South Dakota State University

Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Electronic Theses and Dissertations

2023

Effect Of Lighter (273 Kg) and Heavier (356 Kg) Initial Weight on Growth Performance of Single-Source, Pre-Conditioned Beef Steers Fed A Single Growing-Finishing Diet

Thomas C. Norman
South Dakota State University, thomas.norman@sdstate.edu

Follow this and additional works at: https://openprairie.sdstate.edu/etd2

Part of the Beef Science Commons

Recommended Citation

Norman, Thomas C., "Effect Of Lighter (273 Kg) and Heavier (356 Kg) Initial Weight on Growth Performance of Single-Source, Pre-Conditioned Beef Steers Fed A Single Growing-Finishing Diet" (2023). *Electronic Theses and Dissertations*. 685.
https://openprairie.sdstate.edu/etd2/685

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.

EFFECT OF LIGHTER (273 KG) AND HEAVIER (356 KG) INITIAL WEIGHT ON GROWTH PERFORMANCE OF SINGLE-SOURCE, PRE-CONDITIONED BEEF STEERS FED A SINGLE GROWING-FINISHING DIET

BY

THOMAS C. NORMAN

A thesis submitted in partial fulfillment of the requirements for the degree

Master of Science

Major in Animal Science

South Dakota State University

2023

THESIS ACCEPTANCE PAGE

Thomas Norman

This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Warren Rusche
Advisor Date

Robert Thaler
Department Head Date

Nicole Lounsbery, PhD
Director, Graduate School Date

I am dedicating this work to my grandfather, Robert Jarchow. I would not be where I am today without your continuous support in all facets of life. Thank you for instilling academic excellence, goal setting, and self-belief into me at a very young age. You have been an inspiring role model to me, and I hope I make you proud.

ACKNOWLEDGEMENTS

The 2.5 years was well worth it, and I am incredibly honored to have been given this opportunity by Dr. Zachary Smith, Dr. Rusche, and the Department of Animal Science. This journey has been fun, strenuous, challenging, but most of all, gratifying. The list of individuals that I need to thank is lengthy, and I am sure I will forget some. Just know, each of you have been a cornerstone of my development, and this thank you is not enough.

Dr. Smith, you are wildly intelligent. Although maybe not in each present time, I truly appreciate each challenge and goal you have faced me with. Being able to digest, interpret, and use a sliver of your knowledge I have obtained over the past 2+ years will push me to have a greater explorative mindset for years to come. I am honored to have been able to study within your lab group.

Dr. Rusche, you are an incredible resource of knowledge, mentorship, and integrity. Your open-door policy, no matter the topic, allowed me to grow both personally and professionally. Thank you for being patient with me and always providing a high level of support. My schedule between both roles I served in throughout my time here at SDSU was not always convenient, and I appreciate you being understanding and helping me adapt to be the best I could within both roles.

Brady Jensen, a thank you does not touch the surface for the knowledge, professionalism, and opportunities you have gifted me with. You will be a lifelong mentor and friend. Thank you to you and your family for everything.

Dr. Rosie Nold, your mentorship, intelligence, and guidance speaks volumes. Thank you for directing me, trusting me, and supporting me. Our friendship has kept my wheels spinning and I will always consider you one of my biggest role models.

To the Department of Animal Science, thank you for providing me with 6 years of knowledge and lifelong wisdom. It has been far more than a sturdy foundation to shape me into who I am today. My time here has been well spent, and I am blessed to be an alumnus.

To my family and close friends, thank you for the continuous support. The kick of motivation here and there has gotten me to where I am today. Thank you for being understanding when my schedule gets too busy to come home, and your contribution in all aspects never went unnoticed.

TABLE OF CONTENTS

ABREVIATIONS…………………………………………………………………..vii

LIST OF FIGURES……………………………………………………….........x

LIST OF TABLES……………………………………………………………..xi

ABSTRACT…………………………………………………………………..xii

CHAPTER 1: REVIEW OF LITERATURE……………………..…………………......1

SECTION 1: INTRODUCTION……..…………………………………….....1

SECTION 2: FACTORS INFLUENCING GROWTH……………………....…2

SECTION 3: CARCASS DETERMINATION…………………………...…....7

SECTION 4: STRATEGIES TO MANIPULATE BODY COMPSOTION……..15

SECTION 5: SUMMARY…………………………………………………….20

LITERATURE CITED………………………………………………………..22

CHAPTER 2: EFFECT OF LIGHTER (273 KG) AND HEAVIER (356 KG) INITIAL WEIGHT ON GROWTH PERFORMANCE OF SINGLE-SOURCE, PRE-CONDITIONED BEEF STEERS FED A SINGLE GROWING-FINISHING DIET…....30

ABSTRACT………………………………………………………………...…30

INTRODUCTION…………………………………………………………….32

MATERIALS AND METHODS……………………………………………...33

RESULTS……………………………………………………………………..40

DISCUSSION AND IMPLICATIONS………….………………..…………...43

LITERATURE CITED………………………………………………………..46

TABLES AND FIGURES……………………………………………………..51

ABBREVIATIONS

ADF acid detergent fiber

ADG average daily gain

BW body weight

CP crude protein

CRNSIL corn silage

d day

DDGS dried distillers grains plus solubles

DM dry matter

DMI dry matter intake

DOF days on feed

DP dressing percentage

DRC dry rolled corn

EBF empty body fat

EBW empty body water

EE ether extract

EG daily energy gain

EM maintenance energy

FBW final BW

FFG feed available for gain

FFM feed available for maintenance

FHP fasting heat production

g grams

G:F gain to feed

GH grass hay

h hour

HCW hot carcass weight

HMC high moisture corn

kg kilogram

LS liquid supplement

LWG live weight gain

Mcal megacalorie

ME metabolizable energy

MQ estimated maintenance coefficient

NASEM National Academies of Sciences, Engineering, and Medicine

NDF neutral detergent fiber

NE net energy

NEg net energy for gain

NEm net energy for maintenance

RE retained energy

REA ribeye area

RF ribfat

RNC Ruminant Nutrition Center in Brookings, South Dakota

RY retail yield

TBA trenbolone acetate

TMR total mixed ration

USDA United States Department of Agriculture

W weight (kg)

YG calculated yield grade

LIST OF FIGURES

FIGURE 1: RATE OF HIP HEIGHT CHANGE OVER TIME OF STEERS AT DIFFERING INITIAL WEIGHTS……………………………………………………………58

FIGURE 2: UREA SPACE DETERMINATION GRAPH……………………………...59

LIST OF TABLES

TABLE 1: ACTUAL DIET FORMULATION AND NUTRIENT COMPOSITION…..51

TABLE 2: GROWTH PERFORMANCE FOR STEERS WITH LIGHTER OR HEAVIER INITIAL WEIGHTS FED A COMMON DIET FOR 209 d………………...52

ABSTRACT

EFFECT OF LIGHTER (273 KG) AND HEAVIER (356 KG) INITIAL WEIGHT ON GROWTH PERFORMANCE OF SINGLE-SOURCE, PRE-CONDITIONED BEEF STEERS FED A SINGLE GROWING-FINISHING DIET

THOMAS C. NORMAN

2023

The objective of the study was to determine the influence that initial BW has on growth performance responses, efficiency of dietary net energy (NE) utilization, and carcass traits in feedlot steers. Light- and heavy-weight Charolais×Red Angus steers (n = 70) selected from a larger single-source group were used in a 209-d growing-finishing feedlot experiment at the Ruminant Nutrition Center, in Brookings, SD. On d-0 and d-1 weight and hip height (HH) measurements were collected for allotment purposes; the initial experimental weight was the average between d 0 and d 1 BW. Steers were assigned to two groups based on initial BW (light initial weight, LIW = 273kg; heavy initial weight, HIW = 356kg) and allotted into 10 pens (n = 7 steers per pen; 5 pens per experimental group). Steers were fed a common diet containing 16% roughage (13.1% CP and 23.4% NDF, DM basis) once daily. Diet included liquid supplement containing vitamins and minerals to meet or exceed 2016 NASEM requirements with monensin included at 30 g/ton. Experimental data were analyzed as a randomized complete block design with pen as the experimental unit. Treatment was included as a fixed effect and block (location) was considered a random effect in the statistical model. Observed NEm (P = 0.17) and NEg (P = 0.17) for LIW and HIW did not differ. LIW steers had a greater cumulative HH change ($P = 0.04$). A treatment × day interaction ($P = 0.05$) was observed for HH with HIW steers having a greater HH at all time points. Final BW and carcass-adjusted (HCW/0.625) BW were greater for HIW steers by 13.1% and 13.4% respectively ($P \leq 0.01$). HIW steers had a greater DMI ($P = 0.01$) compared to LIW. Cumulative ADG was greater for HIW by 3% ($P = 0.04$). LIW steers had improved feed conversion ($P = 0.01$; 5.95 and 6.62, respectively). HIW steers had greater ($P \leq 0.05$) HCW, marbling scores, and yield grade (YG), with decreased REA/HCW ($P = 0.01$) compared to LIW. The distribution of USDA Yield Grade was altered by initial BW ($P = 0.04$). No differences were detected ($P \geq 0.22$) for the distribution of Quality grade nor liver abscess prevalence and severity. In conclusion, HIW steers had greater growth, but poorer feed efficiency compared to LIW steers. Steers with a HIW produced fatter carcasses with a greater degree of marbling.

CHAPTER I: REVIEW OF LITERATURE

INTRODUCTION

Section 1: Introduction

Understanding compositional changes within growing beef cattle are key factors when analyzing nutrition, production, marketing animals, and the research of beef animals. Beef cattle growth is a key determinant of performance, whether it is increasing skeletal size or accretion of carcass components. Selecting the appropriate slaughter weight has many factors to consider. Sex, breed, age, and previous plane of nutrition all affect the animal, but the end goal should be a targeted composition paired with an acceptable live weight (NASEM, 2016).

Cattle feeders in the Northern Plains routinely feed two district diets during production. Forage-based diets are commonly fed during the backgrounding phase with concentrate-based diets are typical for the finishing phase of production. However, the overall goal of backgrounding programs are 1) managing disease and health, 2) achieving economical gains, 3) enhancing finishing phase feed conversion, 4) achieving maximal total carcass weight gain, 5) managing feeder cattle supply into the feedlot phase of production.

With fewer cattle on feed and increasing demand, the focus on body compositional components has increased. In-vivo dilution, carcass specific gravity, ninth-tenth-eleventh rib section, and dual-energy x-ray absorptiometry have been studied for compositional measurements and carcass determination. Body composition is the sum of all protein, fat, and bone within an animal, and can be used to increase profitability. To produce the most profitable product, the ratio of each body composition component needs to be optimized with efficiency and consumer acceptance in mind.

Section 2: Factors Influencing Growth

Predicting Feed Requirements

Determining accurate feed requirements is useful when allocating individual animals fed in larger pens to calculate cost of gain (COG) and energy utilization. The California Net Energy System (CNES) can project cattle performance based on three components: expected dry matter intake (DMI), a degree of maturity associated with body composition (protein and fat content), and an estimation of net energy (NE) within the diet (Owens and Hicks, 2019). This allows for feedlot managers to record and monitor efficiency and growth of individual pens of cattle. This tool generated by the CNES has allowed for nutritionists to audit feedlot records and quantify results more precisely (Owens and Hicks, 2019). Vasconcelos and Galyean (2008) state “Researchers should be encouraged to calculate diet NE values from performance data because these values can be useful for describing treatment effects and for determining the energy value of novel feeds”. This method helps authors and editors combine data without discrepancies and allows for incorrect information to be readily detected (Owens and Hicks, 2019).

