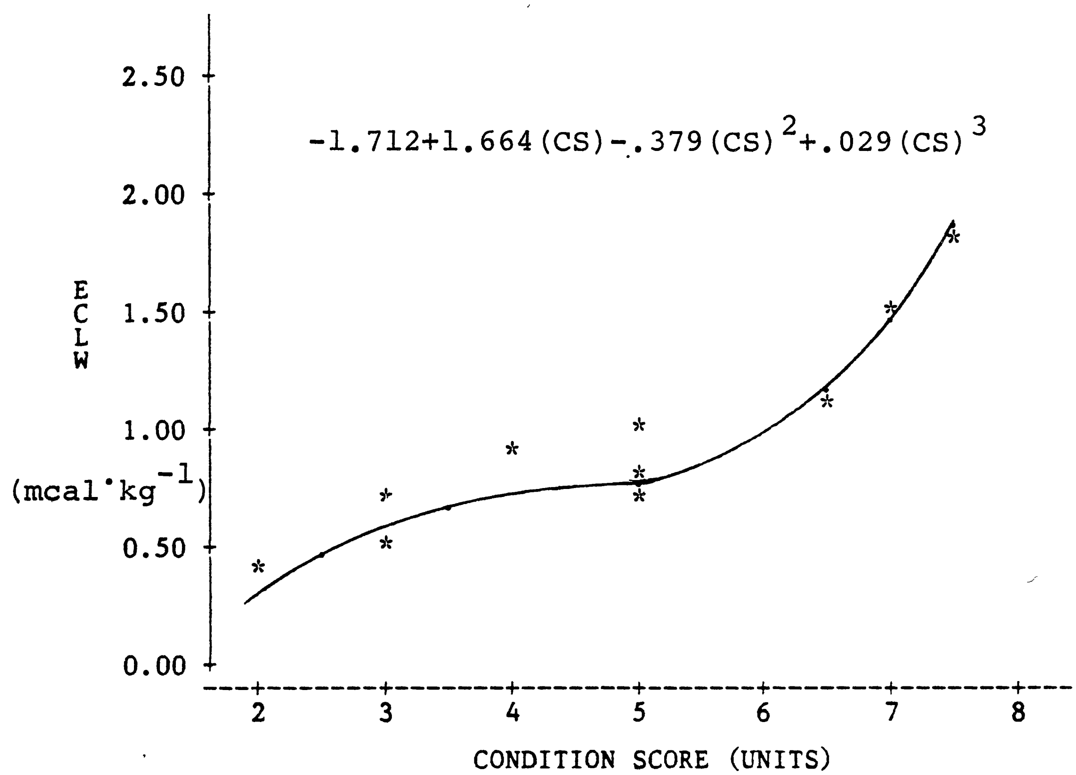

Figure 1. Relationship Between Carcass Energy per Kilogram Body Weight (ECLW) and Condition Score of Cows from Year One Initial Slaughter Group

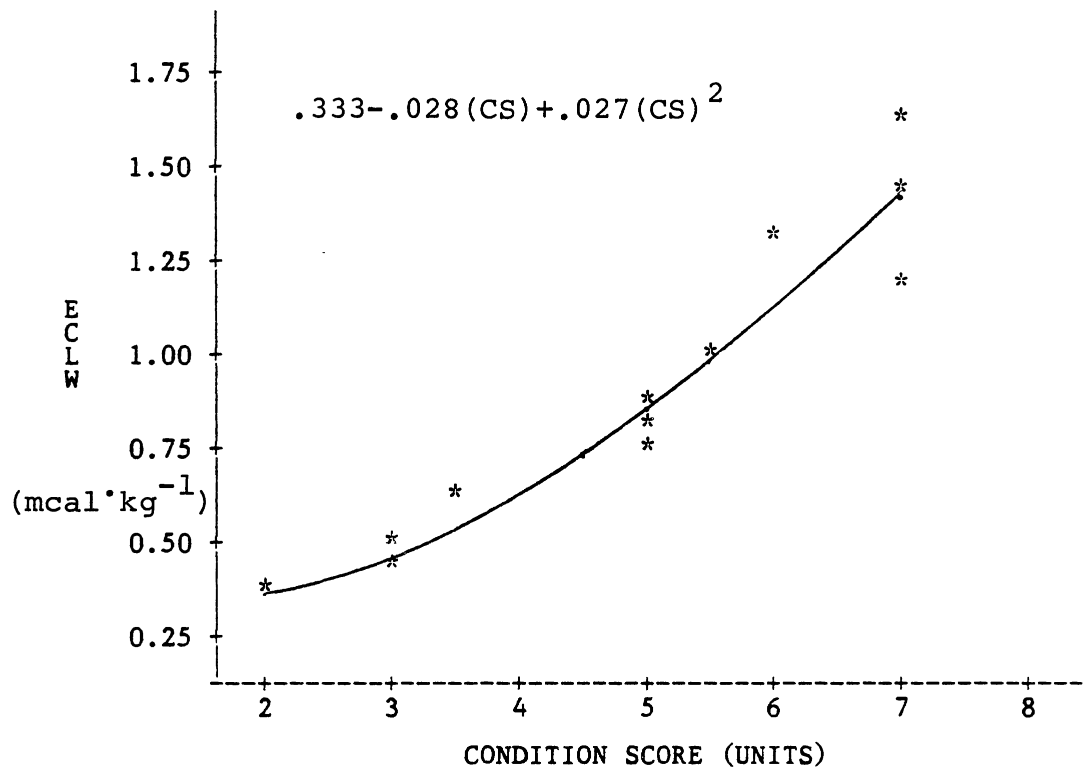

Figure 2. Relationship Between Carcass Energy per Kilogram Body Weight (ECLW) and Condition Score of Cows from Year Two Initial Slaughter Group

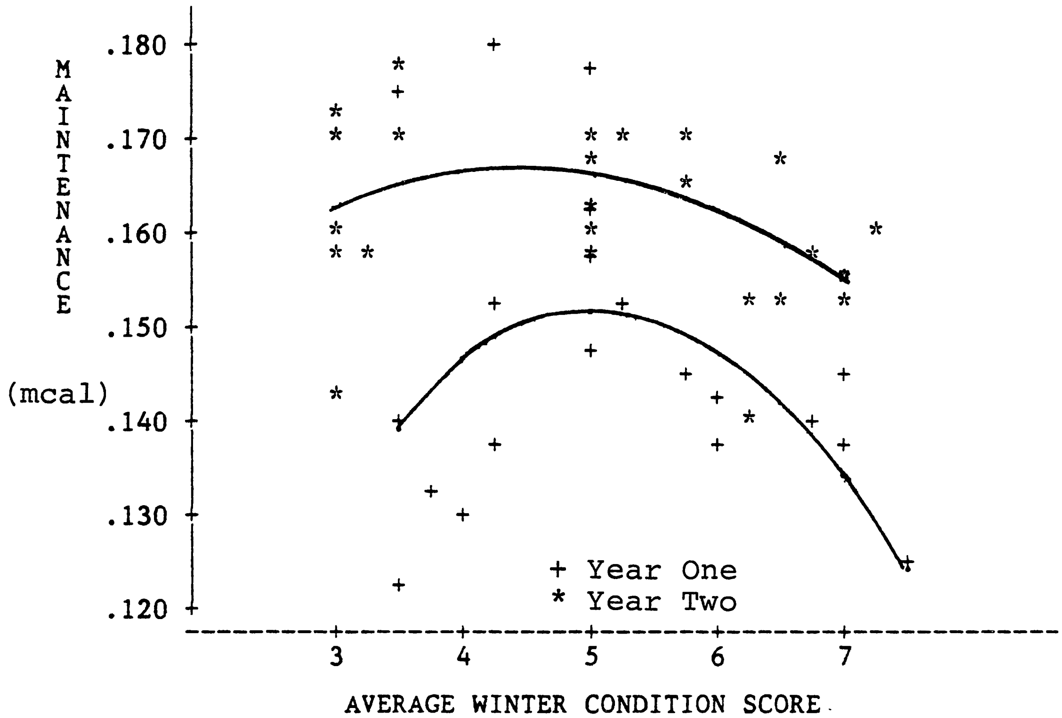

Figure 3. Relationship Between Metabolizable Energy Required for Maintenance per Kilogram Body Weight$^{.75}$ and Average Condition Score During Winter

