EFFECT OF WINTER GROWING PROGRAM ON SUBSEQUENT FEEDLOT PERFORMANCE, BODY COMPOSITION, CARCASS MERIT, ORGAN MASS AND OXYGEN CONSUMPTION IN BEEF STEERS

By

MATTHEW PIERCE MCCURDY

Bachelor of Science
Texas A&M University
College Station, Texas
2000

Master of Science
Michigan State University
East Lansing, Michigan
2003

Submitted to the faculty of the Graduate College of the
Oklahoma State University in parital fulfillment of
the requirements for the degree of
DOCTOR OF PHILOSOPHY
December, 2006

EFFECT OF WINTER GROWING PROGRAM ON

SUBSEQUENT FEEDLOT PERFORMANCE,

BODY COMPOSITION, CARCASS MERIT,

ORGAN MASS AND OXYGEN

CONSUMPTION IN BEEF

STEERS

Dissertation Approved:

Clint Krehbiel
Dissertation Advisor

Gerald Horn

Udaya Desilva

James Breazile

A. Gordon Emslie
Dean of the Graduate College

ACKNOWLEDGMENTS

I would first like to thank to Drs. Breazile, Geisert, and Desilva for serving on my graduate committee. I also wish to express my gratitude to Drs. Clint Krehbiel and Gerald Horn for serving as my advisors and for providing a program of doctoral study that has been both challenging and rewarding. Thanks also to Dr. John Wagner for his cooperation and immense contributions to this research project. I would also like to express my appreciation for the time and effort of all faculty, staff, graduate and undergraduate students, and Continental Beef Research personnel who contributed to the completion of my doctoral research project. It has been a long and complicated task and would never have come to fruition without the concerted efforts of so many individuals.

I wish to thank my family for their tremendous support and the good Lord above without whose help I never would have made it this far. Last, but far from least, thanks go to one of the most talented groups of graduate students I could have hoped to work with, Jake, Luis, Ben, and Levi. In the words of Gus McCrae "by God Woodrow, it's been quite a party hadn't it?"

TABLE OF CONTENTS

Chapter **Page**

LIST OF TABLES

CHAPTER I

INTRODUCTION

As retained ownership, alliances, and vertically coordinated supply chains become an increasingly larger percentage of cattle on feed, it has been estimated that more than 50% of the cattle in the U.S. are trading outside of the cash market (Ritchie, 2002). As segments become increasingly coordinated, it is more important than ever to understand the effects that management and nutrition in each segment have on all subsequent phases of production and final carcass value. Age, weight, physiological maturity, breed type, and body composition upon entering the feedlot phase are all factors that have been taken into account when predicting potential feedlot performance and carcass merit of feeder cattle (Coleman and Evans, 1986; Coleman et al., 1993). Cow nutritional status and subsequent milk production, early or normal weaning, creep-feeding, physical form of the diet (forage vs. concentrate), diet energy density and initiation of concentrate feeding are all interrelated nutritional factors that may influence performance in the finishing phase as well as final carcass value. Numerous investigations have also sought to determine the effects of nutrition and management throughout the production chain on deposition of marbling and subsequent carcass quality (Berger and Faulkner, 2003).

After weaning, calves are generally placed on a growing diet to achieve adequate frame size and carcass weight before entering the feedlot phase. Growing programs in the U.S. vary tremendously. Cool season forages, including wheat pasture, harvested and ensiled crops, or high-concentrate diets fed at restricted levels are some examples of common growing programs. Some cattle may go directly to finishing on a high-concentrate diet immediately following weaning. Because of the variability in growing programs among different regions of the country and in diets that may consist of grazed or harvested forage or a grain-based diet, performance and weight gain of cattle before and after feedlot entry may be vastly different.

Although it is well established that management and nutrition during the growing phase affects performance of cattle during finishing, the nature and the extent of the effect have been questioned. Due to the number of potential factors that may determine performance in the feedlot, and the interdependency of these factors, it is important that any investigation into growth, gain, and efficiency of feedlot cattle provide a complete picture of nutritional management through current and previous production segments. It is equally important that research comprehensively examines all aspects of growth and performance in order to elucidate underlying physiological mechanisms. The purpose of the work published herein was to characterize the effects of different growing phase regimes for feeder cattle, with differences in level of DMI, dietary physical form and composition, energy density, and nutrient availability, on growth rate and efficiency, tissue metabolic activity, and relative rates of tissue accretion.

CHAPTER II

REVIEW OF LITERATURE

Production Systems

In the U.S. steers and heifers are often placed in roughage-based backgrounding programs after weaning (Sip and Pritchard, 1991). These types of forage-based programs provide low-energy growing diets that allow calves to achieve adequate frame size and body weight before entering into a finishing program for fattening (Byers, 1982). These production programs are particularly important in allowing smaller framed, British breed cattle to gain weight as lean tissue instead of fat. Roughage-based systems include grazing programs as well as feeding harvested forages. In the southeastern and southern plains regions of the country where a warmer climate and lower occurrence of snowfall allows for winter grazing, cool season forages are utilized in grazing systems for growing cattle. In the northern plains and Midwestern regions of the U.S., roughages are often harvested and ensiled to provide for winter feeding.

Although high-roughage systems are often required for adequate lean gain during the growing phase, high-concentrate diets provide a cheaper source of energy on an equal unit basis (Sip and Pritchard, 1991). Because of this, it may be more economical to utilize high-concentrate diets for growing cattle as opposed to forage-based diets (Loerch,

1990). High-concentrate diets can be fed at restricted levels to target specific rates of gain similar to that of high-roughage diets fed ad libitum. This can allow for adequate lean growth while using a more economical high-grain diet. It has been demonstrated that high-concentrate diets can be fed at restricted levels to match the rate of gain of calves on ad libitum corn silage diets without detrimental effects on finishing performance (Loerch, 1990). It has also been demonstrated that limit-feeding of a high-concentrate diet as opposed to a roughage-based ration results in more desirable carcass characteristics as well as increased palatability of retail beef cuts (Coleman et al., 1995).

In a review by Galyean (1999), restricted feeding was defined as any method of feed intake management with which intake is restricted relative to actual or anticipated ad libitum intake. Program feeding, however, was defined as a method in which net energy equations are used to calculate quantities of feed required to meet the needs for maintenance and a specific rate of gain. Some of the advantages pointed out by Galyean (1999) for the use of program feeding of high-concentrate diets versus grazing and roughage based systems include cheaper costs at times when pasture costs are high or in short supply. Other advantages for program-fed concentrate diets versus roughage systems discussed in this review are easier adaptation to an ad libitum finishing diet and improvements in feed efficiency.

In some instances calves are moved directly onto an ad libitum high-concentrate finishing diet immediately following weaning. Although feeding at higher intakes will improve daily gain, it may not result in optimum feed efficiency for cattle (Ferrell and Jenkins, 1998). Due to changes in body composition and increased percentage of gain as

fat, the relationship between energy intake and energy gain may be nonlinear (Meissner et al., 1995; Ferrell and Jenkins, 1998).