With value-based markets used in the cattle industry today, individual carcasses should be evaluated, rather than averages of the group (Cross and Whittaker, 1992). Perry and Fox (1997) described methods to assign feed for individual animals with the impact of body size, breed type, and stage/rate of growth. Each animal's feed requirement should be adjusted to what the animals shrunk body weight (SBW) is at a targeted empty body fat (EBF) (Guiroy et al., 2001). The 2000 NASEM incorporated a system that determines energy retained by an equivalent shrunk body weight (EQSBW) (NASEM, 1976). This equation multiplies the shrunk BW of the individual animal by the standard reference weight (SRW) ratio for the anticipated body fat composition to determine adjusted final BW of an animal (Guiroy et al., 2001). To determine the expected weight at different compositional endpoints, these researchers developed a constant that can be used in the equation to tabulate weight change with each percentage unit change in body fat (BF) through a serial slaughter study. To estimate NEg required for shrunk weight gain (SWG) and shrunk body weight (SBW), empty body weight (EBW) and empty body gain (EBG) need to be converted to 4.4% shrunk liveweight gain to develop the Garrett (1980) equations for body composition (NASEM, 1976). All body composition systems developed since the 1984 NRC adjust for a sizing scale to included differences in weight gain at a specific composition (NASEM, 1976).

Compensatory growth is seen when the DMI of an animal is greater than a standard animal of equivalent body weight (Pritchard, 1996). This stimulates a concurrent decrease in the required feed per unit of gain. The reduction in metabolizable energy (ME) necessary for maintenance and increased DMI would cause a substantial increase in ME available for gain (Pritchard, 1996). Even short restrictions can stimulate compensatory gain, although increased feed efficiency is not as evident with short term dietary restrictions. Calf-feds have a better feed conversion than yearlings when addressing compensatory gain (Klopfenstein et al., 1999). The same researchers report that heavier cattle will be less efficient when entering the feedlot, but rapid gain on grass before entering the feedlot does increase feed efficiency through compensatory gain.

Backgrounding diets are typically composed of higher roughage and lower concentrate type diets, whereas finishing phase diets are lower roughage and higher concentrate. Galyean and collaborators stated, “Energy intake is a primary determinant of productivity in all livestock species, and estimates of the availability of energy in feeds are essential to systems for describing nutrient requirements” (Galyean et al., 2016).

Net energy for maintenance (NEm) is defined as the heat production generated at zero feed intake, and the ability of consumed feedstuffs to meet maintenance requirements of the animal (NASEM, 2016). Net energy for gain (NEg) is explained as the energy content of the tissue deposited, noted as the function of fat and protein proportion in empty body tissue gain (Garrett et al., 1959). Energy concentrations of various feedlot diets are generally similar across the industry. Backgrounding diets of NEg are variable, as targeted goals may be different, but generally less than finishing diets whether that is by feeding a lower energy diet or restricting total animal intake. Standard grower diets, or backgrounding diets, target a rate of gain to 0.68 – 1.13kg per day (Rusche, 2015). Finishing diets would target a much more aggressive energy diet and a higher rate of daily gain. A survey conducted by Samuelson et al. (2016) recommends finishing diets should target a NEg concentrations of 1.50 to 1.54 Mcal/kg.

The genetic code a mammal is born with sets the mechanism of growth and development, with the first tissue affected being adipose during times of discontinuous growth or caloric restriction. The rate of protein and fat accumulation within the body is higher in normal animals of the same BW during realimentation (Pritchard, 1996). Eventual deterioration of skeletal muscles will be secondarily affected with the impact of inadequate caloric intake, but to a lessened degree than fat accretion (Pritchard, 1996). It is anticipated to see a reduction in visceral organ mass and decreased fasting heat production (FHP) in this state.

Implant Alterations to Body Composition

Beef cattle producers have used multiple types of growth-enhancing technology (GET) for more than 60 years (Smith and Johnson, 2020). The changes in composition and energy utilization with the use of implants offers a significant return on investment to animal production. Most GET contain anabolic activity, or orally activated beta-adrenergic agonists, used to promote skeletal muscle growth, increased average daily gain (ADG), alterations of dry matter intake (DMI), and alter carcass leanness (Smith and Johnson, 2020). This technology increases ADG, with only moderately affecting DMI, when comparing to non-implanted cattle. The increase of live weight gain with less energy required increases feed efficiency (G:F), allowing for a range of 8%-28% increase in ADG and a 5%-20% more favorable G:F (Smith and Johnson, 2020). Implanting cattle reduces cost of production, while improving feed efficiency (Reinhardt, 2007). Implanted cattle have increased ribeye size by 5%, reduced fat cover and marbling by 7 and 5%, respectively, resulting in 17% fewer carcasses grading Choice or above (Reinhardt, 2007). The same study indicated that implanting cattle decreases their physiological age and allows them an extended period of lean accretion. This is the cause of delayed fattening in the cattle after being implanted, and their lower marbling content.

There are more than 30 commercially available implants marketed within the United States for beef cattle production. Further classification of anabolic and orally activated adrenergic agonists can be arranged in low, medium, and high potency, with the addition of coated or non-coated (Johnson and Beckett, 2014). Endogenously produced hormones are referenced in three categories: androgens (i.e. male hormones), estrogens (i.e. female hormones), and progestins (i.e. pregnancy hormones) (Smith and Johnson, 2020). A subcutaneous method is used to administer these implants on the posterior side of the animals' ear. The release method of these implants can be affected by their compositional make up. A non-coated implant with an anabolic compound is released slowly into the circulatory system for 60-120d (Mader, 1998). Implant payout refers to the duration of days that an implant has influence on the animal. This payout of anabolic function can be altered through various excipient compounds, such as cholesterol or lactose, during implant formulation (Smith and Johnson, 2020). Polymers and the amount of pressure applied during the formulation of the implant can have an impact on the time period that the pelleted implant releases the anabolic compounds into the blood circulatory system (Lee et al., 2000).

Section 3: Carcass Determination

Body Compositional Measurement

Growth and development of meat animals have been studied to establish economic importance to livestock production. Most research is focused during the growth pattern of the animal to their desired market weight. Although growth during pregnancy and lactation are of concern, animals with the intent of harvest do not have primary function of reproduction.

Complete dissection into viscera, skin, bones, muscle, and fatty tissue has been considered the most direct way to measure body composition (Mitchell, 2007). With this process being labor intensive, separating the meat into primal cuts to estimate lean yield allows for more efficiency. In the 1930's, Germany developed x-ray measurements in an attempt to calculate body composition. Although this was a step in the right direction from previously used visual appraisal, this method was not widely adopted because of labor requirements. Mitchell (2007) reported that during the 1950's the use of ultrasonography became used to estimate body composition. At this time, cross-sectional area of the longissimus muscle and thickness of subcutaneous fat were used as predictors of composition.

With body composition measurements providing a greater level of precision for livestock producers to visually appraise animal's make-up, carcass composition can offer a more direct determination (Ross, 2005). Chemical composition can accurately estimate total body composition, but does require total destruction of the carcass (Ross, 2005).

With most techniques that measure composition of meat animals, a loss of edible product is seen, especially in total chemical composition. Equations have evolved to convert water, crude protein, and fat proportions to total carcass analysis. The use of densitometry x-ray scans have predicted carcass lean, fat, and ash of a carcass (Ross, 2005). The measurement of lean is a combination of crude protein and water used to predict components of the rib section. Measurements of urea dilution aid in determining the empty body water, crude protein, and fat, while allowing the animal to remain alive during the carcass estimation process. This integrates away from past methods that require full or partial carcass destruction.

In-Vivo Dilution

Tritium, deuterium oxide, and urea have been used as *in vivo* dilution techniques to predict body composition of cattle (Owens et al., 1995). Rule's group (1986a) stated "The substance must be 1) rapidly and uniformly distributed; 2) non-destructive and non-formative; 3) without influence on body water distribution; 4) slowly eliminated; 5) non-toxic; 6) accurately and easily determined." Urea dilution has offered more reliability and advantages over other methods for body composition predictors. Wagner (1985) reported that urea is relatively inexpensive, non-toxic, and a naturally occurring compound found within the body. Preston and Kock (1973a) describe the process where urea diffuses into cellular water and free water in the animal's body in roughly 15 minutes. The urea concentration in the body tissues is equal to the amount in the blood, therefore assists in the body water measurement (Preston and Kock, 1973a). Body water determination supports calculations of protein and fat, with the latter component being negatively association with water, because of fat acting as a diluter to body water (Pace and Rathbun, 1945). Bartle and Preston (1986) conclude that body composition can then be measured if the weight of the animal and percent of body water are known factors through urea dilution.

Preston and Kock (1973a) performed extensive studies using urea dilution techniques to quantify body composition. Multiple equations have proposed predictors of empty body water of beef cattle (Hammond et al., 1984; Bartle and Preston, 1986; Rule et al., 1986; Bartle et al., 1987). Rule and co-workers (1986) concluded that based on their findings, urea dilution is a sustainable measurement for empty body water estimations.

Other studies by Hammond et al. (1984) have suggested that urea dilution is an accurate estimation method of body water, but additional research is necessary to estimate protein and fat more accurately. Ross (2005) claims the issues with using this body composition method is the unknown urea amount equilibrating with reticulo-rumen water and the amount excreted in urine pools. Bartle and Preston (1986) found that urea will not disseminate into the gastrointestinal water in notable amounts when the animal is in a fasted state. Non-fasted animals could present more variation in predictability of *in vivo* dilution. Previously, Bartle et al. (1983) claimed that gastrointestinal fill does influence the reliability of urea space estimation.

Urea space is defined by Kock and Preston (1979) as the volume of water at which urea equilibrates. Equilibrium is a balanced state of opposing forces. Extrapolation of plasma urea concentration is used when determining urea space by dividing the total amount of urea injected into the animal by the change of plasma urea concentration from the sample taken prior to injection (Preston and Kock, 1973a). Although Hammond et al. (1990) and Wells and Preston (1998) tabulated calculations on an empty body basis, Bartle et al. (1987), Hammond et al. (1984), and Rule et al. (1986a) used live weight. Results showed a more accurate read when using a live weight basis for calculations in beef cattle within above studies.

When infusing urea into the body, Kock and Preston (1979) and Hammond et al. (1988) found that 12 minutes post-infusion were necessary to reach equilibrium and provide for greatest accuracy. Within all weight groups sampled through trials conducted by Kock and Preston (1979), a 12-minute equilibrium period resulted in a significant correlation between composition of the rib section and specific gravity measurements. Ross (2005) claimed that some results show variability when using urea space, and that differences in sex, breed, and phycological condition of the animal affect the body composition estimation.

Estimation of body water dilution techniques were developed to calculate lean tissue mass and carcass fat in meat animals (Rule et al., 1986a). Although deuterium oxide showed a high degree of accuracy early on, lactation and rapid growth influenced the estimation of body water (Rule et al., 1986a). Equilibration, time requirements, and necessary resources to use deuterium oxide or tritiated water dilution techniques made them less desirable than use of a soluble compound, such as urea or antipyrine (Rule et al., 1986a).

Carcass Specific Gravity

Research done by Behnke et al. (1942) confirmed that density of a carcass is an indicator of fatness, using the body specific gravity method. This technique is validated because fat is less dense than muscle and bone, correlating with gravity measurements. This provides a measurement of density when weight from the animal is suspended in water, an indicator of carcass lean muscle mass (CLMM). Garrett (1968) claimed specific gravity was a viable technique to estimate body composition. High correlation coefficients with low standard errors reported by Garrett and Hinman (1969) show evidence that specific gravity and carcass density are predictors of carcass composition. Preston et al. (1974) stated that specific gravity provides more value as a prediction tool for carcass composition than the weight of the carcass.