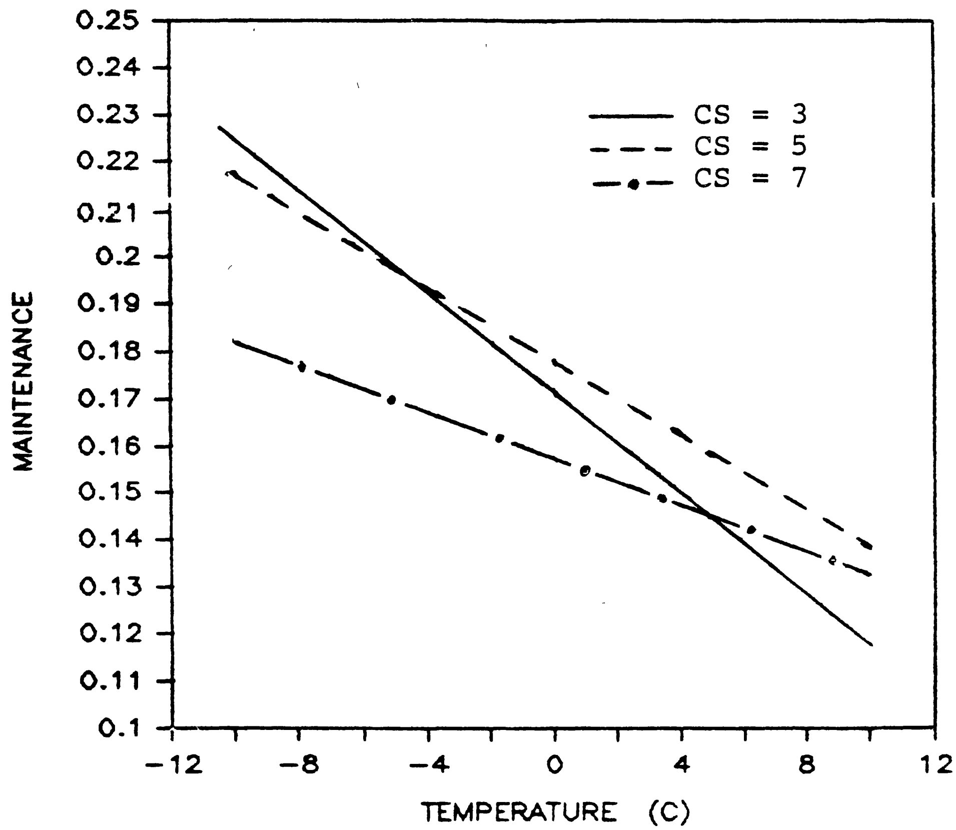

Figure 4. Relationship Between Metabolizable Energy (mcal) Required for Maintenance per Kilogram Body Weight$^{.75}$ and Average Weekly Temperature for Cows of Condition Score 3, 5 and 7 Units

CHAPTER V

SUMMARY AND CONCLUSIONS

Body condition score (CS), live weight (LW), weight:height ratio (WTHT) and urea water space (US) were evaluated and compared as estimators of carcass composition in beef cows. Seventy-one nonpregnant, nonlactating, mature Hereford cows ranging in LW, CS and WTHT from 275 to 595 kg, 2.0 to 8.0 units and 2.29 to 4.62 $kg \cdot cm^{-1}$ respectively, were slaughtered as part of a regression study investigating the effects of carcass composition on metabolizable energy requirements for maintenance during winter.

Live weight, CS or WTHT predicted total carcass energy (TMCAL, mcal; r^2 = .81 vs .85 or .83), carcass fat (FAT, kg; r^2 = .78 vs .82 or .80), carcass protein (PRO, kg; r^2 = .71 vs .74 or .70) and carcass water (WAT, kg; r^2 = .78 vs .71 or .77) with similar accuracy, respectively. When composition was expressed on a per unit weight basis, CS was superior to LW or WTHT as predictors of $TMCAL \cdot kg^{-1}$ hot carcass weight, $TMCAL \cdot kg^{-1}$ LW and $FAT \cdot kg^{-1}$ hot carcass weight$\cdot$100% (r^2 = .82 vs .60 and .64, .83 vs .58 and .62, and .82 vs .64 and .68, respectively).

Correlation coefficients between predictor variables and $WAT \cdot kg^{-1}$ hot carcass weight (WATPR) or $PRO \cdot kg^{-1}$ hot carcass weight (PROPR) were low and equations developed to predict WATPR or PROPR were of limited value. Urea water space was weakly correlated

($r < .40$) with carcass composition and prediction equations developed to estimate composition from US were of limited value.

Thirty-five cows in 1982 and 36 cows in 1983 were randomly assigned to one of three feeding regimes to either lose, maintain or gain weight and condition. By November in year 1 and October in year 2, LW ranged from 275 to 595 kg and CS ranged from 2 to 8 units. In December of each year, 12 cows representing the entire range of CS were slaughtered. Regression equations were developed from the initial slaughter groups to predict the initial composition of the remaining cows. Remaining cows were individually fed a complete diet (2.50 mcal ME per kilogram dry matter) in drylot for 115 days. Daily feed intakes were adjusted each week to maintain LW throughout the winter. In March, all cows were slaughtered and final composition was determined.

Data were analyzed by fitting the model, ME intake = k^{-1}(carcass energy change) + $f(CS)LW^{.75}$, where k = efficiency of ME use for carcass energy change and f(CS) = function of CS. The expression, $.1028 + .0234(CS) - .0025(CS)^2$, accounted for 41% of the variation in ME (mcal) for maintenance per kilogram $LW^{.75}$. The efficiency of ME utilization for carcass energy change per kilogram $LW^{.75}$ was 1.09. Equating the first derivative of the maintenance function of CS, $.0234 - .005 \cdot CS$, to zero and solving for CS indicates that maximum mcal $ME \cdot (LW^{.75})^{-1}$ occurs at CS = 4.68 units. Cows in thin condition (CS = 3) required 95.6% of the maximum mcal $ME \cdot (LW^{.75})^{-1}$ while cows in fat condition required 91.1% of the maximum mcal $ME \cdot (LW^{.75})^{-1}$.

The efficiency of fat accretion was 9.11(±3.63) mcal ME per kilogram carcass fat. The efficiency of protein accretion was not significantly different from zero. Maintenance of carcass protein and fat tissue required .531 and -.084 mcal ME per kilogram, respectively.

Data reported in this study suggest that cows in fatter body condition (CS = 7 units) have a lower ME requirement per kilogram body weight$^{.75}$ than do cows carrying a moderate degree of fat (CS = 5 units). Johnson (1984) suggested that up to 91% of the energy intake by mature cows is partitioned to maintenance. Consequently, even a small savings in maintenance could significantly improve net returns per cow.

Thompson et al. (1983) discussed the potential significance of manipulating body condition to reduce maintenance costs of the cow herd. Wagner et al. (1984) demonstrated that the weight and condition of Spring calving cows could be efficiently increased prior to winter. However, data from experiment two of the current study may be interpreted to suggest that fat cows lose more weight and condition than thin cows during the winter when supplemented alike. In addition, fat cows are heavier than thin cows and may require more feed for maintenance due to their increased weight. Based on prediction equations developed in this study, a moderate Hereford cow (CS = 5 units) would weigh 381 kg and require 13.6 mcal ME per day, while the same cow in fat condition (CS = 7 units) may weigh 486 kg and require 14.9 mcal ME per day for maintenance.