Management problems arising from programmed intake feeding versus ad libitum feeding have been a concern of cattle feeders in the past (Galyean, 1999), however Rakestraw and Lusby (1991) demonstrated successful, commercial-scale application of a limit-fed growing system versus an ad libitum fed system for weaned calves. These researchers also reported improved feed conversion during finishing, and increased final live weight and carcass weight for limit-fed steers versus ad libitum fed steers. Although cattle fed at restricted intake may demonstrate more aggressive behavior at the feed bunk, it has been reported that increasing bunk space does not affect gain or feed efficiency, and does not increase within pen variation in performance for program feeding compared with ad libitum feeding (Gunter et al., 1996). However, due to increased rates of consumption with restricted intake, increased concentrations of ionophore in the diet may be necessary to avoid digestive upset (Sip and Pritchard, 1991).

It may be advantageous for larger-framed cattle that contain a high percentage of continental breeding to begin an ad libitum high-concentrate diet earlier in life in order to insure that an adequate level of body fat is achieved before live weight becomes excessive. It has been demonstrated that larger-framed, faster growing steers had increased feed efficiency on an ad libitum fed high concentrate diet versus a restricted fed high concentrate diet (Gunter et al., 1996). This is also a means of allowing marbling deposition to be stimulated earlier so that desired carcass quality is met. In smaller framed cattle, however, ad libitum feeding of a high-concentrate diet immediately after weaning may be a detriment to carcass quality by advancing physiological maturity to a

point where cattle do not have adequate time on feed to develop intramuscular fat (Schoonmaker et al., 2004). These findings are supported by Coleman et al. (1993) in a study comparing Angus and Charolais steers in growing and finishing systems and suggest early feeding of a high-concentrate diet for later maturing, Continental breeds, but not for smaller British breeds.

Over the past decade researchers have also begun to look at the possibility of starting calves on high-concentrate diets even earlier in life by weaning calves at earlier ages. It has been shown that early-weaned calves are highly efficient at converting feed to live weight gain and in some instances has been shown to improve carcass quality grades (Myers et al., 1999a, 1999b; Wertz et al., 2001; Meyer et al., 2005). According to Bruns et al. (2004), rate of intramuscular fat accretion is greater in cattle when projected hot carcass weight is less than 300 kg. It has also been demonstrated that intramuscular fat is deposited at a faster rate relative to subcutaneous fat in calves as opposed to yearlings (Wertz et al., 2001). This would not only suggest that intramuscular fat accretion is nonlinear, but also that management and nutrition early in life may be just as important of a determinant of carcass quality as management during the finishing phase.

Compensatory Gain

Sainz et al. (1995) defined compensatory gain as the more rapid and efficient growth of an animal following a period of nutritional restriction. Numerous segments of the beef cattle industry obtain profit margins primarily by the differences in selling weight and purchasing weight for their particular phase of the production cycle. Because of the more rapid and efficient gain experienced during compensatory growth, there is a

perceived value for cattle that have experienced previous nutritional restriction over and above cattle that have been fed to meet all their nutrient requirements.

Experiments conducted in this area have yielded conflicting results as to the nature and extent of compensatory gain (Fox et al., 1972; Carstens et al., 1991; Hersom et al., 2004a). There has also been evidence to show that compensatory gain is a complex phenomenon that exhibits interactions with age, mature body size, and breed type of the animal (Coleman and Evans, 1986; Coleman et al., 1993), as well as length and severity of nutrient restriction (Sainz and Paganini, 2004), and composition of the diet fed to the restricted cattle (Sainz et al., 1995). Interactions with mature body type and physiological age may play an important role in the extent to which compensatory gain is seen. A study by Coleman and Evans (1986) was designed in an attempt to examine the effect of previous weight gain, along with age and size on compensatory gain. The study was designed as a 2 x 2 x 2 factorial that utilized spring-born (older) and fall born (younger) calves, control (dehydrated alfalfa pellets) versus restricted (grass-alfalfa hay) diet calves, and Charolais and Angus calves. The design provided groups of similar age but different weights (growing regimen within age) and steers of similar weights but different age (older-restricted versus younger controls). It was shown that older restricted steers compensated during the finishing phase as compared with older control steers. However within age, younger restricted steers did not experience the same compensatory gain as compared with younger control steers. This agrees with the findings of Morgan (1972). Overall feed/gain was lower for restricted steers versus control steers however; younger steers were more efficient than older steers in feed/gain ratio. Overall the study

demonstrated that previous nutritional restriction influenced weight gain in the next phase, however the weight that animals entered the next phase was just as important.

Actual live weight gain in cattle following a period of nutrient restriction has been seen in numerous experiments; however, the reasons behind this gain are less clear. Compensatory live weight gain on a full body basis is partially attributable to differences in gut fill due to an increased dry matter intake (**DMI**) in steers. Carstens et al. (1991) reported that steers that were restricted nutritionally during the growing period had heavier empty body weight (**EBW**) than control steers when expressed on an equal live weight basis. During realimentation to ad libitum feeding, the compensating steers had lighter EBW than control steers on an equal live weight basis, showing that gut fill was increased. Sainz et al. (1995) also pointed to an increase in DMI and an increase in gut fill for compensating steers compared with control steers. Because of the differences in gut fill and weights of digesta for compensating steers, both of the aforementioned studies chose to examine the compensatory gain differences on an EBW basis. However, EBW gain still showed compensatory gain in the previously restricted steers in both studies.

It has also been suggested that increased digestibility of the diet may occur during the initial part of the finishing phase in steers that were restricted in energy during the growing phase (Choat et al., 2003). This is, however, in disagreement with Coleman and Evans (1986) who asserted that previous nutritional restriction in the growing phase does not influence digestibility of the finishing diet, but that compensatory gain arises from increased utilization of nutrients post-absorption.

It is hypothesized that the more efficient compensatory gain is due to a reduced maintenance energy requirement, a reduction in energy requirement for growth, or a combination of both. The increase in DMI and subsequent gut fill for compensating versus non-compensating steers points to the possibility that gut size and visceral organ mass may be increased during compensatory gain and lead to an increase in maintenance energy requirements. These proposed mechanisms as they relate to not only compensatory growth due to previous nutrition, but determination of cattle performance, will be discussed in detail in the following sections of this review.