Flaws to carcass specific gravity were described by Kraybill et al. (1952) when air retention in the lungs and production of gas in the abdominal cavity is present. This group conducted a trial using two different methods of specific gravity measurements. An issue with this method is predicting accuracy of lean animals. Johnson et al. (1990) recognized that measurements from specific gravity show the most accuracy with fat carcasses, as fat is the largest factor influencing the measurement. Gil et al. (1970) did find accurate results using this method in fat animals (30 to 42% fat), with percent water, protein, and fat, in comparison to younger and leaner animals. Work done by Alhassan et al. (1975) created equations for thin cattle (less than 20% fat) and reported accurate measurements. However, further reporting is needed with a larger sample size. Regardless of more research suggested to be done, Owens et al. (1995) emphasized this method to estimate carcass composition is one of the most proven techniques.

Ninth-Tenth-Eleventh Rib Section

Hankins and Howe (1946) reestablished a theory earlier investigated by Lush (1926) and Hopper (1944). Hopper (1944) found a strong correlation between ninth-tenth-eleventh rib section and carcass composition, particularly with estimates of fat content. This is compatible with the work done by Lush (1926) where the wholesale rib cut's fat content and the total fat of the carcass were positively correlated. Bradley (1938) suggested that bone percentage in a dressed beef carcass can be estimated by the content of bone in this rib section. The correlation coefficient of 0.83 was found through the development of these equations.

A relationship was found by Hankins and Howe (1946) between separable fat of the rib section and dressed carcasses in steers ($R^2 = 0.93$), and in heifers ($R^2 = 0.88$), indicating minimal variation between steers and heifers. Ether extract values within the edible portion of the rib section were strongly correlated to total carcass fat. When using the separable lean from the rib section, estimations of the lean carcass showed strong correlation for steers ($R^2 = 0.90$). Lean determination in heifers was not as strong ($R^2 = 0.72$). Dressed carcasses had an overall $R^2 = 0.83$, when referencing separable bone of the rib section, and $R^2 = 0.93$ relationship between water in the rib section and a dressed carcass. However, Hankins and Howe (1946) did not find correlation for ash content within the rib section and the dressed carcass.

These prediction equations by Hankins and Howe (1946) were evaluated by Powell and Huffman (1968) and concluded that this method showed the most accuracy when estimating protein and carcass fat. The validation by Powell and Huffman (1968) compared carcass specific gravity and yield grade to ninth-tenth-eleventh rib section estimation.

Dual-Energy X-Ray Absorptiometry

Dual energy x-ray provides a non-invasive procedure to yield highly accurate results with little radiation to predict body composition in humans (Ross, 2005). Algorithms used during this process differ between high (70keV) and low (38 keV) x-ray absorbance activity (Mitchell et al., 1997). In the early 2000's, Chauhan et al. (2003) claimed this method was the best estimation technique for body composition in humans. Tissue masses of bone, density, fat, and lean are the standard parameter estimated using this technology; however, thick tissues can become problematic for accurate estimations. Lukaski (1993) reported DXA (dual energy x-ray absorptiometry) shows inaccuracy of compositions that vary in thickness and depth.

More work done by Mitchell et al., (1996, 1997, 1998, 2003) has demonstrated this method's benefit in chemical composition of swine and cattle. The Mitchell et al. (1996) study found that the use of dual energy x-ray absorptiometry scanning to predict an estimated total fat ($R^2 = 0.99$) and lean body tissue ($R^2 = 0.97$) for the whole body of sacrificed pigs against chemical analysis. DXA was used in a 2003 study to scan a cross-section of pork carcasses and showed to be closely linked to total carcass composition (Mitchell et al., 2003). In 1997, Mitchell and collaborators conjectured beef tissues can be accurately estimated by DXA scanning as well (Mitchell et al., 1997). It was found that one side of a beef carcass was too large to use the DXA scanning machine, thus, ninth-tenth-eleventh rib section estimation technique with DXA may be more beneficial for use in beef cattle.

Lukaski and collaborators (1999) claim that DXA scanning overestimated fat when using dissection for measurements. The DXA scanning machine had difficulty differentiating fatty and lean tissue types because of greater tissue depth. The same group concluded that dual energy x-ray absorptiometry underestimated total fat content of the carcasses, paired up against chemical analysis, although strong correlations were still found ($R^2 = 0.91$) with percent fat.

Section 4: Strategies to Manipulate Body Composition

Beef Cattle Growth

In 1976, the National Research Council released feed requirements for beef cattle to predict growth rate for cattle of differing frame size (NASEM, 1976). Although a common system today, it is recognized that this technique does not take genetic background or previous plane of nutrition into account. Beef cattle growth is dependent on formulation of diets and the levels of energy and essential nutrients (NASEM, 1976). Pritchard describes beef cattle growth as the increase in dimensions or accumulation of total mass as organisms advance towards cellular and chemical maturity (Pritchard, 1996). Pritchard also states the growth process is set by the genetic makeup at conception. The NASEM (1976) states when excess energy is consumed by cattle over maintenance requirements, growth, reproduction, and lactation can occur. Since the mid 1970's, the introduction of continental European breeds and greater selection for growth of all breeds have influenced the current population of beef cattle. The same effect is represented when studying the wide range of management systems, from grassland to more intensive feeding systems. In 1984, Fox and Black (1984) developed adjustment factors to account for breed, sex, frame size, and use of feed or hormonal treatments that influence growth.

At the cellular level, hyperplasia and hypertrophy are confounding factors when determining an increase in size, number, or mass. Parks (1982) states that growth does not include the phenomenology and etiology of growth, such as energy transactions in the growing animal in terms of the process of metabolism, nutrition, and genetics. Hypertrophy notes the increase in cell size, whereas hyperplasia depicts the increase in cell number (Berg and Butterfield, 1976). The growth of an animal can be determined by both genetic and non-genetic factors, with additive and non-additive genetic combinations that influence growth (Arango and Van Vleck, 2002). Genetic combinations interact with environmental factors such as climate, nutrition, and management, and with inherent effects of age, sex, and physiological status (Arango and Van Vleck, 2002). With multiple factors influencing the standard growth of beef animals, growth has shown to follow a sigmoid curve. This figure represents the variation in rate of growth with age, which will slowly decline to a plateau once the mature weight/size of the animal is achieved (Arango and Van Vleck, 2002).

Growth patterns of cattle are described by Fred Owens (1996) in 4 manners, being 1) normal; 2) retarded; 3) compensatory; and 4) hypercompensatory. It is known that deficiencies in protein and specific minerals in utero can delay, or stunt, an animal's rate of weight gain and mature weight (Fred Owens, 1996). Both compensatory models describe when an animal energy intake is restored after a limited plane of nutrition, with hypercompensatory representing a more accelerated version of compensatory gain.

Efficiency of producing beef carcasses with large amounts of muscle with desirable fat thickness has been the major objective in beef production (Berg and Butterfield, 1976). Many efforts have been presented to increase gain more rapidly, particularly by incorporating genetics with larger mature size. With skeletal muscle representing the greatest change in mass associated with animal growth, the primary concern of study should be focused on muscle (Pritchard, 1996). Berg and Butterfield

(1976) stated that these parameters are paralleled with the trend to move in the direction of less fat. Larger mature size and later fattening result in slaughter animals at heavier weights without additional waste fat (Berg and Butterfield, 1976). Body fat as a proportion of total body weight changes with age. 4 to 6% is the proportion at birth, with an increase to 14 to 16% at puberty, and 28 to 30% proportion of body fatness to body weight in Choice steers (Pritchard, 1996).

As body fat, adipose tissue, and skeletal muscle increasing with maturity, bone growth will begin to plateau once puberty is attained. Pritchard states that bone growth can continue after puberty is reached, especially in castrated animals, until the epiphysis is closed (Pritchard, 1996). Discontinuous growth can be seen in animals that do not have sufficient energy intake to support normal growth, which initiates the conservation of life (Pritchard, 1996). During a state of negative energy balance, adipose tissue is affected first, followed by skeletal muscle, and finally visceral organs. Factors beyond this threshold can equate to permanent growth stunting (Pritchard, 1996).

Crude protein (CP) and carbohydrates are dietary factors that an influence rumen fermentation, metabolism, digestibility, and meat quality (Warren et al., 2008). Both dietary components are large factors of energy, necessary for beef cattle growth, performance, and retained energy that influence body composition. Growth rates and accretion of muscle and carcass fat typically increase at a greater rate in cattle fed grain-based diets compared to forage-based diets. Seventy to eighty percent of ruminant energy requirements come from volatile fatty acids (VFA), which stem from carbohydrates via hydrolysis through rumen microbes (Clark et al., 1992).

Selection of Slaughter Weight

"Slaughter weight has a large influence on carcass composition but in cannot be considered independent of breed, sex and nutritional history" (Berg and Butterfield, 1976). This concept recognizes the effect of previous environment on cattle growth and the challenge of determining the ideal slaughter weight. It is known that after puberty, with a positive plane of nutrition, animals will reach slow the rate of muscle growth in relation to fat deposition (Berg and Butterfield, 1976). Factors that influence the rate of fattening and fat deposition are plane of nutrition, breed, sex, and maturity of the animal (Berg and Butterfield, 1976). Thus, the ideal slaughter weight should tandem a specific maturity point and optimal fat level.

When fattening is past desirable, muscle growth will be slow based on standard growth curves of cattle. Berg and Butterfield (1976) state that energy costs of depositing fat and heightened maintenance costs of heavier animals can result in critically low biological efficiency of muscle tissue growth. This additional growth can be considered economically inefficient weight gain.

Multiple taste panel data was collected and analyzed by Fox and Perry (1996), with overall consumer acceptability scores being 5.3, 5.5, 5.7, 5.8 and 6.2 for Standard, Low Select, High Select, Low Choice, and Mid Choice. These outcomes suggest that quality grade can be a useful predictor of eating satisfaction. Smith and collaborators (1995) reported percent of steaks with less desirable eating quality for prime, choice, select, and standard grades were 5.6, 10.8, 26.4, and 59.1%. This information was presented in the 1995 National Beef Quality Audit, and up to 20% of all beef did not warrant satisfaction from consumers and suggests the percentage of total cattle grading low choice and above be increased (G. C. Smith., 1995).

The Influence of Sex and Growth

The influence of tissue growth is relative to sex, further altering carcass composition and distribution of weight within tissues (Berg and Butterfield, 1976). The fattening process is known to have the largest variation between sex of the animal, with heifers tending to enter the fattening phase of the growth curve at a lighter weight in comparison to steers, and steers later than intact males (Berg and Butterfield, 1976). Although changes are noted in fattening when comparing heifers to steers, they do not differ much in terms of muscle. Muscle to bone can be found presented in a ratio format (muscle:bone), but at equal levels of fat, there is not a difference within the ratio of steers to heifers (Berg and Butterfield, 1976). This should increase the focus of desired endpoint composition for producers, when feeding cattle of different sex.

The Influence of Breed and Growth

With high demands of heavy muscled carcasses with an appropriate degree of marbling, genetic potential is a main factor. Different breeds of beef cattle have been tested with different management/production systems, as well as their crosses. Although reproductive efficiency is not always of focus within the feedlot industry, Berg and Butterfield (1976) see the concept producing offspring that have the genetic potential to reach an ideal weight and composition at slaughter. The same partnership of researchers proposed that there is not just one specific breed with the highest ability to excel regardless of environmental condition. When considering the growth curve previously discussed, fattening begins at different weights dependent on breed (Berg and Butterfield, 1976). It is suggested that breeds that fatten early can be considered for use when feed resources or intake is limited. Later maturing cattle that are slower to fatten, with good environmental and supplementation conditions, should be used when heavier weights are profitable. Cross breeding between the two maturity patterns can show upside to economic efficiency and ideal carcass composition.

With changing input costs, rapid growth of beef animals has been important the past 30 years (Berg and Butterfield, 1976). With the trend to later fattening with efficient feed conversion, the relationship of growth and carcass composition cannot be generalized but investigated further for optimal potential.