The utility of manipulating body fatness in an attempt to reduce maintenance costs is limited under Oklahoma range conditions. Perhaps fat condition is more readily maintained under management systems utilizing higher energy, harvested forages to winter cows. In northern climates, the insulatory value of subcutaneous fat reserves may be of more significance in determining energy requirements for maintenance. The insulatory benefits of additional fat may overcome the cost of maintaining additional weight.

Cows in thin condition (CS = 3) required 4.4% less ME per kilogram metabolic weight than moderate cows, weighed approximately 333 kg and would require 11.7 mcal ME per day for maintenance. A 14.0% savings in feed costs, primarily due to lower LW, could be realized by maintaining cows in thin condition. The relationship between reproduction and cow weight and condition is well established (Dunn and Kaltenbach, 1980). At present, it is not feasible to keep cows in thin condition and maintain satisfactory reproductive performance. If factors initiating estrus and maintaining pregnancy could be identified and managed in a manner promoting satisfactory reproduction under adverse conditions, maintaining cows in thin condition may become a viable option for cattlemen.

The results obtained from the current study are most useful as a tool to help budget feed requirements more precisely. Maintenance requirements per unit metabolic weight are not static and vary with environmental conditions, plane of nutrition, genotype, physiological status and carcass composition. Body condition scoring appears to be a useful predictor of carcass composition in cows. Although subjective in nature, CS offers sufficient accuracy and repeatability for many research and management situations. Daily metabolizable energy (mcal) required by mature, nonpregnant, nonlactating Hereford cows during winter were best described by the expression, $[.1028 + .0234(CS) - .0025(CS)^2]LW^{.75}$.

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APPENDIXES

APPENDIX A

DERIVATION OF THE MODEL USED TO ANALYZE THE INFLUENCE OF BODY CONDITION ON METABOLIZABLE ENERGY REQUIREMENTS

Derivation of the model used to analyze the influence of body condition on metabolizable energy requirements.

$$NE_m = aBW^{.75}$$

NE_m = Net energy for maintenance.

a = maintenance coefficient.

BW = kilograms body weight.

$$ME_i = \frac{NE_m}{k_m} + \frac{NE_g}{k_g} = \frac{aBW^{.75}}{k_m} + \frac{RE}{k_g}$$

ME_i = metabolizable energy intake.

NE_g = net energy for gain.

k_m = efficiency of metabolizable energy utilization for maintenance.

k_g = efficiency of metabolizable energy utilization for gain.

RE = retained energy.

Hypothesis:

a = function of body condition.

$$ME_i = \frac{(\text{function of CS})\ BW^{.75}}{k_m} + \frac{RE}{k_g}$$

CS = condition score.

$$ME_i/BW^{.75} = \frac{\text{function (CS)}}{k_m} + \frac{RE/BW^{.75}}{k_g}$$

Model used to analyze the influence of environmental conditions on maintenance requirements.

$$ME_i/BW^{.75} = \frac{\text{function (CS + ENV + CS*ENV)}}{k_m} \quad \frac{WC/BW^{.75}}{k_w}$$

ENV = average daily temperature and precipitation for the week.

CS*ENV = interactions between CS and ENV.

k_w = energetic efficiency of live weight change.

WC = weight change each week.

APPENDIX B

CARCASS COMPOSITION AND MAINTENANCE REQUIREMENT DATA

Carcass composition and maintenance requirement data.

COW	cow number
SLG	slaughter group, 1 = initial kill year one, 2 = cows fed during year one, 3 = initial kill year two, 4 = cows fed during year two
INWT	initial weight (kg)
SLGTWT	slaughter weight (kg)
INSC	initial condition score (units)
SLGTSC	slaughter condition score (units)
HPHT	hip height (cm)
WTHT	weight:height ratio (kg/cm)
CWT	hot carcass weight (kg)
BWT	bone weight (kg)
PROWT2	boneless carcass weight (kg)
KGFAT2	fat weight (kg, including KHP)
KGPRO2	protein weight (kg)
WATWT	water weight (kg) x 100
ASHWT	ash weight (kg)
LIVERM	liver weight (kg)
FATPER	percentage ether extract (wet basis)
PROPER	percentage crude protein (wet basis)
DMPR	percentage dry matter (wet basis)
ASH	percentage ash (wet basis)
MI	urea infused (mg)

U0	plasma urea concentration (mg urea-N/dl) time 0
U6	plasma urea concentration (mg urea-N/dl) time 6 min
U12	plasma urea concentration (mg urea-N/dl) time 12 min
U18	plasma urea concentration (mg urea-N/dl) time 18 min
U24	plasma urea concentration (mg urea-N/dl) time 24 min
TFIDM	total feed intake (kg, dry basis)
DAYS	days on feed

OBS	COW	SLG	INWT	SLGTWT	INSC	SLGTSC	HPHT	WTHT
1	68	3	361	361	3.5	3.5	117 6	3.06973
2	76	3	404	404	5.0	5.0	124.0	3.25806
3	78	1	473	473	7.0	7.0	124.5	3.79920
4	82	3	285	285	3.0	3.0	116 8	2.44007
5	84	3	314	314	2.0	2.0	124.5	2.52209
6	94	3	464	464	6.0	6.0	121.4	3.82208
7	123	1	336	386	2.0	2.0	121.9	3 16653
8	141	3	386	386	5.0	5.0	120.1	3.21399
9	155	3	513	513	7.0	7.0	119.4	4.29648
10	180	1	382	382	7.0	7.0	120.0	3.18333
11	315	3	559	559	7.0	7.0	126.5	4.41897
12	427	3	417	417	5.5	5.5	121.9	3.42084
13	433	1	380	380	5.0	5.0	121.3	3.13273
14	504	3	360	360	3.0	3.0	120.1	2.99750
15	661	1	371	371	5.0	5.0	120.7	3 07374
16	709	3	362	362	5.0	5 0	116 8	3.09932
17	811	1	378	378	3.0	3.0	125 7	3.00716
18	848	1	383	383	4.0	4.0	126 4	3.03006
19	943	1	382	382	6.5	6.5	124.5	3.06827
20	960	3	478	478	7.0	7.0	125.2	3.81789
21	4070	1	365	365	5.0	5.0	118.1	3.09060
22	4116	1	489	489	7.5	7.5	122.6	3.98858
23	4119	1	343	343	3.0	3.0	118.1	2.90432
24	4122	1	417	417	5.0	5.0	124.5	3.34940
25	18	2	404	404	4.0	4.0	124.5	3.24498
26	83	2	357	347	6.0	5.5	119.4	2 90620

CWT	BWT	PROWT2	KGFAT2	KGPRO2	WATWT
170	36.6	119 0	10.7300	21.3010	8913.1
206	39 8	153.6	17.9064	29.9520	10705 9
262	42.6	216 6	56.3176	34.6560	12952.7
144	32 2	98.4	4.8392	17.6136	7645 7
150	41.0	97.0	3.7280	15.9080	7760.0
270	39.0	216.2	42.2998	37.8350	13988.1
140	43.4	95.2	4.9032	17.6120	7539.8
194	37.2	144.6	13.9464	27.0402	10498.0
320	41.4	259.0	64.6880	41.4400	15721.3
218	37.8	179.4	44.6122	29 4216	11248.4
314	50.6	242.6	61.8276	39.5438	14798.6
244	39.2	189 0	24.1130	34.0200	13230.0
170	36.2	133 6	16.7944	26.4528	9298.6
168	39.0	116 0	4.6640	20.8800	9129.2
180	33.4	147 0	22.7450	24 9900	10084 2
206	32.4	159 8	15.5624	30.0424	11409 7
174	43.4	131.0	11.5180	27.6410	9471.3
198	43 4	154.0	21.8660	26.4880	10641 4
192	37.0	153.8	22.3402	34.2974	10335.4
266	37.4	190.2	40.5968	34.6164	12153.8
178	36.2	143 2	14.0288	26.2056	10510.9
264	40 4	222.8	74.9628	33 8656	12432.2
154	40.2	111.2	5.3368	21.2392	8784.8
186	46 0	140.0	15.2400	26.0400	9884.0
216	46.0	170.6	14.7950	35.8260	12556 2
194	37.6	157.0	22.8960	30.4580	10723.1