Composition and Energy Requirements for Gain

Rate of gain and efficiency in the finishing phase can be affected by plane of nutrition and energy density of the diet during the growing phase. Steers that are fed to have high rates of gain during the growing period accrete a larger percentage of their body weight gain as adipose tissue than steers that have been nutritionally restricted, and are fatter at all measures of carcass composition upon feedlot entry (Baker et al., 1992; Sainz et al., 1995; Hersom et al., 2003a). Whether steers have high or low rates of gain during the growing phase, they appear to accrete similar amounts of lean tissue, and thus nutritionally restricted steers have higher protein content as a percentage of BW (Fox et al., 1972; Sainz et al., 1995). This has also been demonstrated in lambs (Drouillard et al., 1991). Body weight gained as fat tissue requires more energy than lean accretion and thus requires a higher dietary energy content. Thus cattle gaining a larger percentage of their BW as fat have a higher net energy requirement for gain ($\mathbf{NE_g}$), and growth efficiency decreases linearly with increasing subcutaneous fat (Wertz et al., 2001). Because of this cattle that have had higher rates of gain during the growing phase and

consequently have a higher percentage of body fat upon feedlot entry are generally assumed to be less efficient and have reduced gains during the finishing phase. Therefore, fleshier feeder cattle have traditionally received a discounted purchase price from feedlots (Mies, 1992).

Carstens et al. (1991) demonstrated a reduction in NE_g requirement was a primary reason for increased gain in previously restricted steers. In the experiment, estimates were made for the amount of each body component for EBW gain that was realized during a period of realimentation. Estimates of NE_g were then calculated by multiplying the protein and fat contents of EBW gain by their respective energy coefficients. From this it was calculated that NE_g requirements were decreased 18% for previously restricted steers and thus concluded that the reduced requirements in NE_g for compensating cattle as set forth by the NRC (1984) were justified by the results of the experiment. This type of adjustment remains consistent with more current nutritional models and the 1996 Beef Cattle NRC Level 1 model also has a negative correlation between predicted ME allowable ADG and initial body fat content. Hersom et al. (2004a) found that fatter wheat pasture grazed cattle subjected to higher rates of gain during the growing period did not, however, experience reduced growth performance during the finishing period compared with steers that were grazed on restricted wheat pasture or on dormant native winter range. Even though cattle that were grazed on unrestricted wheat pasture had a significantly higher percentage of body fat upon feedlot entry, average daily gains remained similar to nutritionally restricted steers, and reached a common compositional endpoint with less days on feed. Similar results were found in a study by Choat et al. (2003) comparing wheat pasture grazed steers with steers grazed on dormant native

winter range. It was thus concluded that wheat pasture grazed cattle entering the feedyard with a higher percentage of body fat may not experience reduced feed efficiency, and that traditional price discounts for fleshier feeder cattle that have been grown on wheat pasture due to decreased predicted gain may not be justified.

The reduction in NE_g to which Carstens et al. (1991) attributed compensatory gain was calculated from the differences in composition of gain by the compensating cattle. Because cattle exhibiting compensatory gain have been observed to have less fat and more lean tissue as a percentage of body weight gain during realimenation, the gain is thought to be more energetically efficient. Unlike Carstens et al. (1991), where nutritionally restricted steers remained leaner throughout grazing and realimentation, Fox et al. (1972) showed an increase in lean gain for compensating steers during the initial part of realimentation to a finishing diet, but showed no differences in body composition at final slaughter. Compensating steers took longer (54 to 75 d) to reach the same endpoints in live weight for control steers and required a similar amount of total metabolizable energy to reach that weight. Similar findings were reported by Rompala et al. (1985) with other breed types. Previously restricted steers have been shown to have an initial period of increased protein and water gain followed by rapid fat accretion (Wright and Russel, 1991). In the study by Carstens et al. (1991) steers were harvested at a constant number of days rather than a common compositional endpoint. Therefore the steers experiencing compensatory gain may not have reached their maximum rate of fat accretion before the final harvest date. If the study were carried out to a greater number of days and heavier final weights (>500kg) it is plausible the compensating steers would

have required more days on feed to reach a common compositional endpoint as compared with continuous-fed steers.

Because differences in compensatory gain may be attributed to net energy requirements for growth and maintenance related to gut fill, gut size, and composition of gain, it is reasonable to believe that mature body type and physiological age influence composition of gain during growing and finishing. A study by Coleman et al. (1993) examined the effects of similar age steers at different weights and steers of similar weights but different ages by using different breed types and growing regimens. Overall the study showed that steers that entered the feedlot at a lighter weight, either due to previous restriction or younger age, accumulated fat more rapidly than larger steers.

This difference in composition of gain has been demonstrated by Sainz et al. (1995). In this study steers were fed in two phases. Both the growing phase and the finishing phase were based on a constant weight. During the growing phase steers were fed either a low energy diet on an ad libitum basis (**FA**), a high energy diet fed on a limited basis to match the gain of FA steers (**CL**), or a high energy diet ad libitum (**CA**). During the finishing phase steers were fed a high-concentrate diet on either an ad libitum basis (CA) or at 70% of the intake of CA steers (CL). This resulted in five total groups (FA-CA, CL-CA, CA-CA, FA-CL, and CL-CL). Serial slaughter groups were harvested at the beginning of the growing and the feeding phase as well as the end of finishing. Several measures of fatness were examined in this study including backfat, kidney, pelvic, and heart fat (KPH), abdominal fat, and marbling score. Total fat content of the carcass was also estimated based on density. During the growing phase, steers on both of the restricted diets (FA and CL) had less fat for all measures as compared with CA steers

and had a greater percentage of EBW as protein. There were also no differences in 12th-rib longissimus muscle area and it was thus concluded that the nutrient restriction does not effect muscle development but fat accretion only. In the finishing phase, steers that were nutritionally restricted during the growing phase showed reduced backfat as compared with full-fed controls. However, abdominal fat and total carcass fat were only affected by nutrient restriction in the finishing phase and not for steers restricted in the growing phase. Marbling scores were not affected significantly by restriction in either phase. Therefore the composition of gain and its subsequent differences were not believed to play a major role in the compensatory gain mechanism for this study. Steers fed a restricted amount of the-high concentrate diet had increased growth efficiency compared with control steers and did not require more total feed to reach the same compositional endpoint. Estimation of net energy for maintenance requirements (**NE_m**) showed that both groups of steers that were limit-fed a high-concentrate diet during the growing phase (CL-CL and CL-CA) had lower NE_m requirements as compared with CA-CA steers.

Maintenance Energy

Increased dry matter intake during the subsequent finishing period for previously restricted steers accounts for some of the compensating increase in live weight gain (Carstens et al., 1991; Sainz et al., 1995). Although live weight gain on a full body basis is partially attributable to differences in gut fill due to an increased DMI in steers that are compensating, steers that were restricted nutritionally during the growing period still exhibited greater gains in the finishing phase than control steers when expressed on an EBW basis (Carstens et al., 1991; Sainz et al., 1995). However, Hersom et al. (2004a)

showed an increase in DMI for previously restricted steers but did not show an increase in performance for those groups. It was estimated that the net energy for maintenance content of the diet was decreased for both groups of previously restricted steers, regardless of whether they were restricted by lower energy density of the diet or by reduced dry matter intake.