Section 5: Summary

Carcass determination techniques, cattle growth curves, and biological influences on each, have been studied to maximize performance to meet the demand of consumers, and provide a baseline to nutritionist, researchers, and meat scientists. Many methods have been discussed for past evaluation of cattle growth and carcass composition, as well as more recently used techniques. Although producers typically target an end weight, carcass composition can be used to increase accuracy. Scientist and cattle feeders have used many different technologies to meet consumer demands while attempting to keep input costs low. The resources above describe methods to estimate the compositional make up of meat animals, with sources to increase the understanding of efficient cattle production.

LITERATURE CITED

Alhassan, W., J. Buchanan-Smith, W. Usborne, G. Smith, and G. Ashton. 1975. Predicting empty body composition of cattle from carcass weight and rib cut composition. Canadian Journal of Animal Science 55(3):369-376. doi: https://doi.org/10.4141/cjas75-045

Arango, J., and L. D. Van Vleck. 2002. Size of beef cows: early ideas, new developments. Faculty Papers and Publications in Animal Science:237.

Bartle, S., S. Kock, R. Preston, T. Wheeler, and G. Davis. 1987. Validation of urea dilution to estimate in vivo body composition in cattle. journal of Animal Science 64(4):1024-1030. doi: https://doi.org/10.2527/jas1987.6441024x

Bartle, S., J. Males, and R. Preston. 1983. Evaluation of urea dilution as an estimator of plasmabody composition in mature cows. Journal of Animal Science 56(2):410-417. doi: https://doi.org/10.2527/jas1983.562410x

Bartle, S., and R. Preston. 1986. Plasma, rumen and urine pools in urea dilution determination of body composition in cattle. Journal of Animal Science 63(1):77-83. doi: https://doi.org/10.2527/jas1986.63177x

Behnke, A. R., B. Feen, and W. Welham. 1942. The specific gravity of healthy men: body weight÷ volume as an index of obesity. Journal of the American Medical Association 118(7):495-498.

Berg, R. T., and R. M. Butterfield. 1976. New concepts of cattle growth. Sydney University Press, University of Sydney.

Bradley, M. A. 1938. Index to Publications of the United States Department of Agriculture 1931-1935. US Government Printing Office.

Chauhan, S., W. W. Koo, M. Hammami, and E. M. Hockman. 2003. Fan beam dual energy X-ray absorptiometry body composition measurements in piglets. Journal of the American College of Nutrition 22(5):408-414. doi: https://doi.org/10.1080/07315724.2003.10719324

Clark, J., T. Klusmeyer, and M. Cameron. 1992. Microbial protein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. Journal of dairy science 75(8):2304-2323.

Cross, H., and A. Whittaker. 1992. The role of instrument grading in a beef value-based marketing system. Journal of Animal Science 70(3):984-989. doi: https://doi.org/10.2527/1992.703984x

G. C. Smith., J. W. S., H. G. Dolezal, T. G Field, D. R. Gill, D. B. Griffin, D. S. Hale, J. B. Morgan, S. L. Northcutt, and J. D. Tatum. 1995. Improving the Quality, Consistency, Competitiveness and Market Share of beef. . National Beef Quality Audit-1995

Garrett, W. 1968. Experiences in the use of body density as an estimator of body composition of animals. Body Composition in Animals and Man. National Academy Science, Washington, DC:170-185.

Garrett, W., and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. Journal of Animal Science 28(1):1-5. doi: https://doi.org/10.2527/jas1969.2811

Gil, E., R. Johnson, V. Cahill, K. McClure, and E. Klosterman. 1970. An evaluation of carcass specific volume, dye dilution and empty body parameters as predictors of beef carcass composition over a wide range of fatness. Journal of Animal Science 31(3):459-469. doi: https://doi.org/10.2527/jas1970.313459x

Guiroy, P., D. Fox, L. Tedeschi, M. Baker, and M. Cravey. 2001. Predicting individual feed requirements of cattle fed in groups. Journal of Animal Science 79(8):1983-1995. doi: https://doi.org/10.2527/2001.7981983x

Hammond, A., T. Rumsey, and G. Haaland. 1984. Estimation of empty body water in steers by urea dilution. Growth 48(1):29-34.

Hammond, A., T. Rumsey, and G. Haaland. 1988. Prediction of empty body components in steers by urea dilution. Journal of animal science 66(2):354-360. doi: https://doi.org/10.2527/jas1988.662354x

Hammond, A., D. Waldo, and T. Rumsey. 1990. Prediction of body composition in Holstein steers using urea space. Journal of dairy science 73(11):3141-3145. doi: https://doi.org/10.3168/jds.S0022-0302(90)79003-0

Hankins, O. G., and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. US Department of Agriculture.

Hopper, T. 1944. Methods of estimating the physical and chemical composition of cattle. Journal of Agricultural Research 68:239-268.

Johnson, B., and J. Beckett. 2014. Application of growth enhancing compounds in modern beef production executive summary. Reference Paper. Champaign (IL): American Meat Science Association:1-15.

Johnson, L., M. Miller, K. Haydon, and J. Reagan. 1990. The prediction of percentage of fat in pork carcasses. Journal of animal science 68(12):4185-4192. doi: https://doi.org/10.2527/1990.68124185x

Klopfenstein, T. J., D. Jordon, I. G. Rush, and T. Milton. 1999. Predicting amount of compensatory gain. Nebraska Beef Cattle Reports:412.

Kock, S., and R. Preston. 1979. Estimation of bovine carcass composition by the urea dilution technique. Journal of Animal Science 48(2):319-327. doi: https://doi.org/10.2527/jas1979.482319x

Kraybill, H., H. Bitter, and O. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. Journal of applied physiology 4(7):575-583. doi: https://doi.org/10.1152/jappl.1952.4.7.575

Lee, J.-C., S. Pushpala, and C. E. Lee. 2000. Polymeric microporous film coated subcutaneous implant. Google Patents.

Lukaski, H. C. 1993. Soft tissue composition and bone mineral status: evaluation by dual-energy X-ray absorptiometry. The Journal of nutrition 123(suppl_2):438-443. doi: https://doi.org/10.1093/jn/123.suppl_2.438

Lukaski, H. C., M. J. Marchello, C. B. Hall, D. M. Schafer, and W. A. Siders. 1999. Soft tissue composition of pigs measured with dual X-ray absorptiometry: comparison with chemical analyses and effects of carcass thicknesses. Nutrition 15(9):697-703. doi: https://doi.org/10.1016/S0899-9007(99)00154-9

Lush, J. 1926. Practical methods op estimating the proportions of fat and bone in cattle slaughtered in com-mercial packing plants1. Journal of Agricultural Research 32(8)

Mader, T. L. 1998. Implants. Veterinary Clinics of North America: Food Animal Practice 14(2):279-290. doi: https://doi.org/10.1016/S0749-0720(15)30254-1

Mitchell, A., J. Conway, and W. Potts. 1996. Body composition analysis of pigs by dual-energy x-ray absorptiometry. Journal of Animal Science 74(11):2663-2671. doi: https://doi.org/10.2527/1996.74112663x

Mitchell, A., R. Rosebrough, and J. Conway. 1997. Body composition analysis of chickens by dual energy x-ray absorptiometry. Poultry Science 76(12):1746-1752. doi: https://doi.org/10.1093/ps/76.12.1746

Mitchell, A. D. 2007. Impact of Research with Cattle, Pigs, and Sheep on Nutritional Concepts: Body Composition and Growth. The Journal of Nutrition 137(3):711-714. doi: 10.1093/jn/137.3.711

Mitchell, D., M. N. Haan, F. M. Steinberg, and M. Visser. 2003. Body composition in the elderly: the influence of nutritional factors and physical activity. The journal of nutrition, health & aging 7(3):130-139.

NASEM. 1976. Nutrient requirements of beef cattle. National Academy of Sciences.

Owens and Hanson. 1996. New Management Approaches to Alter Mature Body Size adn Body Composition. Texas Tech University Department of Animal Science and Food Technology.

Owens, F. N., D. R. Gill, D. S. Secrist, and S. W. Coleman. 1995. Review of some aspects of growth and development of feedlot cattle. Journal of Animal Science 73(10):3152-3172. doi: 10.2527/1995.73103152x

Owens, F. N., and R. B. Hicks. 2019. Can net energy values be determined from animal performance measurements? A review of factors affecting application of the California Net Energy System1. Translational Animal Science 3(3):929-944. doi: 10.1093/tas/txy130

Pace, N., and E. N. Rathbun. 1945. Studies on body composition. 3. The body water and chemically combined nitrogen content in relation to fat content. Journal of Biological Chemistry 158:685-691.

Parks, M. M. 1982. Visual results in aphakic children. American journal of ophthalmology 94(4):441-449. doi: https://doi.org/10.1016/0002-9394(82)90237-9

Perry, D. G. F. a. T. C. 1996. The Composition of Growth in Beef Cattle in Honor of Rodney L. Preston, Ph. D. Texas Tech University Department of Animal Science and Food Technology.

Perry, T., and D. Fox. 1997. Predicting carcass composition and individual feed requirement in live cattle widely varying in body size. Journal of Animal Science 75(2):300-307. doi: https://doi.org/10.2527/1997.752300x

Powell, W., and D. Huffman. 1968. An evaluation of quantitative estimates of beef carcass composition. Journal of animal science 27(6):1554-1558. doi: https://doi.org/10.2527/jas1968.2761554x

Preston, R., and S. Kock. 1973. In vivo prediction of body composition in cattle from urea space measurements. Proceedings of the society for experimental biology and medicine 143(4):1057-1061. doi: https://doi.org/10.3181/00379727-143-374

Preston, R., R. Vance, V. Cahill, and S. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. Journal of animal science 38(1):47-51. doi: https://doi.org/10.2527/jas1974.38147x

Pritchard, R. H. 1996. Compensatory Growth. Texas Tech University Department of Animal Science and Food Technology.

Reinhardt, C. 2007. Growth-Promotant Implants: Managing the Tools. Veterinary Clinics of North America: Food Animal Practice 23(2):309-319. doi: https://doi.org/10.1016/j.cvfa.2007.03.004

Ross, R. A. 2005. Evaluation of Techniques to Estimate Carcass Composition of Beef Cattle, Oklahoma State University.

Rule, D., R. Arnold, E. Hentges, and D. Beitz. 1986. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: validation of published equations and comparison with chemical composition. Journal of Animal Science 63(6):1935-1948. doi: https://doi.org/10.2527/jas1986.6361935x

Smith, Z. K., and B. J. Johnson. 2020. Mechanisms of steroidal implants to improve beef cattle growth: a review. Journal of Applied Animal Research 48(1):133-141. doi: 10.1080/09712119.2020.1751642

Vaseoncelos, J., and M. Galyean. 2008. Do dietary net energy values calculated from performance data offer increased sensitivity for detecting treatment differences? Journal of animal science 86(10):2756-2760.

Wagner, J. J. 1985. Carcass composition in mature Hereford cows: Estimation and influence on metabolizable energy requirements for maintenance during winter. Oklahoma State University.

Warren, H. E., N. D. Scollan, G. Nute, S. Hughes, J. Wood, and R. Richardson. 2008. Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. II: Meat stability and flavour. Meat science 78(3):270-278.