OBS	ASHWT	LIVERM	FATPER	PROPER	DMPR	ASH	MI
1	1.17810	.	7.0	17.9	25.1	0.99	22200
2	1.59744	.	9.9	19.5	30.3	1.04	24900
3	1.86276	.	23.6	16.0	40.2	0.86	29100
4	0.98400	.	3.8	17.9	22 3	1.00	17500
5	0.92150	.	2.4	16.4	20.0	0.95	19300
6	2.01066	.	17.9	17.5	35.3	0.93	28500
7	1.34232	.	4.1	18 5	20 8	1.41	20700
8	1.48938	.	8.4	18.7	27.4	1.03	23800
9	2.40870	.	23.2	16.0	39.3	0.93	.
10	2.58336	.	21.3	16.4	37.3	1.44	27100
11	2.20766	.	22.6	16.3	39.0	0.91	34400
12	1.79550	.	11.7	18.0	30.0	0.95	25700
13	1.41616	.	10.4	19.8	30.4	1.06	23400
14	1.20640	.	2.9	18.0	21.3	1.04	22200
15	1.60230	.	13.5	17 0	31.4	1.09	22900
16	1.64594	.	8.8	18.8	28.6	1.03	28500
17	1.03490	.	7.8	21.1	27.7	0.79	23200
18	1.50920	.	12.9	17.2	30.9	0.98	23600
19	2.38390	.	12.9	22.3	32.8	1.55	23500
20	1.71180	.	18.4	18.2	36.1	0.90	29400
21	2.07640	.	8.4	18.3	26.6	1.45	22500
22	3.38656	.	30.1	15.2	44.2	1.52	30100
23	1.60128	.	3.9	19.1	21.0	1.44	21100
24	2.01600	.	9.1	18.6	29.4	1.44	25700
25	2.11544	2.90381	7.5	21.0	26.4	1.24	24800
26	1.41300	2.92650	12.8	19 4	31.7	0.90	21400

U0	U6	U12	U18	U24	TFIDM	DAYS
9.7	23.0	19 8	21.2	19 5	.	
6.8	20 6	17.2	17.1	14 6	.	.
12.3	29.1	24.5	24.9	25 0	.	.
7.9	20.8	18 7	17.9	18.2	.	.
8.7	24.9	20.9	20.4	18.2	.	.
12.4	28.6	24.5	23.2	24.0	.	.
7.7	30.7	25.0	21.0		.	.
10.9	27.6	24.5	25.7	21.0	.	.
.		.	.	.	.	.
9.2	27.2	24.4	23 6	22.1	.	
7.2	24 5	22.3	18.5	17.5	.	
10.9	25.9	23.9	22.1	21.9	.	.
8.1	26.7	25.6	25.4	22.6	.	.
8.4	18 7	16.3	17.4	16.6	.	.
10.4	26.8	24.6	22.7	23.5	.	.
7.8	25 3	21.1	20.6	18.7	.	.
12.4	30 8	26.0	25.7	26.8	.	.
7.0	25.6	20.4	17 7	18.3	.	.
18.1	33 8	33.5	33.2	32.1	.	.
8.3	22 2	17.1	19.6	16.6	.	.
9.2	20 0	17.5	16 1	16.8	.	
10.1	26 7	23.8	22.6	21.6	.	.
12.0	29.3	24.3	23.4	23.7	.	.
10.7	27 4	23.5	21.4	20.1	.	.
6.8	21.1	18.5	16.5	15.8	543.184	114
8.1	24.0	18.8	17.2	16.6	546.973	114

OBS	COW	SLG	INWT	SLGTWT	INSC	SLGTSC	HPHT	WTHT
27	142	2	499	512	7 0	7 0	124 5	4.11245
28	349	2	357	363	3.0	4 0	119.4	3.04020
29	359	2	340	345	5 0	5 0	111 1	3 10531
30	402	2	360	356	4 5	4.0	118 1	3.01439
31	652	2	424	417	6 0	6.0	120 0	3 47500
32	657	2	449	447	7 0	6.5	121 3	3 68508
33	659	2	450	440	6.0	6 0	125 7	3 50040
34	739	2	356	361	3 0	4 0	121 9	2 96144
35	743	2	576	595	7 0	8 0	128.9	4 61598
36	924	2	312	328	3 0	4 0	120 7	2.71748
37	931	2	407	408	6 0	6.0	116 8	3.49315
38	933	2	365	368	4 0	4 5	124 5	2 95582
39	940	2	338	342	4.0	4 5	121 9	2 80558
40	945	2	335	333	3.5	4 0	116 8	2 85103
41	948	2	330	334	4 0	4 0	123 2	2 71104
42	4024	2	431	431	5 0	5.5	123 8	3.48142
43	4027	2	380	376	5 0	5.0	120 7	3 11516
44	4046	2	358	353	4.5	4 0	120 7	2 92461
45	4078	2	472	475	7 0	7.0	118 7	4 00168
46	4126	2	397	386	5.0	5 0	122.5	3.15102
47	4131	2	409	423	5 0	5 0	120 0	3 52500
48	21	4	395	412	6 5	6 0	118 1	3 48857
49	74	4	394	393	5.0	5.0	120.7	3 25601
50	88	4	294	300	3 0	3 0	120.7	2.48550
51	89	4	273	275	3.0	3 0	120 1	2 28976
52	106	4	396	401	7 0	6.0	120 1	3 33888

CWT	BWT	PROWT2	KGFAT2	KGPRO2	WATWT
270	40.8	228.2	50 0990	40.1632	14308 1
172	36 4	136 0	17.2320	26 6560	9343 2
172	32.6	138 8	21 0828	25 5392	9327 4
194	37 4	156.8	17 6936	32 7712	10913 3
228	37.0	190 6	34.0336	37.5482	12655.8
230	38 2	191.2	42.5224	38.2400	12351 5
236	42 8	193 2	42.1740	34 7760	12133 0
192	37.6	153 6	22.0608	28.2624	10321 9
330	50.2	279.4	73.0796	46.6598	16568 4
182	35 4	146.0	18 8280	27.4480	10015 6
218	37.2	180.4	35.5288	32 4720	11563 6
190	38 8	152.0	22.5640	28 5760	10032 0
196	42.4	161.2	20.2544	35 3028	11155 0
172	37.4	134.6	11 4642	25.4394	9664 3
188	39.2	149 0	13.3710	28 6080	10817 4
232	40 8	191.2	30.8680	38 4312	12810 4
196	36.8	158.8	20.7620	31.6012	11052 5
180	38 2	140 8	16.2944	28 1600	9827 8
250	39.4	209.8	62.3186	37.7640	12189 4
212	37.6	174.8	33 2908	32.3380	11204 7
210	40 8	171 2	27.1968	32 5280	11470 4
244	40 6	194 0	43.2020	32.0100	12513 0
226	42 2	173 4	21.4070	32.5992	12190.0
170	37.8	127.4	9.1714	24 0786	9312 9
152	37.8	106.8	3.7836	20 9328	8212 9
254	40.8	200.2	35.6326	34.6346	13353 3