The plane of nutrition during the growing phase can determine the maintenance requirement of cattle in the subsequent finishing phase, and increased gain in the feedlot by previously restricted cattle has been attributed to decreased maintenance energy requirement (Fox et al., 1972). Sainz et al. (1995) estimated NE_m requirements in steers that were fed a high-concentrate diet ad libitum during the growing phase and steers that were limit-fed (70% of control steers) a high-concentrate diet during the growing phase. It was determined that the limit-fed steers had 17% lower requirements for NE_m during the finishing phase compared with ad libitum fed steers during finishing. Steers fed a high-forage diet during the growing phase had 21% higher maintenance requirements as compared with steers fed a high-concentrate diet ad libitum. Variation in maintenance requirements due to previous feed or forage intake appears to be attributed not to differences in body composition but to size of visceral organs and liver (Ferrell and Jenkins, 1985; Burrin et al., 1990).

Visceral Organ Growth and Development

Depending on the quality and energy density of the diet, maintenance requirements can account for more than half of the metabolizable energy intake of beef cattle (Beef Cattle NRC, 1996). Due to high rates of protein synthesis and energy demand, visceral organs and liver comprise 50% of the energy expenditure for

maintenance (McBride and Kelly, 1990) even though they represent a small percentage of body weight (Ferrell and Jenkins, 1985). Maintenance requirements increase with increases in visceral organ mass (Ferrell and Jenkins, 1998), which is in turn dependent on plane of nutrition (Burrin et al., 1989; Sainz and Bentley, 1997).

In a study by Ferrell et al. (1986), lambs were fed a common diet for 42 d in amounts to achieve 16 (**H**), 5 (**M**), or -6 (**L**) kg of BW gain. Afterwards lambs from the H and M groups were fed to achieve 16 (**HH, MH**), 5 (**HM, MM**) or -6 (**HL, ML**) kg of BW gain for a second 42-d period. Lambs in the L group were fed to achieve 27 (**LS**), 16 (**LH**), or 5 (**LM**) kg of BW gain. The design of the experiment resulted in lambs of different treatments during the first 42-d period having similar live weights after 84-d (HM, MH, and LS in one group; HL, MM, and LH in a second group; ML and LM in a third group). Within groups that had similar final live weight, there were no significant differences in body composition. However fasting heat production was increased for lambs with higher planes of nutrition during the first 42-d period and higher planes of nutrition during the first period resulted in increased mass of the liver and portal-drained viscera (**PDV**). Organ mass was dependent on rate of gain in the first period and was not a constant function of BW. Thus increased rate of gain in period one resulted directly in increased maintenance requirements for period two.

Differences have been reported in visceral organ mass and in individual mass of metabolically important organs due to DMI, physical form of the diet, and energy density of the diet (Burrin et al., 1989, 1990; Sainz and Bentley, 1997; Hersom et al., 2004b). Previously restricted ruminants that have been fed an energy dense diet with a resulting decreased dry matter intake have been shown to have a decreased maintenance

requirement; whereas, animals restricted by a low-quality, low-energy (forage) diet with a resulting increase in dry matter intake will have increased maintenance requirements (McLeod and Baldwin, 2000). Hersom et al. (2004b) reported that previously restricted steers, whether restricted by DMI or energy density of the diet, had greater gastrointestinal tract (**GIT**) mass in relation to BW and specifically, larger rumino-reticulums. Increased rumino-reticulum mass due to increased DMI was also demonstrated by Jones et al. (1985) and Myers et al. (1999a). McLeod and Baldwin (2000) reported increases in the gastrointestinal tract when metabolizable energy intake (**MEI**) was increased in forage diets but not in concentrate diets. Forestomachs (rumino-reticulum, omasum, and abomasums) appear to respond to physical form of the diet and fiber content (Sainz and Bentley, 1997). In heifers fed alfalfa or concentrate diets at isoenergetic intakes, heifers fed concentrate diets had lower fasting heat production as compared with alfalfa-fed heifers and a smaller percentage of the concentrate-fed heifer's heat increment was due to PDV and liver O_2 consumption (Reynolds et al., 1991). It has also been demonstrated that substrate oxidation by rumen epithelial cells *in vitro* was not altered by MEI or forage:concentrate ratio of the diet (Baldwin and McLeod, 2000). Thus it appears that these factors do not alter metabolism on a cellular level and changes in energy demand of the forestomach follow changes in mass (Burrin et al., 1990; McLeod and Baldwin, 2000).

Liver mass appears to be dependent on nutrient load, and increases with DMI and higher energy density of the diet (Jones et al., 1985; Sainz and Bentley, 1997; Hersom et al., 2003b), and it has been demonstrated that this is due mostly to increases in liver cell size (Burrin et al., 1992; Sainz and Bentley, 1997). It has also been reported that liver

growth increases as the nutrient load increases for previously restricted steers during realimentation to ad libitum feeding (Carstens et al., 1991). Small intestinal mass appears to be dependent on both nutrient load and physical form of the diet and increases are due to greater cell number (Sainz and Bentley, 1997; McLeod and Baldwin, 2000). Drouillard et al (1991) reported that nutrient restriction, from either protein or energy, resulted in smaller livers in lambs. Both liver and small intestinal mass was reduced by energy restriction. These differences persisted after realimentation to feed but there was no compensatory growth due to the reduction in organ weight. These researchers concluded that greater total visceral organ mass was due to greater workload, but dietary factors (fiber content and nutrient density) determined the workload for individual organs.

Carcass Composition and Value

One of the greatest challenges facing the beef industry is the lack of sufficient marbling in carcasses of beef cattle to meet the demands of the consumer. Marbling is the amount and distribution of visible intramuscular fat in the muscle. Increased marbling has been correlated with increased beef tenderness (Smith and Carpenter, 1974; Tatum et al., 1980; Dolezal et al., 1982; Berry, 1993) and beef flavor (Francis et al., 1977; Neely et al., 1998; Wheeler et al., 1999). Marbling continues to receive primary consideration in the assessment of quality in the U.S. beef grading system (USDA, 1975; Tatum et al., 1982), and thus within a carcass maturity classification, marbling is the major determinant of USDA Quality Grade. According to the 2000 National Beef Quality Audit (**NBQA**)(Smith et al., 2000), insufficient marbling/ low USDA Quality

Grade caused economic losses to the beef industry of $20.96 for each fed steer and heifer slaughtered in 2000.

Although a minimum amount of external fat aides tenderness by slowing the process of carcass chilling and preventing sarcomere shortening (Smith et al., 1976), subcutaneous fat has not been shown to be an effective indicator of beef tenderness or palatability (Tatum et al., 1982). It has been demonstrated that beef tenderness is improved when carcasses have at least 5.08 mm of external fat thickness; however, there is little improvement in tenderness or palatability above this level (Dolezal et al., 1982; Tatum et al., 1982; Shackelford et al., 1994). Because the 2000 NBQA (Smith et al., 2000) showed that only 4.9% of the 9,396 carcasses evaluated had less than 5.08 mm (0.2 inches) of subcutaneous fat thickness, the contribution of subcutaneous fat thickness to beef palatability may already be close to maximization. Thus, the negative effect that excess external fat accumulation has on carcass yield is of much greater concern. It was estimated that $50.96 for each steer and heifer harvested in 2000 was lost due to excess external fat (Smith et al., 2000).