Wells, R. S., and R. L. Preston. 1998. Effects of repeated urea dilution measurement on feedlot performance and consistency of estimated body composition in steers of different breed types. Journal of animal science 76(11):2799-2804. doi: https://doi.org/10.2527/1998.76112799x

CHAPTER II

EFFECT OF LIGHTER (273 KG) AND HEAVIER (356 KG) INITIAL WEIGHT ON GROWTH PERFORMANCE OF SINGLE-SOURCE, PRE-CONDITIONED BEEF STEERS FED A SINGLE GROWING-FINISHING DIET

ABSTRACT

The objective of the study was to determine the influence that initial BW has on growth performance responses, efficiency of dietary net energy (NE) utilization, and carcass traits in feedlot steers. Light- and heavy-weight Charolais×Red Angus steers (n = 70) selected from a larger single-source group were used in a 209-d growing-finishing feedlot experiment at the Ruminant Nutrition Center, in Brookings, SD. On d -1 and d 1 weight and hip height (HH) measurements were collected for allotment purposes; the initial experimental weight was the average between d 0 and d 1 BW. Steers were assigned to two groups based on initial BW (light initial weight, LIW = 273kg; heavy initial weight, HIW = 356kg) and allotted into 10 pens (n = 7 steers per pen; 5 pens per experimental group). Steers were fed a common diet containing 16% roughage (13.1% CP and 23.4% NDF, DM basis) once daily. The diet included liquid supplement containing vitamins and minerals to meet or exceed 2016 NASEM requirements with monensin included at 30 g/ton. Experimental data were analyzed as a randomized complete block design with pen as the experimental unit. Treatment was included as a fixed effect and block (location) was considered a random effect in the statistical model. Observed NEm (P = 0.17) and NEg (P = 0.17) for LIW and HIW did not differ. LIW steers had a greater cumulative HH change (*P* = 0.04). A treatment × day interaction (*P* = 0.05) was observed for HH with HIW steers having a greater HH at all time points. Final BW and carcass-adjusted (HCW/0.625) BW were greater for HIW steers by 13.1% and 13.4% respectively ($P \leq 0.01$). HIW steers had a greater DMI (*P* = 0.01) compared to LIW. Cumulative ADG was greater for HIW by 3% (*P* = 0.04). LIW steers had improved feed conversion (*P* = 0.01; 5.95 and 6.62, respectively). HIW steers had greater ($P \leq$ 0.05) HCW, marbling scores, and yield grade (YG), with decreased REA/HCW (*P* = 0.01) compared to LIW. The distribution of USDA Yield Grade was altered by initial BW (*P* = 0.04). No differences were detected ($P \geq 0.22$) for the distribution of Quality grade nor liver abscess prevalence and severity. In conclusion, HIW steers had greater growth, but poorer feed efficiency compared to LIW steers. Steers with a HIW produced fatter carcasses with a greater degree of marbling.

KEY WORDS: Beef cattle growth, carcass composition, feedlot, frame size, urea space

INTRODUCTION

Cattle feeders in the Northern Plains routinely feed two distinct diets during production. Forage-based diets are commonly fed during the backgrounding phase with concentrate-based diets fed during the finishing phase. Overall goals of backgrounding programs include: 1) managing disease and health, 2) achieving economical gains, 3) enhancing finishing phase feed conversion, 4) optimizing total carcass weight gain, and 5) managing feeder cattle supply into the feedlot phase of production. Previous work within our lab group conducted by Hamilton (2022) demonstrates cattle fed a single growing-finishing diet had similar growth performance and carcass traits upon harvest as compared to steers fed within a two-diet phase system.. However, that experiment used steers that were uniform in weight. It was not clear if using steers with similar genetics but differing initial weight would demonstrate the same growth responses when fed a single diet an extended growing-finishing period. The objective of this experiment was to determine the influence that estimated frame size (smaller or larger) at placement had on growth performance responses, changes in body composition, efficiency of dietary net energy (NE) utilization, and carcass traits in steers fed a single diet during a 209-d growing - finishing period.

MATERIALS AND METHODS

Use of Animal Subjects

This study was conducted at the Ruminant Nutrition Center (RNC) in Brookings, SD, USA between December 2021 and July 2022. Animal care and handling procedures used in this study were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval Number: 2110-063A).

Animals, Initial Processing, and Study Initiation

Pre-conditioned crossbred beef steers (n = 70; initial shrunk [4%] BW = 329 ± 72.6 kg) were used in a 209-d experiment at the Ruminant Nutrition Center (RNC) in Brookings, SD. Steers were fed once daily, and bunks were managed according to a slick bunk management system. Light- and heavy-weight Charolais×Red Angus steers selected from the heavy and lighter tails of a larger group from a single South Dakota ranch. Steers were received approximately 2 months (56 d) before study initiation were used. Cattle were fed in 7.62 × 7.62 m concrete surface pens (n = 10 pens total; 7 steers/pen; 5 replicate pens/treatment mean) with 7.62 m of bunk space and heated, concrete, continuous flow waterers.

Steers were vaccinated at receiving against viral respiratory diseases (Bovishield Gold 5; Zoetis, Parsippany, NJ), clostridial species (Ultrabac 7/Somubac, Zoetis), and administered pour on moxidectin (Cydectin, Bayer, Shawnee Mission, KS) before the initiation of this study. At study initiation, steers were weighed (scale readability 0.454 kg) and processed on d-1 and were weighted again and allocated to study pens on d1.

Individual BW and hip heights (HH) were collected at study initiation. Steers were administered an implant on d1 (100 mg trenbolone acetate and 14 mg estradiol benzoate; Synovex Choice, Zoetis) and reimplanted on d112 (200 mg trenbolone acetate and 28 mg estradiol benzoate; Synovex Plus, Zoetis). Implant retention was checked on d 63 and d 153 with no major abnormalities noted.

Experimental Design and Treatments

This experiment was a randomized complete block design with 7 steers per pen, blocked by pen location. A total of 10 pens were used with 5 replicates per experimental group. Treatments included 1) Lighter Initial Weight (LIW) and 2) Heavier Initial Weight (HIW).

Dietary Management

Steers were fed a common diet containing 16% roughage (13.1% CP and 23.4% NDF; Table 1). Finishing diets consisted of dry rolled corn (DRC), high moisture corn (HMC), liquid supplement (LS), dried distiller's grains (DDGS), and corn silage (CRNSIL). Liquid supplement (LS) was provided to add 30 g/ton of monensin sodium to diet DM along with supplemental vitamins and minerals to meet (NASEM, 1976) requirements.

A slick bunk management approach was used with feed bunks visually assessed for residual feed daily at 0700 daily. Fresh feed was manufactured once daily at 0800 for each treatment in a single batch using a mixing wagon (2.35 m^3; scale readability 0.454 kg). Diets were fortified to provide vitamins and minerals to meet or exceed nutrient requirements (NASEM, 1976) and provided monensin sodium (Rumensin 90; Elanco, Indianapolis, IN) at 30 g / 907 kg (DM basis). Steers were fed ractopamine hydrochloride (Optaflexx 45, Elanco, Indianapolis, IN) at a rate of 300 mg per steer for the final 28-d before harvest. Orts were collected, weighed, and dried in a forced air oven at 100 °C for 24 h to determine DM content if carryover feed went out of condition or was present on weigh days.

Diets presented in Table 1 are actual diet DM formulation based upon weekly ingredient DM analyses (drying at 60 °C until no weight change) and tabular nutrient values for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, ether extract (EE) and tabular energy values according to (Preston, 2016).

Growth Performance Calculations

All steers were weighed individually on d-1, 1, 63, 112, 125, 153, 181, and 209. All interim period growth performance data was based upon live weight reduced 4% to account for digestive tract fill. Cumulative growth performance was based upon initial BW (average BW from d -1 and 1 with a 4% shrink applied to account for digestive tract fill) and final BW from d209 (FBW, shrunk 4%) and carcass-adjusted final BW (HCW divided by 0.625. Average daily gain (ADG) was calculated as the difference between FBW and initial shrunk BW, divided by days on feed and feed efficiency was calculated from ADG/DMI.

Growth performance was used to calculate performance-based dietary NE to determine efficiency of dietary NE utilization. The performance-based dietary NE was calculated from daily energy gain (EG; Mcal/d): $EG = ADG^{1.097} \times 0.0557W^{0.75}$, where W is the mean equivalent shrunk BW [kg; (NRC, 1996)] from mean feeding shrunk BW and final BW at 28% estimated empty body fatness (AFBW) was calculated as: [median feeding shrunk BW × (478/AFBW), kg; (NASEM, 1984)]. Maintenance energy (EM) was calculated by the equation: EM = 0.077 × median feeding shrunk BW$^{0.75}$. Dry matter intake is related to energy requirements and dietary NEm (Mcal/kg) according to the following equation: DMI = EG/(0.877NEm − 0.41), and can be resolved for estimation of dietary NEm by means of the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2c}$, where a = −0.41EM, b = 0.877EM + 0.41DMI + EG, and c = −0.877DMI (Zinn and Shen, 1998). Dietary NEg was derived from NEm using the following equation: NEg= 0.877NEm − 0.41 (Zinn, 1987).

Hip Height Collection

Hip height (HH) collections occurred on all steers on d1, 63, 112, 125, 153, 181, and 209. A tape measure was secured to the top of the chute 183 cm from the chute flooring. The tape measure was pulled down to meet the hip of the steer perpendicularly. This measurement was then subtracted from the height above the chute floor to calculate HH.

Urea Space Determination

Urea space measurements were determined using the technique described by (Preston and Kock, 1973b) on sentinel steers (n = 1 steer/pen), selecting a steer that represents the median weigh of each pen. The urea solution was 20% urea in 0.9% saline solution (w/v) and was infused at a rate of 0.75 mL solution per kilogram of shrunk body weight or 150 mg urea per kilogram of live body weight. Before infusion, the solution was filtered through a 0.8 µm filter unit. The urea solution was mixed and filtered within 24 h of infusion. The solution was stored at 4°C. Feed nor water were withheld prior to infusions. Urea infusions were accomplished using jugular venipuncture with a 16-gauge x 1 ½ inch needle to ensure that all the infusate would go directly into the blood supply and reduce the possibility of injecting the infusion solution subcutaneously. The tubing was flushed with 5 mL of heparinized saline (100 units heparin per mL of saline). Before collecting a sample, approximately 5 mL of blood was drawn into a syringe and then reinjected through the catheter; thus, allowing for all blood samples collected to be fresh and have a homogeneous urea concentration. A 10 mL blood sample was collected (T0) before injecting any infusate into the steer. Blood samples were stored on ice and in a sterile Vacutainer® (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) with no additive and centrifuged at 4°C at 1250 × g to harvest sera. The predetermined volume of infusate, 0.75 mL solution per kilogram of shrunk live body weight, was infused within 2 minutes using a 60 mL syringe. Infusion times were recorded on a data sheet, using the mid-point of infusion as the starting time, along with animal number, weight, and quantity of infusate injected. Twelve minutes later (T12), a blood sample was taken using the same collection procedure as above. The accuracy of the volume of infusate injected was gravimetrically determined by infusing into three volumetric flasks, once each at the beginning, mid-point, and end of the sampling day. Blood samples were centrifuged at 3,000 x G for 20 minutes. Sera urea nitrogen (SUN) analysis was performed within 24 h according to the methods described by (Fawcett and Scott, 1960).

Percent urea space (US) was calculated using the equation described by (Adamski, 2013): $\frac{mg\ urea\ infused}{Delta\ SUN\ \left(\frac{mg}{dL}\right)\times EBW)}$, where Delta SUN is the change in SUN concentration of the blood between T0 and T12 and EBW was calculated as unshrunk BW multiplied by 0.857. All samples were analyzed in triplicate and samples were considered for reruns if the coefficient of variation within triplicate runs was greater than 10%. The intra- and inter- assay coefficient of variation were less than 12%. Percent empty body water (EBH_2O), percent empty body fat (EBF) and percent carcass protein of each steer was calculated with the following equations (Rule et al., 1986b).

1. % EBH_2O = 59.1 + 0.22 × US% – 0.04 × EBW
2. % EBF = 19.5 – 0.31 × US% + 0.05 × EBW
3. % Carcass Protein = 16.7 + 0.07 × US% + 0.01 × EBW

Carcass Trait Determination

Steers were marketed and harvested at a commercial abattoir when treatment blinded personnel determine that 60% of the population has sufficient fat cover to grade USDA Choice. Steers were loaded onto trucks, shipped 238 km, and harvested the following day at Tyson Fresh Meats in Dakota City, NE. Liver abscess prevalence and severity was determined by a trained technician using the Elanco system as: Normal (no abscesses), A- (1 or 2 small abscesses or abscess scars), A (2 to 4 well organized abscesses less than 1 in. diameter), or A+ (1 or more large active abscesses greater than 1 in. diameter with inflammation of surrounding tissue). Video image data was obtained from the plant for rib eye area, rib fat, kidney-pelvic-heart fat, calculated USDA Yield

Grade and USDA marbling scores. Dressing percentage was calculated as HCW/(final BW × 0.96). Estimated empty body fat (EBF) percentage and AFBW was calculated from observed carcass traits (Guiroy et al., 2002), and proportion of closely trimmed boneless retail cuts from carcass round, loin, rib, and chuck was determined according to the equation described by (Murphey et al., 1960).