OBS	ASHWT	LIVERM	FATPER	PROPER	DMPR	ASH	MI
27	2.09944	4.24229	19.5	17 6	37 3	0 92	31500
28	1.22400	3.90200	11 2	19 6	31.3	0 90	22400
29	1.37412	2.47278	13.1	18.4	32.8	0 99	21300
30	1.42688	3.38022	10 2	20 9	30 4	0 91	21900
31	1.67728	3.35753	15 6	19.7	33 6	0 88	25700
32	2.16056	3.74319	20.2	20.0	35 4	1 13	27500
33	1.42968	4 15154	19 5	18 0	37 2	0 74	27100
34	1.48992	2.76770	12 8	18 4	32 8	0 97	22200
35	2.15138	4.08348	23.4	16.7	40.7	0 77	36700
36	1.56220	2.56352	11.8	18 8	31 4	1 07	20100
37	1.67772	3.35753	17 2	18 0	35.9	0 93	.
38	1.10960	2.94918	13 2	18 8	34.0	0 73	22700
39	1.53140	3.06261	11 2	21 9	30 8	0 95	21100
40	1 88440	2.90381	7 7	18 9	28 2	1 40	20500
41	2.29460	2 83575	7 9	19.2	27 4	1 54	20600
42	1.83552	4 21960	14.0	20.1	33 0	0 96	26500
43	1 66740	3 60708	11 5	19 9	30 4	1 05	23100
44	1.49248	3.40290	9.3	20 0	30.2	1 06	21700
45	1.82526	3.49365	25.7	18 0	41.9	0 87	29300
46	1.59068	3.85662	17.1	18.5	35.9	0 91	23800
47	1.67776	4.08348	13.9	19.0	33.0	0 98	26000
48	1 78480	3.94737	18 3	16 5	35.5	0.92	25400
49	1.69932	3.56171	10 5	18 8	29 7	0 98	24200
50	1.31222	2.99456	6.1	18 9	26 9	1 03	18500
51	1.10004	3.06261	2 7	19 6	23 1	1 03	16900
52	1.88188	3.90200	16.3	17 3	33.3	0 94	24700

UO	U6	U12	U18	U24	TFIDM	DAYS
11 9	29 8	26 5	26.4	24.8	615 705	107
7 5	21 1	18 8	15.5	16.8	684 979	114
8 2	25 1	20 6	18 7	17 8	592 614	114
7 9	24.0	22.0	20 9	20.0	599.559	114
8 0	22.2	18.8	.	17.3	643 757	114
10 1	24.8	21.5	21.3	21 3	648 267	121
10.1	25.8	22.9	21.7	21 0	716 188	121
7.0	19 8		17.2	.	568 080	114
13 7	27 6		27.5	24 0	670 637	107
10 0	26 2	22.5	21 2	20.3	439 094	107
			.		603 799	114
9 3	25.6	22.7	20 4	20.7	554.550	114
8.5	25 8	20 4		18 3	510 622	107
6.7	21.9	15 3	17 0	16 2	500 249	121
5.3	18 4	15 3	14 1	14.3	504 308	121
8.0	29.2	22.9	19 3	18.3	669 825	107
9 3	23 0	21 8	20 1	19 0	695 081	121
7.3	20.5	19 1	17.8	14 6	679 567	114
9.9	26 8	22 3	21 0	20.6	706 356	114
6 3	24 1	17 3	16 4	15.5	766.249	114
10.0	29.8	21.6	22 8	19.5	614 984	107
10.3	26.3	21.8	21.6	22.8	667 931	115
9.3	23.5	20.0	19.3	18.7	658.911	108
5.9	17.9	15.5	14.5	13.7	553 738	115
5.8	17 1	16.7	14.6	13.7	496 010	115
7.3	21.1	18.4	17.1	17.9	674 425	115

OBS	COW	SLG	INWT	SLGTWT	INSC	SLGTSC	HPHT	WTHT
53	138	4	459	462	6.0	7.0	119 4	3.86935
54	153	4	339	333	3.0	3.0	120.1	2.77269
55	156	4	445	443	7.0	6.5	123.2	3.59578
56	176	4	530	532	7.0	7.5	125.2	4.24920
57	501	4	322	336	3.0	3.5	120.1	2.79767
58	515	4	458	458	5.5	6.0	125 2	3.65815
59	518	4	482	495	7.0	7.0	120.7	4.10108
60	535	4	531	532	7.0	7.0	127.0	4.18898
61	641	4	449	463	5.0	5.0	127.0	3.64567
62	671	4	402	397	5.0	5.0	121.4	3.27018
63	675	4	350	355	3.0	4.0	125.7	2.82418
64	928	4	316	326	3.0	4.0	120 1	2.71440
65	929	4	353	354	5.5	5.0	117.6	3 01020
66	935	4	317	312	3.0	3.0	121.9	2.55947
67	959	4	285	295	3.0	3.0	121.9	2.42002
68	969	4	383	380	6.5	6.0	119 4	3.18258
69	979	4	381	402	5.0	5.0	123.2	3.26299
70	4061	4	430	427	5.5	6 0	116.3	3.67154
71	4077	4	377	383	5.0	5.0	120.1	3.18901

CWT	BWT	PROWT2	KGFAT2	KGPRO2	WATWT
256	42.2	199.0	39.5270	34.2280	12835.5
176	37.8	122.6	7.9944	22.4358	9256.3
274	39.4	220.6	50.5848	36.8402	13787 5
316	42 2	233.0	58.6970	39.1440	14399.4
180	37.8	126 8	10.8832	23.5848	9104 2
252	48.8	191.6	32.6576	35.8292	12703.1
298	40.0	240 0	58.8200	39 1200	14856.0
318	47.2	258 6	56.8028	40.8588	16369.4
270	48 2	205.8	33.2468	36.2208	13788.6
226	39.2	174 0	19.6480	33.4080	12093.0
196	42.6	137.6	8.3800	26.6944	10333.8
190	37.2	141.2	10.7544	26 5456	10392.3
210	36.8	161.6	23.9160	28.7648	10762.6
176	35.6	124.6	10.8220	22.6772	9220.4
168	37.6	107.6	4.5356	20.7668	8156.1
236	35.0	186.2	35.7160	32.0264	11991.3
168	46.2	173 4	18.7134	30.8652	12155 3
230	37.8	169 6	31.0096	31.3760	11142 7
208	41 6	156 2	18.2704	29.3656	11121.4

OBS	ASHWT	LIVERM	FATPER	PROPER	DMPR	ASH	MI
53	1.89050	4.35572	17.3	17.2	35.5	0.95	28500
54	1.36086	3.62976	4.4	18.3	24.5	1.11	20500
55	2.11776	3.99274	20.8	16.7	37.5	0.96	27200
56	2.05040	5.08167	20.9	16.8	38.2	0.88	32700
57	1.30604	3.44828	7.4	18.6	28.2	1.03	20700
58	1.87768	4.85481	13.6	18.7	33.7	0.98	28200
59	1.94400	4.40109	21.3	16.3	38.1	0.81	30500
60	2.22396	5.17241	19.8	15.8	36.7	0.86	32700
61	1.91394	4.53721	14.6	17.6	33.0	0.93	28500
62	1.89660	4.12886	10 2	19.2	30.5	1 09	24400
63	1.52736	3.81125	5.0	19.4	24.9	1.11	21800
64	1.46848	3.22142	6.2	18.8	26.4	1.04	20100
65	1.64832	3.47096	13.5	17.8	33.4	1.02	21800
66	1.28338	3.26679	7.0	18.2	26 0	1.03	19200
67	1.19436	2.94918	3.1	19.3	24.2	1 11	.
68	1.73166	3.53902	18.0	17.2	35.6	0.93	23400
69	1.80336	3.58439	10.1	17.8	29.9	1.04	24700
70	1.66208	3.35753	15.1	18.5	34.3	0.98	.
71	1.51514	3 49365	9.2	18.8	28.8	0 97	23600

U0	U6	U12	U18	U24	TFIDM	DAYS
10.5	26 8	22.3	22.4	20.6	753.892	122
7.2	21.5	18.7	17.1	16.8	590 539	108
11.7	27.5	23.3	21.1	21.4	721.961	115
12.5	29 3	24.2	21.5	23.5	768.955	108
9.7	26 9	19.6	19.4	19.9	628.243	122
9.6	26 6	22.4	20.5	20 5	800.525	115
8.4	25 7	22.3	19.4	20.3	766.159	115
11.3	26.6	22.7	20.9	.	820.549	122
7 9	24 0	21.4	18.8	18.4	779 238	115
9.5	24 2	20.4	20.3	19.0	693.277	122
6.8	20 0	18 6	17 6	17.1	689 579	115
5.9	18 2	15.9	14.4	14.3	597.124	108
6.1	20 2	17.8	16.0	15.5	657.648	115
7.7	19.1	17.3	17.5	16.2	622.109	115
.	.	.	.	.	496.010	122
8.5	20.4	19.6	18.0	18.9	534 886	108
6.3	19 4	16 1	14.8	15.3	711.678	122
.	.	.	.	.	685 520	108
12.3	26 1	23.1	22.6	22.7	681.822	115

APPENDIX C

WEEKLY FEED INTAKE, LIVE WEIGHT

AND ENVIRONMENTAL DATA

Weekly feed intake, live weight and environmental data.