Because the goals of beef production require a reduction in subcutaneous adipose tissue and an increase in the amount of intramuscular adipose tissue, the needs of the industry run in opposing directions. Thus the current beef industry faces a difficult challenge in altering the fat content of its product, and it is necessary that the effects of each segment of production on the development of different fat depots be understood thoroughly in order to maximize value of the final product.

Fat Tissue Accretion

Body composition and fat tissue accretion are directly related to final carcass characteristics and consequently the final retail value of the carcass. Previous studies have shown that nutritional plane has a minimal effect on the total amount of protein deposition and that periods of nutritional restriction primarily affect body composition through differences in fat deposition (Fox et al., 1972; Hersom et al., 2003a). It has been demonstrated in lambs grazing ryegrass pasture that supplementation with barley did not alter nutrient utilization in the hindlimb (Majdoub et al., 2003). These findings suggest that the additional energy from the supplementation went almost exclusively to adipose tissue lipogenesis. Sainz et al. (1995) demonstrated that steers on diets restricted for DMI or for energy intake had less fat for all measures compared with steers that had been fed ad libitum concentrate diets, and had a greater percentage of EBW as protein. There were no differences in 12^{th}-rib longissimus muscle area between groups, and it was thus concluded that nutrient restriction does not significantly affect muscle development but fat accretion only. In a study conducted by Smith et al. (1984), steers were fed on a high concentrate diet or an alfalfa diet. Steers fed the alfalfa diet had a slightly higher MEI, but steers fed the high concentrate diet had higher rates of gain, primarily in the fat depots. This suggests that diet type (forage versus concentrate) as well as MEI plays an important role in determining rate of fat gain.

It has been demonstrated that adipose tissue deposition is subject to nutrition and management through dietary composition and energy density (Smith, 1995). However, the relationship between deposition of adipose tissue in different depots of the body is not consistently correlated with nutrition (Zinn et al., 1970). According to Hood (1983) fat is

preferentially deposited in the following tissue sites: perirenal and omental > subcutaneous > intermuscular > intramuscular. However fat deposition that influences carcass yield, and fat deposition that influences carcass quality appear to have a differential degree of response to nutritional manipulation (Smith and Crouse, 1984). It has been demonstrated that previous nutritional restriction during the growing phase decreases total body fat and markedly decreases backfat in steers harvested at a common weight (Fox et al., 1972; Carstens et al., 1991; Sainz et al., 1995). However, reductions in marbling due to the same type of previous nutritional restriction have not been seen and final carcass marbling scores do not seem to be affected significantly by restriction in either the growing or the finishing phase (Sainz et al., 1995; Hersom et al., 2003a). It was also concluded by Klopfenstein et al. (2000) that there were no differences in marbling due to type of backgrounding program or growing rate of gain when steers were fed to a common depth of 12^{th}-rib backfat. It has been shown however, that prolonged restriction may decrease carcass quality either by permanent impairment of marbling deposition or by increasing feedlot entry weight to the point that the finishing phase is too short for adequate marbling to develop (Sainz and Paganini, 2004). Cattle that have been fed to slaughter weights, extreme in relation to industry standards, have accumulated large amounts of subcutaneous fat, but this has not been accompanied by significant increases in marbling (Dubeski et al., 1997). Cunha (1974) observed that many cattle reach the USDA Choice Quality Grade with only 0.2 to 0.3 inches of backfat and the 2000 NBQA (Smith et al., 2000) determined that cattle grading USDA Choice spanned USDA Yield Grades 1 to 5. Increases in marbling have been shown by starting cattle on high-concentrate rations at earlier ages (Myers et al., 1999a; 1999b; Wertz et al., 2001);

however, these cases dealt with calves that were early weaned and started on feed at extremely early ages (70-100 d).

In 1984, Smith and Crouse reported that previous studies indicated that marbling scores were less subject to manipulation through nutrition compared with 12th-rib fat thickness or total carcass fat. This relationship was consistent with their study, in which cattle fed a higher energy corn diet did not display significantly greater marbling scores than cattle fed a lower energy corn silage diet when fed to 16 or to 18 months of age. Cattle on the higher energy diet did, however, have greater backfat thickness and a greater percentage of kidney, pelvic, and heart fat. It was thus concluded that lipogenesis in the two depots was controlled by different means.

Comparative Biology of Adipose Tissue Depots

Evidence has accumulated to indicate that intramuscular adipocytes represent a cell population different from the more extensively investigated subcutaneous adipocytes (Lin et al., 1992). A number of studies have shown that intramuscular adipocytes are smaller cells on average, with less cell volume and correspondingly less lipid content than subcutaneous adipocytes (Hood and Allen, 1973; Smith and Crouse, 1984; Miller et al., 1991; May et al., 1994). The smaller size and volume of adipocytes in the intramuscular adipose is associated with decreased lipogenic activity (Hood and Allen, 1978). In cattle, as in other ruminant species, the majority of *de novo* fatty acid synthesis takes place in adipose tissue. Hood and Allen (1978) concluded that lipid was synthesized at a slower rate in intramuscular adipose than in subcutaneous adipose and that this was directly related to a smaller adipocyte volume. In addition to cellularity, differences exist between subcutaneous and intramuscular adipose tissue depots in their

preferential uptake of substrates for fatty acid synthesis. Subcutaneous adipocytes primarily use acetate-derived substrates as precursors for fatty acid synthesis. However, glucose-derived carbon units provide the main source of substrate for fatty acid synthesis in intramuscular adipose tissue. In studies on *in vitro* lipogenesis it was observed that acetate provided 70 to 80% of the acetyl units for lipogenesis in subcutaneous adipose tissue but only 10 to 25% for intramuscular tissue. Glucose provided only 1 to 10% of the acetyl units for fatty acid synthesis in subcutaneous adipose but provided 50 to 75% of the units for intramuscular fatty acid synthesis (Smith and Crouse, 1984).

Many of the enzymes that are required for the use of glucose in fatty acid synthesis are limited in ruminants to conserve glucose. In liver and in adipose the enymes ATP-citrate lyase and NADP-malate dehydrogenase (malic enzyme) are involved in the utilization of glucose for incorporation of pyruvate into acetyl-CoA and production of NADPH, which is necessary for fatty-acid synthesis (Smith, 1995). Both of the enzymes are less abundant and less active in ruminant species (Smith and Crouse, 1984). Additionally, pyruvate carboxylase and glucokinase are limited in adipose tissue and in liver, respectively, to limit the production of acetyl units from glucose for lipogenesis (Smith et al., 1995).