Management of Pulls and Removals

All steers that were pulled from their home pen for health evaluation were monitored in individual hospital pens prior to being returned to their home pens. When a steer was moved to a hospital pen the appropriate amount of feed from their home pen was removed and transferred to the hospital pen. If the steer in the hospital returned to their home pen, this feed remained credited to the home pen. If the steer did not return to their home pen, all feed that was delivered to the hospital pen was deducted from the feed intake record for that particular pen back to the date the steer was hospitalized. Three steers were removed from their home pens during this experiment for treatment and returned to their home pen upon recovery, with illness reasons unrelated to treatment.

Statistical Analysis

Growth performance, carcass traits, and efficiency of dietary NE utilization was analyzed as a randomized complete block design using the GLIMMIX procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. The model included the fixed effect of treatment and random effect of pen location. Least squares means were generated using the LSMEANS statement of SAS and treatment effects were analyzed using the pairwise comparisons PDIFF and LINES option of SAS 9.4. Distribution of USDA Yield and Quality grade data as well as liver abscess prevalence and severity were analyzed as a multinomial distribution in the GLIMMIX procedure of SAS 9.4 with fixed effect in the model as described previously. Regression coefficients for empty body percentages of water, fat and protein were calculated using PROC GLM. Linear and quadratic models for body composition parameters were compared using the adjusted r-squared value as the selection criteria. Regressions coefficients for the two treatment groups were compared using procedures as detailed in Steel and Torrie (1960). An α of 0.05 or less was used to determine significance with tendencies between 0.05 and 0.10.

RESULTS

Growth Performance day 1 to day 112

Growth performance and carcass data from this experiment are located on Table 2. HIW steers had heavier (*P* = 0.01; 356 vs. 273 kg) initial BW compared to LIW by design, and HIW treatment remained heavier (*P* = 0.01; 527 vs. 442 kg) through d 112. Initial HH was greater (*P* = 0.01) for HIW steers and remained larger framed (*P* = 0.01) through d 112 compared to LIW. Daily HH change from study initiation until d 112 was greater for LIW steer (*P* = 0.03). ADG did not differ (*P* = 0.50; 1.66 vs. 1.61 kg) during this feeding period. DMI (kg) was greater for HIW steers (*P* = 0.01; 11 vs. 9.62 kg) compared to LIW. LIW steers were more efficient (G:F) (*P* = 0.01) from study initiation to d112 than HIW. An increased maintenance coefficient (MQ) was noted for HIW (*P* = 0.02) compared to LIW steers. Observed dietary NEm and NEg (Mcal/kg) based on growth performance were increased for LIW (*P* = 0.02).

Growth Performance day 113 to day 209

After reimplantation on d 112, HH daily gain was not significantly different (*P* = 0.26) between treatment groups. No difference was noted for ADG (*P* = 0.26) during this period. DMI was greater for HIW steers (*P* = 0.01; 11.91 vs. 10.78 kg) compared to LIW steers. LIW steers tended (*P* = 0.08) to have increased efficiency (G:F). No difference between treatments was noticed for MQ (*P* = 0.85) or observed NEm or NEg (*P* = 0.99).

Cumulative Growth Performance

BW was increased for HIW cattle (*P* = 0.01; 701 vs. 610 kg) and had greater final HH (*P* = 0.01) compared to LIW steers. Carcass adjusted (HCW/0.625) BW was increased for HIW steers (*P* = 0.01) and carcass adjusted ADG (*P* = 0.04) was also greater for HIW. Cumulative HH daily gain was increased for LIW steers (*P* = 0.04). Cumulative DMI was increased for HIW steers (*P* = 0.01; 11 vs. 9.61 kg). LIW steers were more efficient as measured on either a live (*P* = 0.01) or carcass adjusted (*P* = 0.01) basis. No differences were noted between treatment groups for cumulative live, or carcass adjusted MQ (*P* = 0.19 and *P* = 0.29, respectively). Performance-adjusted observed NEm and NEg (*P* = 0.17) did not differ between treatment groups when measured over the entire experiment.

Carcass composition determined from urea space

Regression coefficients for empty body percentages of water, fat and protein were calculated using PROC GLM and represented on Figure 1. Coefficients for the two treatment groups were compared using procedures as detailed in (Steel and Torrie, 1960). Regression coefficients did not differ between LIW and HIW for urea space calculations of empty body water, fat, or protein ($P \geq 0.70$). A quadratic response was noted for empty body fat (EBF), empty body water (EBH20), and carcass protein (CP). Empty body water decreased at an increasing rate as both treatment groups gained weight. Empty body fat increased at a decreasing rate as the treatment groups got heavier. Carcass protein gradually increased as the cattle put on weight. The quadratic equations for HIW had greater r-squared than LIW across the three studied components. With the HIW treatment group starting and ending the trial ~80kg heavier, the proportion of each component (EBF, EBH20, and CP) would have been greater, causing a greater r-squared value.

Carcass Characteristics

Carcass data from this experiment are located on Table 2. HIW steers had increased HCW (*P* = 0.01) compared to LIW cattle. No difference was detected for dressing percentage (*P* = 0.58) between treatment groups. A tendency was found (*P* = 0.06) for HIW steers to have a larger ribeye area (REA), but REA/HCW was greater for

LIW steers (*P* = 0.01). HIW steers tended (*P* = 0.09) to have more rib fat (RF, mm). HIW steers had a greater degree of marbling (*P* = 0.05) and a greater numerical yield grade (YG) (*P* = 0.04). LIW steers had a greater proportion (P = 0.04) of YG1 carcasses compared to HIW steers. LIW steers had increased retail yield (*P* = 0.04) and empty body fat (EBF, %) (*P* = 0.02). Adjusted final body weight (AFBW, kg) was greater for HIW steers (*P* = 0.01; 627 vs. 573). Liver abscess severity did not differ between treatment groups (*P* = 0.53).

DISCUSSION AND IMPLICATIONS

Within this experiment, genetics across both treatment groups were similar as they were sourced from a singular ranch with alike gene pools. Both the LIW and HIW cattle were fed a common 16% roughage inclusion diet throughout the duration of the 209 days. Most other research conducted within this field have confounding factors of genetics and comparison of multiple diets when comparing cattle of different frame sizes. The growth performance results in this experiment combined with urea space composition results suggest that these cattle did not differ in frame size, but potentially differ in age as there was a 60-day calving window within the entire group. The HIW steers had increased ADG and final BW, but a poorer G:F compared to LIW cattle. This suggests that composition of gain on HIW, as shown by the urea space determination and carcass results, had a greater proportion of adipose tissue as opposed to muscle later in the feeding period. It is evident the cattle were compositionally growing at the same rate, but with different starting intercepts, suggesting that the higher efficiency in the LIW cattle was due to composition of muscle gain for a longer period. Regression coefficients did not differ between LIW and HIW for urea space calculations of empty body water, fat, or protein ($P \geq 0.70$). This shows that the rate of change when regressing EBF, EBW, and CP against EBW, there was no difference between treatment groups. Conventional knowledge may have predicted the LIW cattle to fatten faster with this treatment group starting on a 16% roughage diet at a lighter entry weight, however; under the conditions of this experiment, LIW did not get fatter faster or affect targeted composition when placed on a 16% roughage diet through the growing-finishing phase. This may suggest that even though the LIW cattle would take longer to reach the same compositional end point as the HIW steers, LIW treatment group grew at the same rate as HIW. However, in this current experiment, all cattle were harvested on the same date, meaning we can only speculate how the LIW cattle would have performed with additional days on feed.

Feedlot producers may do a pre-sort or an end-sort of cattle in their standard practice, but this research suggests that putting cattle with similar entry weights together may be beneficial to ensure steady growth rates to capitalize on an optimal carcass composition upon harvest. This method would help level the field of competition when referencing bunk space. Although the LIW steers had a shorter hip heigh throughout the duration of this trial, the graph exhibited in Figure 1 suggests that LIW would reach similar final hip heigh as HIW cattle with additional days on feed. Throughout the duration of this 209d trial, the LIW steers had a greater cumulative HH rate of increase, seen in Figure 1.

Work done at Cornell University (Simpfendorfer, 1973) used Holstein and Angus bulls and heifers to study the relationship of full body weight, empty body weight, and shrunk body weight. In that experiment, SBW was an excellent predictor of EBW, and authors concluded that EBW could be used as a good predictor of warm carcass weight. Within our experiment, HIW steers had greater HCW and Yield Grade compared to LIW steers, but this information is predictable with this trial creating as stark of a difference as possible with cattle of similar genetic make.

Previous work from our lab (Hamilton, 2022) demonstrated that a single growing-finishing diet achieved a similar outcome compared to a two-diet system. The results of the current experiment show that the larger and smaller tails of a population of cattle grew at similar rates with similar rates of accretion for both protein and fat. Feeding smaller cattle a diet containing 84% concentrate at near ad libitum intake did not result in more rapid fat accumulation. This research suggests that there is no need to feed separate diets to optimize growth, but to sort cattle of like weight together and feed lighter weight cattle longer.

LITERATURE CITED

Adamski, M. 2013. Intravital assessment of body composition of cows in various production periods using urea dilution procedures. Archives Animal Breeding 56(1):899-910.

Alhassan, W., J. Buchanan-Smith, W. Usborne, G. Smith, and G. Ashton. 1975. Predicting empty body composition of cattle from carcass weight and rib cut composition. Canadian Journal of Animal Science 55(3):369-376. doi: https://doi.org/10.4141/cjas75-045

Arango, J., and L. D. Van Vleck. 2002. Size of beef cows: early ideas, new developments. Faculty Papers and Publications in Animal Science:237.

Bartle, S., S. Kock, R. Preston, T. Wheeler, and G. Davis. 1987. Validation of urea dilution to estimate in vivo body composition in cattle. journal of Animal Science 64(4):1024-1030. doi: https://doi.org/10.2527/jas1987.6441024x

Bartle, S., J. Males, and R. Preston. 1983. Evaluation of urea dilution as an estimator of body composition in mature cows. Journal of Animal Science 56(2):410-417. doi: https://doi.org/10.2527/jas1983.562410x

Bartle, S., and R. Preston. 1986. Plasma, rumen and urine pools in urea dilution determination of body composition in cattle. Journal of Animal Science 63(1):77-83. doi: https://doi.org/10.2527/jas1986.63177x

Behnke, A. R., B. Feen, and W. Welham. 1942. The specific gravity of healthy men: body weight÷ volume as an index of obesity. Journal of the American Medical Association 118(7):495-498.

Berg, R. T., and R. M. Butterfield. 1976. New concepts of cattle growth. Sydney University Press, University of Sydney.

Bradley, M. A. 1938. Index to Publications of the United States Department of Agriculture 1931-1935. US Government Printing Office.

Chauhan, S., W. W. Koo, M. Hammami, and E. M. Hockman. 2003. Fan beam dual energy X-ray absorptiometry body composition measurements in piglets. Journal of the American College of Nutrition 22(5):408-414. doi: https://doi.org/10.1080/07315724.2003.10719324

Clark, J., T. Klusmeyer, and M. Cameron. 1992. Microbial protein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. Journal of dairy science 75(8):2304-2323.