WK01	week 1 = Dec. 16-23, 1982; Dec. 15-22, 1983
COW	cow number
YEAR	0 = year 1982-83, 1 = year 1983-84
WK__I	week 1-15 dry matter intake (kg)
HTC__	week 1-15 average daily high temperature (C)
LTC__	week 1-15 average daily low temperature (C)
RM__	week 1-15 average daily rainfall (cm)
SM__	week 1-15 average daily snow (cm)
KG__	week 0-14 live weight (kg)

OBS	COW	YEAR	WKO1I	WKO2I	WKO3I	WKO4I	WKO5I	WKO6I	WKO7I	WKO8I
1	18	0	5.08167	6.44283	6.4428	5.53539	5.53539	5.89837	5.89837	6.12523
2	21	1	7.25953	7.71325	9.5281	6.80581	7.25953	6.80581	7.25953	6.80581
3	74	1	8.62069	9.07441	10.4356	7.25953	6.35209	5.89837	5.89837	5.44465
4	83	0	5.44465	6.35209	5.4446	5.44465	5.89837	6.35209	5.89837	5.89837
5	88	1	7.71325	8.16697	9.9819	6.80581	5.89837	5.44465	5.44465	4.53721
6	89	1	5.89837	6.80581	9.0744	5.89837	5.89837	5.44465	5.44465	4.53721
7	106	1	7.71325	8.16697	9.9819	6.35209	5.89837	6.80581	6.80581	6.80581
8	138	1	9.52813	9.52813	10.8893	8.16697	7.25953	7.25953	7.71325	7.25953
9	142	0	5.39927	6.80581	5.8984	5.89837	5.89837	6.35209	6.80581	7.25953
10	153	1	7.71325	8.16697	9.9819	6.80581	6.35209	5.44465	5.89837	5.89837
11	156	1	9.07441	9.07441	10.4356	8.16697	7.71325	7.25953	7.25953	6.80581
12	176	1	8.62069	9.07441	10.4356	8.16697	8.16697	8.16697	7 71325	7.25953
13	349	0	6.21597	6.66969	6.6697	7.12341	7.12341	7.57713	8.03085	8.48457
14	359	0	7.25953	7.25953	6.3521	6.80581	6.57895	6.12523	6.35209	6.80581
15	402	0	6.76044	6.76044	6.7604	6.76044	6.30672	6.30672	6.57895	7.48639
16	501	1	5.89837	6.80581	8.6207	5.89837	5.89837	6.35209	6.80581	6.35209
17	515	1	9.52813	9.52813	10.8893	8.16697	7.25953	6.35209	6.35209	6.80581
18	518	1	8.62069	9.07441	10.4356	8.16697	7.25953	6.80581	7.25953	6.80581
19	535	1	9.98185	9.98185	11.3430	8.16697	8.16697	7.71325	7.25953	7.71325
20	641	1	9.98185	9.98185	11.3430	8.62069	8.16697	7.71325	7.71325	7.25953
21	652	0	6.80581	7.25953	7.2595	7.25953	7.03267	7.03267	7.03267	7.48639
22	657	0	5.89837	7.25953	5.8984	5.89837	6.35209	6.80581	6.80581	7.25953
23	659	0	8.21234	8.21234	8.2123	8.21234	7.94011	7.48639	7.48639	7.48639
24	671	1	8.62069	9.07441	10.4356	7.71325	6.80581	6.35209	6.35209	5.89837
25	675	1	8.16697	8.62069	11.3430	8.62069	8.16697	7.71325	7.25953	6.80581
26	739	0	5.12704	6.03448	5 1270	5.12704	6.03448	5.58076	6.48820	6.94192
27	743	0	8.30309	8.30309	7.3956	7.39564	6.94192	7.25953	7 25953	7 71325
28	924	0	3.81125	4.26497	5.1724	4.71869	4.71869	4.71869	5.17241	5.62613
29	928	1	8.62069	9.07441	10.4356	7.25953	6.80581	6.80581	5 89837	4.99093
30	929	1	8.16697	8 62069	10.4356	7.71325	7 71325	6 80581	6 80581	6 35209
31	931	0	4.67332	5.12704	6.3521	6.35209	6.80581	6.35209	6 80581	7.25953
32	933	0	4.31034	4.76407	7.0327	5.67151	6.12523	7.03267	6.80581	7.25953
33	935	1	7.71325	8.16697	10.4356	6.80581	6.80581	6.35209	6 35209	5.44465
34	940	0	4.03811	5.39927	6.5789	6.57895	5.67151	5.67151	5 67151	6.12523
35	945	0	3.62976	3.62976	6.3521	4.53721	4.53721	5.44465	5.44465	6.35209
36	948	0	4.53721	5.35390	5.3539	5.35390	5.35390	4.90018	5.12704	5.58076
37	959	1	6.35209	6.80581	9.0744	5.89837	5.89837	5.44465	5 44465	4.53721
38	969	1	6.35209	6.80581	8.1670	5.89837	5.44465	5.44465	5.89837	5 89837
39	979	1	9.98185	9.98185	11.3430	6.80581	5.89837	5.89837	5 89837	5.89837
40	4024	0	7.12341	7.12341	7.1234	7.12341	7.12341	7.12341	8 03085	8.48457
41	4027	0	8.03085	6.21597	7.1234	6.66969	6.66969	7.12341	7 12341	8.03085
42	4046	0	6.94192	5.35390	6.0345	8.30309	7.25953	8.30309	8 75681	8 30309
43	4061	1	9.07441	9.07441	10.4356	6.80581	6.80581	5 89837	6.80581	6.35209
44	4077	1	9.07441	9.07441	10.4356	6.35209	5.89837	5.89837	5.44465	5.44465
45	4078	0	6.57895	7.48639	7.4864	7.48639	7.48639	7.94011	7 48639	8.39383
46	4126	0	7.94011	7.94011	8.8475	8.16697	8.84755	9 30127	8.84755	7.94011
47	4131	0	7.39564	7.39564	7.3956	6.48820	6.48820	6.48820	6.48820	7.84936