The location of intramuscular adipose tissue suggests that it is a biologically active depot and the most immediate source of energy for muscle tissue. If this is the case it may be assumed that only when an animal is on a high plane of nutrition or a high-energy status will intramuscular adipose be allowed to accumulate significant lipid content. An elevated level of glucose, particularly in ruminants, would suggest a high level of nutrient availability to an animal's biological system, and thus perhaps allow for

significant lipogenesis in the animal's intramuscular depots. This may be a biological mechanism that shows why the lipogenic precursors for de novo fatty acid synthesis in intramuscular adipose tissue are derived primarily from glucose. The earlier this process happens in the animal's life the earlier and more fully the intramuscular depots may be allowed to develop as evidenced by studies dealing with early weaning (Myers et al., 1999a; 1999b; Wertz et al., 2001). If greater energy density of the diet, higher starch content of DMI, and higher availability of glucose are present in cattle fed a high concentrate diet, it is possible that the use of glucose derived carbon for de novo fatty acid synthesis is increased (Berger and Faulkner, 2003). Thus introduction of cattle to high-concentrate diets prior to the finishing phase may provide positive stimulation of marbling earlier in life.

The previous studies examining the growth and development of feeder cattle indicate a variety of mechanisms are responsible for determining subsequent feedlot performance and final carcass composition. Variations in intake, dietary composition, and dietary energy density are implicated as primary factors that affect feeding performance by altering maintenance energy requirements of cattle. Maintenance energy needs, in turn, are highly dependent on the mass and metabolic activity of visceral organs, which can change with nutritional management. Nutrition and rate of gain during the stocker or backgrounding phase also has a direct effect on live weight (and age) at feedlot entry, as well as body composition upon entering the finishing phase. The rate of gain during the growing phase and the level of fatness at feedlot entry are associated with subsequent gain in the feedlot and it has traditionally been accepted that cattle

experiencing high rates of gain during the growing phase and entering the feedlot at heavier weights will have lower gains during finishing.

Each of the factors that have been implicated in feeding performance (reductions in energy requirements for maintenance and gain, altered body composition, gut fill, DMI, visceral organ mass and activity, age and mature body type) are interrelated and also indicate a number of complex interactions. Additionally, nutritional factors and rates of gain during previous production segments ultimately determine total fat accretion and carcass composition and may play a role in the differential deposition of adipose tissue that affects carcass quality and yield.

It is our hypothesis that different growing phase diets for feeder cattle will result in altered finishing performance and final carcass composition. It is therefore the objective of our experiment to determine the effects of winter growing diet on subsequent feedlot performance, body composition, carcass merit, and organ mass and metabolic activity in beef steers that are grown in one of four different winter growing programs that are commonly used for backgrounding feeder calves in the United States.

Literature Cited

Baker, R. D., N. E. Young, and J. A. Lewis. 1992. The effect of diet in winter on the body composition of young steers and subsequent performance during the grazing season. Anim. Prod. 54:211-219.

Baldwin, R. L., VI, and K. R. McLeod. 2000. Effect of diet forage:concentrate ratio and metabolizable energy intake on isolated rumen epithelial cell metabolism in vitro. J. Anim. Sci. 78:771-783.

Berger, L. L. and D. B. Faulkner. 2003. Lifetime nutritional effects on feedlot performance and carcass merit. Pages 63-78 Plains Nutrition Council Spring Conference Proceedings.

Berry, B. W. 1993. Tenderness of beef loin steaks as influenced by marbling level, removal of subcutaneous fat, and cooking method. J. Anim. Sci. 71:2412-2419.

Bruns, K. W., R. H. Pritchard, and D. L. Boggs. 2004. The relationships among body weight, body composition, and intramuscular fat content in steers. J. Anim. Sci. 82:1315-1322.

Burrin, D. G., R. A. Britton, C. L. Ferrell, and M. L. Bauer. 1992. Level of nutrition and visceral organ protein synthetic capacity and nucleic acid content in sheep. J. Anim. Sci. 70:1137-1145.

Burrin, D. G., C. L. Ferrell, R. A. Britton and M. L. Bauer. 1990. Level of nutrition and visceral organ size and metabolic activity in sheep. Br. J. Nutr. 64:439-448.

Burrin, D. G., C. L. Ferrell, J. H. Eisemann, R. A. Britton and J. A. Nienaber. 1989. Effect of level of nutrition on splanchnic blood flow and oxygen consumption in sheep. Br. J. Nutr. 62:23-34.

Byers, F. M. 1982. Nutritional factors affecting growth of muscle and adipose tissue in ruminants. Fed. Proc. 41:2562-2565.

Carstens, G. E., D. E. Johnson, M. A. Ellenberger, and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J. Anim. Sci. 69:3251-3264.

Choat, W. T., C. R. Krehbiel, G. C. Duff, R. E. Kirksey, L. M. Lauriault, J. D. Rivera, B. M. Capitan, D. A. Walker, G. B. Donart, and C. L. Goad. 2003. Influence of grazing dormant native range or winter wheat pasture on subsequent finishing cattle performance, carcass characteristics, and ruminal metabolism. J. Anim. Sci. 81:3191-3201.

Coleman, S. W., and B. C. Evans.1986. Effect of nutrition, age, and size on compensatory growth in two breeds of steers. J. Anim. Sci. 63:1968-1982.

Coleman, S. W., B. C. Evans, and J. J. Guenther. 1993. Body and carcass composition of Angus and Charolais steers as affected by age and nutrition. J. Anim. Sci. 71:86-95.

Coleman, S. W., R. H. Gallavan, C. B. Williams, W. A. Phillips, J. D. Volesky, S. Rodriguez, and G. L. Bennett. 1995. Silage or limit-fed grain growing diets for steers: I. Growth and carcass quality. J. Anim. Sci. 73:2609-2620.

Cunha, T. J. 1974. Eliminating excess fat in meat animals. Proc. Symp. Changing the fat content and composition of animal products. Nat. Acad. Sci. Washington D. C.

Dolezal, H. G., G. C. Smith, J. W. Savell, and Z. L. Carpenter. 1982. Comparison of subcutaneous fat thickness, marbling and quality grade for predicting palatability of beef. J. Food Sci. 47:397-401

Drouillard, J. S., T. J. Klopfenstein, R. A. Britton, M. L. Bauer, S. M. Gramlich, T. J. Wester, and C. L. Ferrell. 1991. Growth, body composition, and visceral organ mass and metabolism in lambs during and after metabolizable protein or net energy restrictions. J. Anim. Sci. 69:3357-3375.

Dubeski, P. L., J. L. Aalhus, S. D. M. Jones, A. K. W. Tong, and W. M. Robertson. 1997. Fattening heifers to heavy weights to enhance marbling: efficiency of gain. Can. J. Anim. Sci. 77:625-633.

Ferrell, C. L. and T. G. Jenkins. 1985. Cow type and the nutritional environment: nutritional aspects. J. Anim. Sci. 61:725-741.

Ferrell, C. L. and T. G. Jenkins. 1998. Body composition and energy utilization by steers of diverse genotypes fed a high-concentrate diet during the finishing period: I. Angus, Belgian Blue, Hereford, and Piedmontese sires. J. Anim. Sci. 76:637-646.

Ferrell, C. L., L. J. Koong, and J. A. Nienaber. 1986. Effect of previous nutrition on body composition and maintenance energy costs of growing lambs. Br. J. Nutr. 56:595-605.