Cross, H., and A. Whittaker. 1992. The role of instrument grading in a beef value-based marketing system. Journal of Animal Science 70(3):984-989. doi: https://doi.org/10.2527/1992.703984x

Fawcett, J. K., and J. E. Scott. 1960. A rapid and precise method for the determination of urea. J Clin Pathol 13(2):156-159. doi: 10.1136/jcp.13.2.156

Fred Owens, J. H., and Christa Hanson. 1996. New Management Approaches to Alter Mature Body Size adn Body Composition. Texas Tech University Department of Animal Science and Food Technology.

G. C. Smith., J. W. S., H. G. Dolezal, T. G Field, D. R. Gill, D. B. Griffin, D. S. Hale, J. B. Morgan, S. L. Northcutt, and J. D. Tatum. 1995. Improving the Quality, Consistency, Competitiveness and Market Share of beef. . National Beef Quality Audit-1995

Galyean, M. L., N. A. Cole, L. O. Tedeschi, and M. E. Branine. 2016. BOARD-INVITED REVIEW: Efficiency of converting digestible energy to metabolizable energy and reevaluation of the California Net Energy System maintenance requirements and equations for predicting dietary net energy values for beef cattle1. Journal of Animal Science 94(4):1329-1341. doi: https://doi.org/10.2527/jas.2015-0223

Garrett, W. 1968. Experiences in the use of body density as an estimator of body composition of animals. Body Composition in Animals and Man. National Academy Science, Washington, DC:170-185.

Garrett, W., and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. Journal of Animal Science 28(1):1-5. doi: https://doi.org/10.2527/jas1969.2811

Garrett, W. N., J. H. Meyer, and G. P. Lofgreen. 1959. The Comparative Energy Requirements of Sheep and Cattle for Maintenance and Gain1. Journal of Animal Science 18(2):528-547. doi: 10.2527/jas1959.182528x

Gil, E., R. Johnson, V. Cahill, K. McClure, and E. Klosterman. 1970. An evaluation of carcass specific volume, dye dilution and empty body parameters as predictors of beef carcass composition over a wide range of fatness. Journal of Animal Science 31(3):459-469. doi: https://doi.org/10.2527/jas1970.313459x

Guiroy, P., D. Fox, L. Tedeschi, M. Baker, and M. Cravey. 2001. Predicting individual feed requirements of cattle fed in groups. Journal of Animal Science 79(8):1983-1995. doi: https://doi.org/10.2527/2001.7981983x

Guiroy, P. J., L. O. Tedeschi, D. G. Fox, and J. P. Hutcheson. 2002. The effects of implant strategy on finished body weight of beef cattle. J. Anim. Sci. 80(7):1791-1800. doi: 10.2527/2002.8071791x

Hamilton, T. G. 2022. Optimization of Forage Use in Diets Fed to Backgrounding and Finishing Cattle in the Northern Great Plains. South Dakota State University.

Hammond, A., T. Rumsey, and G. Haaland. 1984. Estimation of empty body water in steers by urea dilution. Growth 48(1):29-34.

Hammond, A., T. Rumsey, and G. Haaland. 1988. Prediction of empty body components in steers by urea dilution. Journal of animal science 66(2):354-360. doi: https://doi.org/10.2527/jas1988.662354x

Hammond, A., D. Waldo, and T. Rumsey. 1990. Prediction of body composition in Holstein steers using urea space. Journal of dairy science 73(11):3141-3145. doi: https://doi.org/10.3168/jds.S0022-0302(90)79003-0

Hankins, O. G., and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. US Department of Agriculture.

Hopper, T. 1944. Methods of estimating the physical and chemical composition of cattle. Journal of Agricultural Research 68:239-268.

Johnson, B., and J. Beckett. 2014. Application of growth enhancing compounds in modern beef production executive summary. Reference Paper. Champaign (IL): American Meat Science Association:1-15.

Johnson, L., M. Miller, K. Haydon, and J. Reagan. 1990. The prediction of percentage of fat in pork carcasses. Journal of animal science 68(12):4185-4192. doi: https://doi.org/10.2527/1990.68124185x

Klopfenstein, T. J., D. Jordon, I. G. Rush, and T. Milton. 1999. Predicting amount of compensatory gain. Nebraska Beef Cattle Reports:412.

Kock, S., and R. Preston. 1979. Estimation of bovine carcass composition by the urea dilution technique. Journal of Animal Science 48(2):319-327. doi: https://doi.org/10.2527/jas1979.482319x

Kraybill, H., H. Bitter, and O. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. Journal of applied physiology 4(7):575-583. doi: https://doi.org/10.1152/jappl.1952.4.7.575

Lee, J.-C., S. Pushpala, and C. E. Lee. 2000. Polymeric microporous film coated subcutaneous implant. Google Patents.

Lukaski, H. C. 1993. Soft tissue composition and bone mineral status: evaluation by dual-energy X-ray absorptiometry. The Journal of nutrition 123(suppl_2):438-443. doi: https://doi.org/10.1093/jn/123.suppl_2.438

Lukaski, H. C., M. J. Marchello, C. B. Hall, D. M. Schafer, and W. A. Siders. 1999. Soft tissue composition of pigs measured with dual X-ray absorptiometry: comparison with chemical analyses and effects of carcass thicknesses. Nutrition 15(9):697-703. doi: https://doi.org/10.1016/S0899-9007(99)00154-9

Lush, J. 1926. PRACTICAL METHODS OP ESTIMATING THE PROPORTIONS OF FAT AND BONE IN CATTLE SLAUGHTERED IN COM-MERCIAL PACKING PLANTS1. Journal of Agricultural Research 32(8)

Mader, T. L. 1998. Implants. Veterinary Clinics of North America: Food Animal Practice 14(2):279-290. doi: https://doi.org/10.1016/S0749-0720(15)30254-1

Mitchell, A., J. Conway, and W. Potts. 1996. Body composition analysis of pigs by dual-energy x-ray absorptiometry. Journal of Animal Science 74(11):2663-2671. doi: https://doi.org/10.2527/1996.74112663x

Mitchell, A., R. Rosebrough, and J. Conway. 1997. Body composition analysis of chickens by dual energy x-ray absorptiometry. Poultry Science 76(12):1746-1752. doi: https://doi.org/10.1093/ps/76.12.1746

Mitchell, A. D. 2007. Impact of Research with Cattle, Pigs, and Sheep on Nutritional Concepts: Body Composition and Growth. The Journal of Nutrition 137(3):711-714. doi: 10.1093/jn/137.3.711

Mitchell, D., M. N. Haan, F. M. Steinberg, and M. Visser. 2003. Body composition in the elderly: the influence of nutritional factors and physical activity. The journal of nutrition, health & aging 7(3):130-139.

Murphey, C. E., D. K. Hallett, W. E. Tyler, and J. C. Pierce. 1960. Estimating yields of retail cuts from beef carcass. Proc. Am. Soc. Anima. Prod., Chicago, IL.

NASEM. 1976. Nutrient requirements of beef cattle. National Academy of Sciences.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7 ed.

Owens, F. N., D. R. Gill, D. S. Secrist, and S. W. Coleman. 1995. Review of some aspects of growth and development of feedlot cattle. Journal of Animal Science 73(10):3152-3172. doi: 10.2527/1995.73103152x

Owens, F. N., and R. B. Hicks. 2019. Can net energy values be determined from animal performance measurements? A review of factors affecting application of the California Net Energy System1. Translational Animal Science 3(3):929-944. doi: 10.1093/tas/txy130

Pace, N., and E. N. Rathbun. 1945. Studies on body composition. 3. The body water and chemically combined nitrogen content in relation to fat content. Journal of Biological Chemistry 158:685-691.

Parks, M. M. 1982. Visual results in aphakic children. American journal of ophthalmology 94(4):441-449. doi: https://doi.org/10.1016/0002-9394(82)90237-9

Perry, D. G. F. a. T. C. 1996. The Composition of Growth in Beef Cattle in Honor of Rodney L. Preston, Ph. D. Texas Tech University Department of Animal Science and Food Technology.

Perry, T., and D. Fox. 1997. Predicting carcass composition and individual feed requirement in live cattle widely varying in body size. Journal of Animal Science 75(2):300-307. doi: https://doi.org/10.2527/1997.752300x

Powell, W., and D. Huffman. 1968. An evaluation of quantitative estimates of beef carcass composition. Journal of animal science 27(6):1554-1558. doi: https://doi.org/10.2527/jas1968.2761554x

Preston, R. 2016. 2016 feed composition table. Beef Magazine:16-34.

Preston, R., and S. Kock. 1973a. In vivo prediction of body composition in cattle from urea space measurements. Proceedings of the society for experimental biology and medicine 143(4):1057-1061. doi: https://doi.org/10.3181/00379727-143-374

Preston, R., R. Vance, V. Cahill, and S. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. Journal of animal science 38(1):47-51. doi: https://doi.org/10.2527/jas1974.38147x

Preston, R. L., and S. W. Kock. 1973b. In vivo prediction of body composition in cattle from urea space measurements. Proc Soc Exp Biol Med 143(4):1057-1061. doi: 10.3181/00379727-143-37470

Pritchard, R. H. 1996. Compensatory Growth. Texas Tech University Department of Animal Science and Food Technology.

Reinhardt, C. 2007. Growth-Promotant Implants: Managing the Tools. Veterinary Clinics of North America: Food Animal Practice 23(2):309-319. doi: https://doi.org/10.1016/j.cvfa.2007.03.004

Ross, R. A. 2005. Evaluation of Techniques to Estimate Carcass Composition of Beef Cattle, Oklahoma State University.

Rule, D., R. Arnold, E. Hentges, and D. Beitz. 1986a. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: validation of published equations and comparison with chemical composition. Journal of Animal Science 63(6):1935-1948. doi: https://doi.org/10.2527/jas1986.6361935x

Rule, D. C., R. N. Arnold, E. J. Hentges, and D. C. Beitz. 1986b. Evaluation of urea dilution as a technique for estimating body composition of beef steers in vivo: validation of published equations and comparison with chemical composition. J Anim Sci 63(6):1935-1948. doi: 10.2527/jas1986.6361935x

Rusche, W. C., and J. A. Walker. 2015. Integrating Backgrounding Cattle with a Cow-Calf Enterprise, iGrow Beef "Best Management Practices for Cow-Calf Production, South Dakota State Univeristy.

Samuelson, K. L., M. E. Hubbert, M. L. Galyean, and C. A. Löest. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey1. Journal of Animal Science 94(6):2648-2663. doi: 10.2527/jas.2016-0282

Simpfendorfer, S. 1973. Relationship of body type and size, sex, and energy intake to the body composition of cattle. Cornell University.

Smith, Z. K., and B. J. Johnson. 2020. Mechanisms of steroidal implants to improve beef cattle growth: a review. Journal of Applied Animal Research 48(1):133-141. doi: 10.1080/09712119.2020.1751642

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. Principles and procedures of statistics.

Vaseoncelos, J., and M. Galyean. 2008. Do dietary net energy values calculated from performance data offer increased sensitivity for detecting treatment differences? Journal of animal science 86(10):2756-2760.

Wagner, J. J. 1985. Carcass composition in mature Hereford cows: Estimation and influence on metabolizable energy requirements for maintenance during winter. Oklahoma State University.

Warren, H. E., N. D. Scollan, G. Nute, S. Hughes, J. Wood, and R. Richardson. 2008. Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. II: Meat stability and flavour. Meat science 78(3):270-278.