OBS	COW	YEAR	WK09I	WK10I	WK11I	WK12I	WK13I	WK14I	WK15I
1	18	0	5.89837	5.44465	4.99093	4.53721	3.62976	3.17604	.
2	21	1	6.80581	6.35209	5.89837	5.44465	5.89837	5.44465	.
3	74	1	4.99093	4.53721	4.53721	3.62976	4.99093	.	.
4	83	0	5.89837	5.89837	5.44465	5.44465	4.08348	3.17604	4.53721
5	88	1	3.62976	2.72232	2.26860	1.81488	3.17604	2.26860	.
6	89	1	4.99093	4.08348	2.72232	1.81488	2.72232	2.26860	2.26860
7	106	1	6.35209	5.89837	5.89837	5.44465	5.89837	5.44465	4.99093
8	138	1	6.80581	6.35209	4.99093	3.62976	4.53721	3.62976	3.17604
9	142	0	7.03267	7.03267	7.25953	7.25953	6.80581	.	.
10	153	1	5.89837	4.99093	3.62976	2.26860	3.17604	.	.
11	156	1	6.35209	5.89837	4.99093	4.53721	4.99093	4.53721	4.08348
12	176	1	6.80581	7.25953	6.80581	7.25953	7.71325	.	.
13	349	0	8.48457	8.16697	7.48639	6.80581	5.44465	4.08348	4.99093
14	359	0	6.35209	5.89837	5.89837	4.99093	4.08348	3.62976	4.08348
15	402	0	7.03267	6.35209	5.89837	4.53721	3.62976	3.62976	.
16	501	1	6.35209	5.44465	4.99093	4.08348	4.99093	4.53721	4.53721
17	515	1	7.25953	7.25953	6.80581	5.89837	6.80581	6.35209	.
18	518	1	6.35209	6.35209	6.35209	5.89837	6.80581	6.35209	.
19	535	1	6.80581	6.35209	6.80581	5.44465	5.44465	5.44465	4.99093
20	641	1	6.80581	6.35209	5.44465	4.53721	4.99093	4.53721	4.08348
21	652	0	7.03267	6.80581	6.35209	4.99093	4.08348	4.08348	.
22	657	0	7.03267	6.35209	6.57895	5.21779	4.53721	4.99093	4.53721
23	659	0	7.48639	6.80581	6.57895	5.44465	4.53721	3.62976	4.53721
24	671	1	5.44465	4.53721	3.62976	4.08348	4.53721	4.08348	4.08348
25	675	1	6 35209	5.44465	4.53721	3.17604	4.08348	3.62976	3.17604
26	739	0	6.80581	6.57895	6.35209	5.44465	4.53721	4.08348	.
27	743	0	7.25953	7.03267	6.80581	5.44465	4.53721	.	.
28	924	0	5.44465	4.99093	4.53721	4.08348	3.17604	.	.
29	928	1	4.53721	3.62976	2.26860	1.81488	2.72232	.	.
30	929	1	5.89837	4.99093	4.08348	3.17604	4.53721	4.08348	3.17604
31	931	0	7.25953	7.03267	6.80581	5.44465	4.53721	4.08348	4.53721
32	933	0	6.80581	6.35209	5.44465	4.53721	3.17604	2.72232	4.08348
33	935	1	4.53721	3.62976	3.62976	3.62976	4.53721	4.08348	.
34	940	0	6.12523	5.67151	5.44465	4 53721	4.08348	.	.
35	945	0	5.89837	5.44465	5.21779	4.76407	4.08348	2.72232	2.72232
36	948	0	5.44465	4.99093	4 76407	4.08348	3.17604	3.17604	4.08348
37	959	1	3.62976	2.72232	2.72232	1.81488	2.72232	2.26860	1.81488
38	969	1	4.99093	4.08348	3.17604	3.17604	4.08348	.	.
39	979	1	4.99093	4.53721	4.08348	3.17604	4.08348	4.53721	5.44465
40	4024	0	8.25771	8.25771	7.35027	6.44283	5.53539	.	.
41	4027	0	7 57713	7.12341	6.21597	6.21597	5.30853	5.44465	5.44465
42	4046	0	8 75681	7.71325	6.35209	5.67151	4 76407	5.44465	5.44465
43	4061	1	5.89837	5.89837	4.99093	4.08348	4.99093	.	.
44	4077	1	4.99093	4.53721	4.08348	4.53721	5.44465	6.35209	.
45	4078	0	8.39383	7.94011	7.94011	7.03267	5.21779	4.53721	.
46	4126	0	9.75499	7.94011	7.48639	7.71325	5.44465	4.99093	.
47	4131	0	7.39564	6.80581	6.35209	5.44465	4.53721	.	

OBS	YEAR	HTC01	HTC02	HTC03	HTC04	HTC05	HTC06	HTC07	HTC08	HTC09
1	0	6.44444	16.8333	7.2778	4.3889	13.5000	8.5556	3.7222	6 44444	2 0556
2	1	8.72222	6.9444	-7.9444	-8.8889	5.8889	14.4444	-2.6111	3.88889	11.8889

HTC10	HTC11	HTC12	HTC13	HTC14	HTC15
12.2222	15.0556	15 5556	14.1667	17.4444	6.3333
12.2778	18.7778	14.8333	10.5556	12.7222	15.3889

OBS	LTC01	LTC02	LTC03	LTC04	LTC05	LTC06	LTC07	LTC08	LTC09
1	-3.5000	-0.1667	-1.667	-3.944	-2.1667	-4.2778	-3.111	-2.3889	-5.0000
2	-3.1111	-2.6667	-15.167	-14.833	-3.9444	0.0000	-12 556	-5 9444	-0 2222

LTC10	LTC11	LTC12	LTC13	LTC14	LTC15
0.16667	4.94444	1.44444	3.0556	3.88889	-0.88889
-0 50000	3.55556	2.94444	-1.2222	0.00000	5.94444

OBS	YEAR	RM01	RM02	RM03	RM04	RM05	RM06	RM07	RM08
1	0	0.152400	0	0.493486	0	0	0.0544286	0 0653143	0.580571
2	1	0.061686	0	0.083457	0	0	0.0254000	0 0471714	0.000000

RM09	RM10	RM11	RM12	RM13
0 0580571	0 000000	0 453571	0	0.301171
0.0000000	0.119743	0.000000	0	0.134257

OBS	RM14	RM15	SM01	SM02	SM03	SM04	SM05	SM06	SM07
1	0.000000	0.148771	0	0	0.000000	0.00000	0.000000	0 816429	1.45143
2	0.123371	0.145143	0	0	0.907143	1.08857	0.544286	0.000000	2.54000