Fox, D. G., R. R. Johnson, R. L. Preston, and T. R. Dockerty, and E. W. Klosterman. 1972. Protein and energy utilization during compensatory growth in beef cattle. J. Anim. Sci. 34:310-318.

Francis, J. J., J. R. Romans, H. W. Norton. 1977. Consumer rating of two beef marbling levels. J. Anim. Sci. 45:67-70.

Galyean, M. L. 1999. Review: restricted and programmed feeding of beef cattle-definitions, applications, and research results. Prof. Anim. Sci. 15:1-6.

Gunter, S. A., M. L. Galyean, and K. J. Malcolm-Callis. 1996. Factors influencing the performance of feedlot steers limit-fed high-concentrate diets. Prof. Anim. Sci. 12:167-175.

Hersom, M. J., G. W. Horn, C. R. Krehbiel, and W. A. Phillips. 2004a. Effect of live weight gain of steers during winter grazing: I. Subsequent feedlot performance, carcass characteristics and body composition. J. Anim. Sci. 82:262-272.

Hersom, M. J., C. R. Krehbiel, and G. W. Horn. 2004b. Effect of previous live weight gain of steers during the winter grazing: II. Visceral organ mass, cellularity and oxygen consumption. J. Anim. Sci. 82:184-197.

Hood, R. L. 1983. Changes in fatty acid synthesis associated with growing and fattening. Proc. Nutr. Soc. 42:303-313.

Hood, R. L., and C. E. Allen. 1973. Cellularity of bovine adipose tissue. J. Lipid Res. 14:605-610.

Hood, R. L., and C. E. Allen. 1978. Lipogenesis in isolated intramuscular adipose tissue from four bovine muscles. J. Anim Sci. 46:1626-1633.

Jones, S. D. M., R. E. Rompala, and L. E. Jeremiah. 1985. Growth and composition of the empty body in steers of different maturity types fed concentrate or forage diets. J. Anim. Sci. 60:427-433.

Klopfenstein, T., R. Cooper, D. J. Jordon, D. Shain, T. Milton, C. Calkins, and C. Rossi. 2000. Effects of backgrounding and growing programs on beef carcass quality and yield. Proc. Am. Soc. Anim. Sci., 1999. Available at http://www.asas.org/jas/symposia/proceedings/0942.pdf. Accessed 6/2/2006.

Lin, K. C., H. R. Cross, and S. B. Smith. 1992. Esterification of fatty acids by bovine intramuscular and subcutaneous adipose tissue. Lipids 27:111-116.

Loerch, S. C. 1990. Effects of feeding growing cattle high-concentrate diets at restricted intake on feedlot performance. J. Anim. Sci. 68:3086-3095.

Majdoub, L., M. Vermorel, and I. Ortigues-Marty. 2003. Ryegrass-based diet and barley supplementation: partition of energy-yielding nutrients among splanchnic tissues and hindlimbs in finishing lambs. J. Anim. Sci. 81:1068-1079.

May, S. G., J. W. Savell, D. K. Lunt, J. J. Wilson, J. C. Laurenz, and S. B. Smith. 1994. Evidence for preadipocyte proliferation during culture of subcutaneous and intramuscular adipose tissues from Angus and Wagyu crossbred steers. J. Anim. Sci. 72:3110-3117.

McBride, B. W., and J. M. Kelly. 1990. Energy cost of absorption and metabolism in the ruminant gastrointestinal tract and liver: a review. J. Anim. Sci. 68:2997-3010.

McLeod, K. R. and R. L. Baldwin VI. 2000. Effects of diet forage:concentrate ratio and metabolizable energy intake on visceral organ growth and in vitro oxidative capacity of gut tissues in sheep. J. Anim. Sci. 78:760-770.

Meissner, H. H., M. Smutz, D. V. Paulsmeier. 1995. The relationship between feed intake, daily gain, and feed efficiency in fast growing beef steers. In: Symposium: Intake by Feedlot Cattle. P-942. pp 49-55.

Meyer, D. L., M. S. Kerley, E. L. Walker, D. H. Keisler, V. L. Pierce, T. B. Schmidt, C. A. Stahl, M. L. Linville, and E. P. Berg. 2005. Growth rate, body composition, and meat tenderness in early vs. traditional weaned beef calves. J. Anim. Sci. 83:2752-2761.

Mies, W. L. 1992. Determining the value of stocker cattle. Pages 45-47 in Eastern Oklahoma Stocker Cattle Conference Proceedings.

Miller, M. F., H. R. Cross, D. K. Lunt, and S. B. Smith. 1991. Lipogenesis in acute and 48-hour cultures of bovine intramuscular and subcutaneous adipose tissue explants. J. Anim. Sci. 69:162-170.

Morgan, J. H. L. 1972. Effect of plane of nutrition in early life on subsequent weight gain, carcass and muscle characteristics, and eating quality in cattle. J. Agric. Sci. 78:417-423.

Myers, S. E., D. B. Faulkner, F. A. Ireland, D. F. Parrett, and F. K. McKeith. 1999a. Performance and carcass traits of early-weaned steers receiving either a pasture growing period or a finishing diet at weaning. J. Anim. Sci. 77:311-322.

Myers, S. E., D. B. Faulkner, F. A. Ireland, and D. F. Parrett. 1999b. Comparison of three weaning ages on cow-calf performance and steer carcass traits. J. Anim. Sci. 77:323-329.

Neely, T. R., C. L. Lorenzen, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1998. Beef customer satisfaction: role of cut, USDA Quality Grade, and city on in-home consumer ratings. J. Anim. Sci. 76:1027-1032.

NRC. 1984. Nutrient Requirements of Beef Cattle. 6th Ed. National Academy Press. Washington D.C.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. National Academy Press. Washington D.C.

Rakestraw, J., and K. S. Lusby. 1991. Effects of limit-fed growing programs on finishing performance and carcass traits of steers in a commercial feedlot. In: Animal Science Research Report. MP-134. p.222-230. Oklahoma Agric. Exp. Sta., Stillwater, OK.

Reynolds, C. K., H. F. Tyrrell, and P. J. Reynolds. 1991. Effects of diet forage:concentrate ratio and intake on energy metabolism in growing beef heifers: whole body energy and nitrogen balance and visceral heat production. J. Nutr. 121:994-1003.

Ritchie, H. D. 2002. Connecting the cow herd to the carcass: balancing the production environment and the marketplace. Michigan State University Beef Cattle, Sheep, and Forage Systems Research and Demonstration Report. #581:71-78.

Rompala, R. E., S. D. M. Jones, J. G. Buchanan-Smith, and H. S. Bayley. 1985. Feedlot performance and composition of gain in late-maturing steers exhibiting normal and compensatory growth. J. Anim Sci. 61:637-646.

Sainz, R. D. and B. E. Bentley. 1997. Visceral organ mass and cellularity in growth-restricted and refed beef steers. J. Anim. Sci. 75:1229-1236.