Wells, R. S., and R. L. Preston. 1998. Effects of repeated urea dilution measurement on feedlot performance and consistency of estimated body composition in steers of different breed types. Journal of animal science 76(11):2799-2804. doi: https://doi.org/10.2527/1998.76112799x

Zinn, R. A. 1987. Influence of Lasalocid and Monensin Plus Tylosin on Comparative Feeding Value of Steam-Flaked Versus Dry-Rolled Corn in Diets for Feedlot Cattle. J Anim Sci 65(1):256-266. doi: 10.2527/jas1987.651256x

Zinn, R. A., and Y. Shen. 1998. An evaluation of ruminally degradable intake protein and metabolizable amino acid requirements of feedlot calves. J Anim Sci 76(5):1280-1289. doi: 10.2527/1998.7651280x

Table 1: Actual diet formulation and nutrient composition[1,2]

	DOF					
Ingredient Inclusion, %	1-21	22-40	41-82	83-115	116-178	179-209
Dry-Rolled Corn	60.85	31.74	23.64	20.38	16.52	48.20
Liquid supplement	6.08	6.15	5.90	6.20	5.11	4.94
DDGS	15.23	15.29	15.32	14.42	15.31	15.08
Oat Hay	-	-	-	15.08	-	-
Wheatlage	17.84	14.71	-	-	-	-
HMC	-	32.11	23.79	43.92	33.17	-
Corn Silage	-	-	31.35	-	29.90	31.78
Diet Composition						
Dry Matter,%	64.64	62.74	58.79	79.46	56.71	54.54
Crude Protein,%	13.53	13.50	12.83	13.33	12.95	12.82
Neutral Detergent Fiber,%	22.48	20.83	24.67	21.11	24.19	24.84
Acid Detergent Fiber,%	12.08	11.03	13.57	11.19	13.24	13.65
Ash,%	6.75	6.59	6.58	6.48	6.07	6.03
Ether Extract,%	3.61	3.61	3.60	3.59	8.19	8.03
NEm, Mcal/kg	2.01	2.05	2.01	2.05	2.00	1.97
NEg, Mcal/kg	1.32	1.36	1.35	1.36	1.35	1.32

[1]All values except for DM on a DM basis.

[2] Tabular NE and nutrient values from Preston (2016) and actual DM composition from weekly DM assays.

Table 2. Growth performance for steers with lighter or heavier initial weights fed a common diet for 209 d.

Item	Frame Size (Placement BW)		SEM	*P* - value
	Smaller	Larger		
No. pens	5	5	-	-
No. steers	35	35	-	-
Weaning weight[1], kg	217	291	2.5	0.01
Pre-conditioning BW (d -1)[2], kg	283	367	1.6	0.01
Pre-conditioning ADG[3], kg	1.17	1.36	0.041	0.01
Hip Height (HH), cm				
Initial	114.45	122.32	0.188	0.01
d 112	127.15	133.40	0.116	0.01
d 209	135.38	140.51	0.291	0.01
HH daily gain, cm				
Initial to 112	0.1135	0.0988	0.00181	0.03
d 113 to 209	0.0848	0.0734	0.00346	0.26
Cumulative	0.1003	0.0871	0.00172	0.04
BW, kg				
Initial [4,5]	273	356	1.6	0.01
d 112 [5]	442	527	8.2	0.01
d 209 [5]	610	702	5.6	0.01

Carcass-Adjusted (HCW/0.625)	626	723	10.3	0.01
ADG, kg				
Initial to 112	1.51	1.53	0.070	0.50
d 113 to 209	1.73	1.80	0.107	0.26
Cumulative (live)	1.61	1.66	0.034	0.05
Cumulative (Carcass-adjusted)	1.69	1.76	0.048	0.04
DMI, kg				
d 1 to d 112	8.61	10.22	0.429	0.01
d 113 to d 209	10.78	11.91	0.469	0.01
Cumulative	9.62	11.00	0.381	0.01
G:F				
Initial to d 112	0.175	0.150	0.0027	0.01
d 113 to d 209	0.161	0.151	0.0044	0.08
Cumulative (live)	0.168	0.151	0.0031	0.01
Cumulative (Carcass-adjusted)	0.176	0.160	0.0031	0.01
MQ, Mcal/MBS[6]				
Initial to 112	0.098	0.106	0.0022	0.02
d 113 to d 209	0.042	0.042	0.0030	0.85

Cumulative (live)	0.078	0.083	0.0028	0.16
Cumulative (Carcass-adjusted)	0.071	0.075	0.0023	0.22
O/E DMI				
Initial to 112	1.11	1.16	0.013	0.02
d 113 to d 209	0.83	0.83	0.012	1.00
Cumulative (live)	1.00	1.03	0.015	0.19
Cumulative (Carcass-adjusted)	0.97	0.99	0.013	0.29
Observed NEm, Mcal/kg				
Initial to 112	1.85	1.78	0.778	0.02
d 113 to d 209	2.33	2.33	1.429	0.99
Cumulative (live)	2.00	1.96	1.036	0.17
Cumulative (Carcass-adjusted)	2.05	2.03	0.975	0.29
Observed NEg, Mcal/kg				
Initial to 112	1.21	1.15	0.683	0.02
d 113 to d 209	1.64	1.64	1.254	0.99
Cumulative (live)	1.34	1.31	0.909	0.17

Cumulative (Carcass-adjusted)	1.39	1.37	0.854	0.29
O/E NEm				
Initial to 112	0.91	0.88	0.009	0.02
d 113 to d 209	1.17	1.17	0.017	1.00
Cumulative (live)	0.99	0.97	0.011	0.15
Cumulative (Carcass-adjusted)	1.02	1.01	0.011	0.43
O/E NEg				
Initial to 112	0.90	0.85	0.012	0.02
d 113 to d 209	1.22	1.22	0.020	0.93
Cumulative (live)	0.99	0.97	0.016	0.23
Cumulative (Carcass-adjusted)	1.03	1.02	0.013	0.29
HCW based growth (d 1 to 209)				
Initial HCW[7], kg	153.32	207.76	1.0	0.01
Final HCW, kg	391	452	6.4	0.01
HCW ADG, kg	1.14	1.17	0.030	0.09
HCW G:F	0.119	0.106	0.0020	0.01

Carcass traits				
HCW, kg	391	452	6.4	0.01
Dressing[8], %	64.22	64.45	0.398	0.58
REA, cm^2	97.42	103.03	0.336	0.06
REA/HCW	0.017	0.016	0.0003	0.01
RF, cm	1.52	1.75	0.049	0.09
Marbling[9]	472	504	11.4	0.05
Yield Grade	2.94	3.41	0.193	0.04
Retail Yield	50.23	49.26	0.394	0.04
EBF[10], %	30.59	32.79	0.731	0.02
AFBW[10], kg	573	627	24.1	0.01
HCW grouping, %				
Less than 363 kg	5.7	0.0	-	0.01
363 to 408 kg	71.4	5.7	-	-
408 to 454 kg	22.9	40.0	-	-
454 to 476 kg	0.0	42.9	-	-
Greater than 476 kg	0.0	11.4	-	-
Yield Grade, %				
1	5.7	2.9	-	0.04
2	48.6	31.4	-	-
3	40.0	42.8	-	-
4	5.7	20.0	-	-
5	0.0	2.9	-	-
Quality Grade, %				
Select	22.8	11.4	-	0.22

Choice	74.3	85.7	-	-
Prime	2.9	2.9	-	-
			-	-
Liver Scores[11], %				
Normal	94.2	97.1	-	0.53
A-	2.9	2.9	-	-
A	0.0	0.0	-	-
A+	2.9	0.0	-	-

[1] Average on 10/19 and 10/20/2021 BW, no shrink applied.
[2] Body weight captured on 12/14/2021, no shrink applied.
[3] Difference between pre-conditioning BW and weaning weight divided by 56 d.
[4] Average of a 2 d BW collected on 12/14 and 12/15 was used as the initial on test BW.
[5] Shrunk 4% to account for digestive tract fill.
[6] Estimated maintenance requirements
[7] Initial HCW, kg =(0.2598 × initial shrunk BW, $kg^{1.1378}$)
[8] Calculated as: (HCW/final BW shrunk 4%) × 100.
[9] 400 = $small^{00}$
[10] Calculated according to the equations described by Guiroy et al. (2001).
[11] Determined according to the Elanco Liver Scoring System

Figure 1: Rate of hip height change over time of steers at differing initial weights

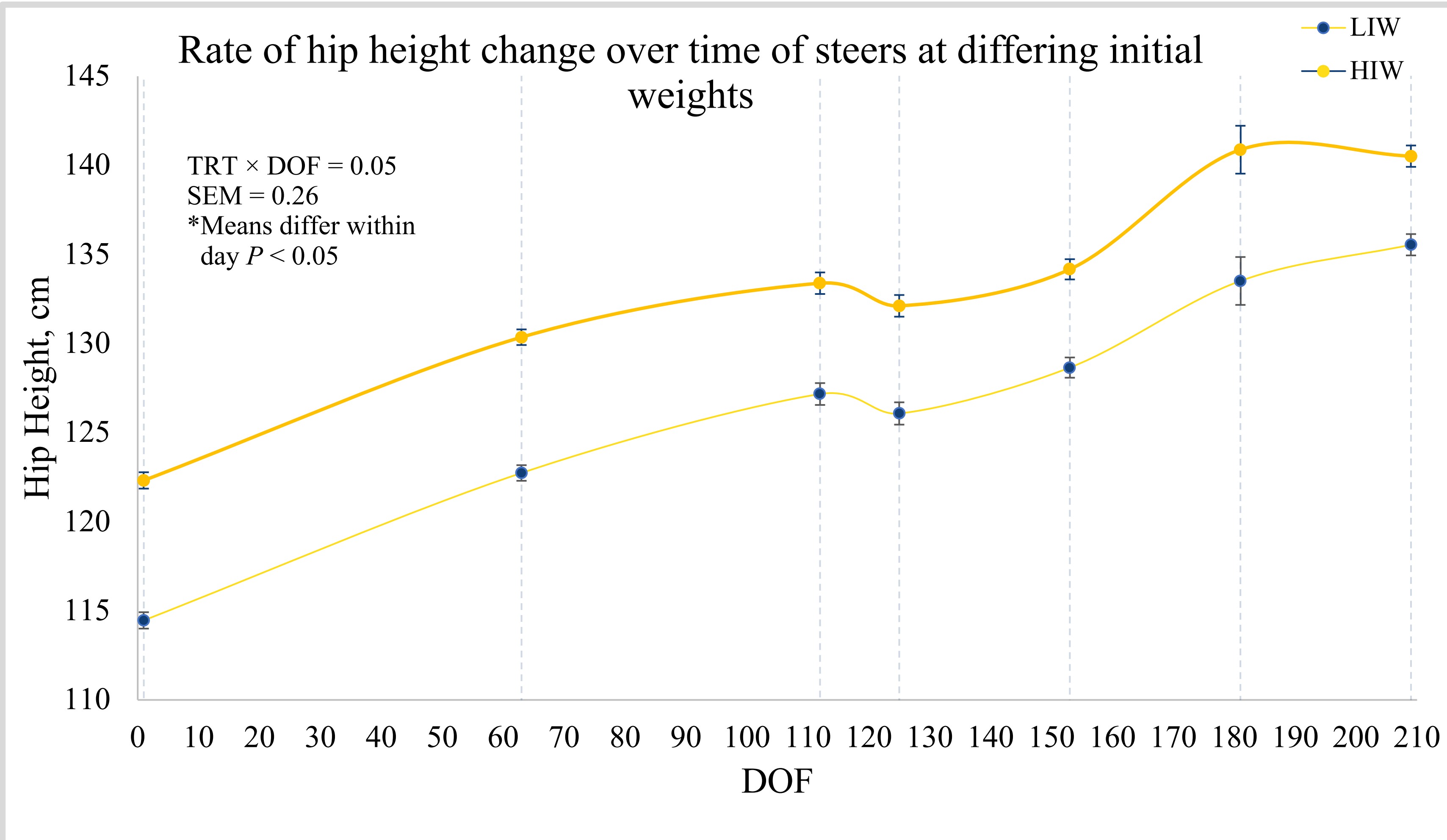

Figure 2: Empty body water, fat, and protein as determined by urea space dilution regressed against empty body weight (EBW).