SM08	SM09	SM10	SM11	SM12	SM13	SM14	SM15
1.08857	0	0	0	0	0	0	0
0.00000	0	0	0	0	0	0	0

OBS	COW	YEAR	KG0	KG1	KG2	KG3	KG4	KG5	KG6	KG7
1	21	1	377.495	374.773	381.125	411.978	404.719	411.071	395.644	403.811
2	74	1	405.626	372.505	387.931	419.691	415.154	401.996	398.820	400.635
3	88	1	291.289	281.760	292.650	331.216	322.142	320.780	301.724	303.993
4	89	1	262.250	251.815	262.250	299.002	287.205	289.020	280.399	289.474
5	106	1	394.737	385.662	392.468	426.497	419.691	385.662	393.376	399.728
6	138	1	462.341	446.915	471.869	485.935	474.138	468.240	455.082	475.953
7	153	1	318.512	306.261	319.419	352.087	348.911	371.143	328.040	329.855
8	156	1	457.804	438.748	461.887	465.971	453.267	456.897	450.998	457.350
9	176	1	504.991	493.648	518.149	534.483	519.510	514.973	522.232	524.955
10	501	1	296.279	290.381	309.891	333.031	331.216	312.613	310.345	319.419
11	515	1	432.849	430.581	449.183	490.926	473.684	458.258	455.082	441.924
12	518	1	462.795	454.628	476.407	494.555	484.120	476.860	465.517	475.045
13	535	1	519.056	512.704	530.853	550.817	528.584	539.474	544.465	525.408
14	641	1	461.434	431.942	453.721	483.212	476.407	470.962	453.721	469.147
15	671	1	387.024	381.579	392.922	430.127	428.312	416.969	412.432	410.617
16	675	1	336.661	326.679	335.299	387.931	366.152	358.439	355.263	360.708
17	928	1	293.103	291.742	323.049	360.254	338.022	327.132	336.207	339.837
18	929	1	346.189	333.485	343.466	373.866	360.254	371.597	360.708	358.439
19	935	1	300.817	275.408	303.539	347.096	330.309	323.503	307.623	322.595
20	959	1	278.131	268.603	291.742	318.512	301.270	302.178	293.103	301.724
21	969	1	368.421	363.884	376.588	404.719	395.191	390.200	380.218	380.672
22	979	1	374.773	370.690	385.662	417.877	414.247	397.459	393.829	389.746
23	4061	1	408.348	407.895	429.220	441.470	431.942	439.201	419.691	426.497
24	4077	1	373.412	362.976	380.672	400.181	387.931	374.319	375.681	368.421
25	945	0	342.559	349.365	334.392	311.252	336.207	343.920	319.419	338.022
26	948	0	342.559	322.142	316.243	323.049	321.688	332.123	339.837	330.762
27	18	0	403.811	397.913	387.477	395.191	414.701	407.895	400.635	406.080
28	940	0	337.568	333.938	324.410	313.521	332.123	349.365	336.661	340.290
29	924	0	311.706	311.252	306.715	302.178	311.252	316.243	315.789	312.160
30	933	0	377.495	362.976	351.633	341.198	359.347	360.708	354.809	367.060
31	739	0	355.717	346.189	338.929	355.263	349.365	343.013	354.356	346.189
32	349	0	358.439	336.207	339.383	343.013	338.929	350.726	349.819	352.087
33	83	0	356.624	344.828	332.123	352.087	352.995	351.180	351.633	359.347
34	142	0	499.093	504.537	480.944	494.555	495.463	498.639	489.564	488.657
35	359	0	339.837	310.799	324.410	341.198	332.577	346.642	348.911	339.383
36	402	0	359.800	334.846	351.180	355.263	353.448	369.782	366.152	360.254
37	652	0	423.775	406.080	401.089	414.247	420.599	427.405	426.951	423.321
38	657	0	449.183	440.109	434.211	451.452	447.368	440.109	441.016	448.276
39	659	0	450.091	418.784	420.599	443.739	444.646	456.443	467.786	447.822
40	743	0	576.225	554.900	560.345	578.040	567.151	580.309	572.595	573.049
41	931	0	407.441	411.071	387.931	391.561	401.089	398.367	406.080	396.098
42	4024	0	431.034	408.348	411.071	423.775	418.784	425.590	427.405	411.978
43	4027	0	379.764	341.652	375.227	360.254	370.236	377.495	372.505	382.033
44	4046	0	357.985	334.392	345.735	338.022	321.234	365.245	343.920	345.735
45	4078	0	471.869	457.350	450.544	465.517	463.249	465.517	465.971	474.592
46	4126	0	396.552	362.523	371.597	369.782	390.200	384.301	389.746	398.820
47	4131	0	409.256	381.125	397.005	405.172	410.617	409.710	412.886	407.895

OBS	COW	YEAR	KG8	KG9	KG10	KG11	KG12	KG13	KG14
1	21	1	395.191	404.265	406.080	404.265	392.922	396.098	411.978
2	74	1	401.089	401.543	395.644	405.626	378.403	392.922	.
3	88	1	311.706	310.345	309.891	309.437	284.029	297.641	299.909
4	89	1	275.862	291.289	305.808	290.835	269.964	275.408	276.316
5	106	1	401.089	402.904	395.644	402.904	395.191	403.811	400.635
6	138	1	486.842	469.601	495.463	490.018	452.813	471.869	475.953
7	153	1	331.670	341.652	373.866	358 439	326.679	333.031	.
8	156	1	461.434	453.721	466.425	455.082	440.109	455.535	457.804
9	176	1	522.232	511.343	534.483	517.241	519.056	532.214	.
10	501	1	319.419	331.216	333.485	333.485	308 076	320.327	322.142
11	515	1	442.377	454.628	470.962	475.499	443.739	454.174	458.258
12	518	1	494.555	473.230	483.666	489.564	470.054	482.759	495.009
13	535	1	563.975	537.205	523.593	563.975	537.205	536.751	548.548
14	641	1	466.425	460.073	465.971	470.508	448.730	452.813	459.619
15	671	1	420.145	421.053	418.784	399.728	392.922	400.635	402.904
16	675	1	362.976	367.514	370.690	381.125	343.466	357.985	360.708
17	928	1	344.828	338.022	342.559	340.290	313.975	325.771	.
18	929	1	371.597	366.606	375.681	372.958	352.541	358.439	369.328
19	935	1	316.697	317.604	319.419	318.058	299.002	308.984	311.706
20	959	1	300.363	298.094	287.659	295.826	273.593	295.372	299.002
21	969	1	393.376	395.191	395.644	388.838	367.967	380.218	.
22	979	1	403.811	391.107	389.292	396.098	369.782	372.051	375.681
23	4061	1	434 664	427.405	435.572	438.748	413.339	426.951	.
24	4077	1	374.773	371.143	381.579	377.042	355.717	363.430	382.940
25	945	0	315 789	357.532	347.096	341.198	340.744	350.272	350.726
26	948	0	323.503	338.475	344.828	341.652	340.744	342.559	336 661
27	18	0	399.728	411 071	424 229	426.497	418.330	422 868	423.321
28	940	0	332.577	341.198	351.180	344.828	348.004	347.550	.
29	924	0	306 261	316 243	329.855	332.123	320.780	329 855	.
30	933	0	359.347	385.662	390.200	395.644	387.477	383.394	374.319
31	739	0	348.457	362.976	363.884	363.884	366.606	372 505	361.615
32	349	0	352.541	359.347	369.782	377.495	371.597	376.588	375.681
33	83	0	355.263	358.893	363.884	363.884	360.708	374.319	368.421
34	142	0	478.675	495.463	504.991	484.120	496.824	512.250	.
35	359	0	334.846	346.642	354.809	348.911	355.263	360.254	348 911
36	402	0	350.272	371.143	378.403	372.958	377.949	372.051	366.606
37	652	0	416.062	438.294	435.572	431.488	440.563	440.563	427.405
38	657	0	428.312	451.906	467.786	445.100	465.971	461.434	446.007
39	659	0	448 276	458.711	462.795	463.702	464.156	467.332	469.147
40	743	0	566.243	588.022	592.105	590.744	593 013	596.189	.
41	931	0	392.922	413.339	412.886	416.062	428.312	416.062	417.877
42	4024	0	424 229	431.942	433.303	440.109	440.109	441.924	.
43	4027	0	365.699	396.098	401.089	393.376	382.033	396.098	381.125
44	4046	0	348.004	366 152	387.024	378.857	365.699	370 690	357.078
45	4078	0	456.443	458.258	476.407	473.230	482.305	493.648	483.666
46	4126	0	375.681	392.922	403.811	406.987	396.552	420 599	402.904
47	4131	0	394 737	424.682	425 136	424.682	421.960	422.414	.

VITA 2

John Joseph Wagner

Candidate for the Degree of

Doctor of Philosophy

Thesis: CARCASS COMPOSITION IN MATURE HEREFORD COWS: ESTIMATION AND INFLUENCE ON METABOLIZABLE ENERGY REQUIREMENTS FOR MAINTENANCE DURING WINTER

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Port Huron, Michigan, May 1, 1958, the son of James A. and Ruth A. Wagner.

Education: Graduated form Anchor Bay High School, New Baltimore, Michigan in June, 1976; received the Bachelor of Science degree from Michigan State University, East Lansing, Michigan, with a major in Animal Husbandry, in June, 1980; received the Master of Science degree in Animal Science from Oklahoma State University in May, 1982; completed the requirements for the Doctor of Philosophy degree in Animal Nutrition at Oklahoma State University in May, 1985.

Experience: Raised on a diversified livestock and crop farm in Southern Michigan; animal caretaker at the Beef Cattle Research Center, Michigan State University 1979-1980; graduate research and teaching assistant, Oklahoma State University, 1980-1984.

Professional Organizations: American Society of Animal Science.