Sainz, R. D., F. De la Torre, and J. W. Oltjen. 1995. Compensatory growth and carcass quality in growth restricted and refed beef steers. J. Anim. Sci. 73:2971-2979.

Sainz, R. D., and R. F. Vernazza Paganini. 2004. Effects of different grazing and feeding periods on performance and carcass traits of beef steers. J. Anim. Sci. 82:292-297.

Schoonmaker, J. P., M. J. Cecava, F. L. Fluarty, H. N. Zerby, and S. C. Loerch. 2004. Effect of source and amount of energy and rate of growth in the growing phase on

performance and carcass characteristics of early- and normal-weaned steers. J. Anim. Sci. 82:273-282.

Shackleford, S. D., M. Koohmaraie, and T. L. Wheeler. 1994. The efficacy of adding a minimum adjusted fat thickness requirement to the USDA beef quality grading standards for select beef. J. Anim. Sci. 72:1502-1507.

Sip, M. L., and R. H. Pritchard. 1991. Nitrogen utilization by ruminants during restricted intake of high-concentrate diets. J. Anim. Sci. 69:2655-2662.

Smith, G. C. and Z. L. Carpenter. 1974. Eating quality of animal products and their fat content. Proc. Symp. Changing the fat content and composition of animal products. Nat. Acad. Sci. Washington D. C.

Smith, G. C., T. R. Dutson, R. L. Hostetler, and Z. L. Carpenter. 1976. Fatness, rate of chilling, and tenderness of lamb. J. Food Sci. 41:748-755.

Smith, G. C., J. W. Savell, J. B. Morgan, T. H. Montgomery, K. E. Belk, J. C. Brooks, Z. L. Carpenter, T. G. Field, D. B. Griffin, D.S. Hale, F. K. Ray, J. A. Scanga. 2000. The Final Report of the Second Blueprint for Total Quality Management in the Fed-Beef (Slaughter Steer/Heifer) Industry: National Beef Quality Audit – 2000. National Cattlemen's Beef Assoc., Englewood, CO.

Smith, S. B. 1995. Substrate utilization in ruminant adipose tissues. Page 166 in Biology of Fat in Meat Animals. S. B. Smith and D. R. Smith, eds. Amer. Soc. Anim. Sci., Champaign, IL.

Smith, S. B., and J. D. Crouse. 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J. Nutr. 114: 792-800.

Smith, S. B., R. L. Prior, C. L. Ferrell, and H. J. Mersmann. 1984. Interrelationships among diet, age, fat deposition and lipid metabolism in growing steers. J. Nutr. 114:153-162.

Tatum, J. D., G. C. Smith, B. W. Berry, C. E. Murphey, F. L. Williams, and Z. L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. J. Anim. Sci. 50:833-840.

USDA. 1975. Official United States standards for grades of carcass beef. Agr. Marketing Service, USDA, Washington, DC.

Wertz, A. E., L. L. Berger, P. M. Walker, D. B. Faulkner, F. K. McKeith, and S. Rodriguez-Zas. 2001. Early weaning and post weaning nutritional management affect feedlot performance of Angus X Simmental heifers and the relationship of 12^{th} rib fat and marbling score to feed efficiency. J. Anim. Sci. 79:1660-1669.

Wheeler, T. L., S. D. Shackelford, and M. Koohmararie. 1999. Tenderness classification of beef: IV. Effect of USDA Quality Grade on the palatability of "Tender" beef longissimus when cooked well done. J. Anim. Sci. 77:882-888.

Wright, I. A. and A. J. F. Russel. 1991. Changes in the body composition of beef cattle during compensatory growth. Anim. Prod. 52:105-113.

Zinn, D. W., R. M. Durham, and H. B. Hedrick. 1970. Feedlot and carcass grade characteristics of steers and heifers as influenced by days on feed. J. Anim. Sci. 31:302-306.

CHAPTER III

EFFECTS OF WINTER GROWING PROGRAM ON SUBSEQUENT FEEDLOT PERFORMANCE, CARCASS CHARACTERISTICS, BODY COMPOSITION, AND ENERGY REQUIREMENTS OF BEEF STEERS[1,2]

M. P. McCurdy*, G. W. Horn[*,3], J. J. Wagner[†], and C. R. Krehbiel[1*]

[*]Department of Animal Science, Oklahoma State University, Stillwater, 74078 and

[†]Southeastern Colorado Research Center, Colorado State University, Lamar, CO 81052

[1]Approved for publication by the Director of the Oklahoma Agric. Exp. Sta. This material is based in part upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No.?

[2]The authors wish to thank Donna Perry, Kim Whittet, and Joan Summers for their help in collection and analysis of samples, Scott Schaeffer, Jim Kountz, and Steve Welty for animal care and sample preparation, the Southeastern Colorado Research Center staff and

animal caretakers, and numerous undergraduate and graduate students who assisted on harvest dates.

[3]Corresponding author: Dept. of Anim. Sci., 208 Anim. Sci. Bldg., Stillwater, OK 74078 phone: 405/744-8857; fax: 405/744-7390; E-mail: gerald.horn@okstate.edu).

ABSTRACT: The purpose of this study was to investigate the effects of winter growing program on subsequent finishing performance, carcass merit, and body composition of beef steers. Four steers were slaughtered to determine initial body composition. Remaining steers (256 hd) were blocked by weight and randomly allotted to one of four treatment groups: 1) ad libitum fed a high-concentrate diet (**CF**); 2) grazed on wheat pasture (**WP**); 3) fed a sorghum silage-based diet (**SF**); or 4) program fed a high-concentrate diet (**PF**). Steers in the WP, SF, and PF groups were managed to achieve approximately equal rates of BW gain. After the growing phase (112 d) six steers were randomly selected from the WP, SF, and PF treatments for determination of body composition. Remaining steers were adapted to a high-concentrate diet for finishing. Steers from all treatments were harvested at 1.27 cm of 12th-rib fat and six steers from each treatment group were used to determine body composition. At each harvest composition was determined for carcass, offal, viscera, and empty body. During the growing phase WP, SF, and PF treatments gained 1.15, 1.10, and 1.18 kg/d, respectively, but ME intake (**MEI**) was similar between treatments. Estimated daily heat production was lowest for PF steers ($P < 0.05$) and accretion of empty body, carcass, and PDV mass was greatest for PF steers ($P < 0.05$). During the finishing phase (123, 104, 104, 196 d for WP, SF, PF, and CF, respectively) DMI was greater ($P < 0.01$) for SF steers (10.9

kg/d) than for PF steers (10.1 kg/d): WP steers were intermediate (10.4 kg/d). ADG was highest for SF steers (2.02 kg/d), intermediate for PF steers (1.85 kg/d), and lowest for WP and CF steers (1.64 and 1.63 kg/d, respectively) ($P < 0.05$) and tissue accretion (kg/d) was lower for WP and CF steers as compared with PF and SF steers for carcass and noncarcass fractions ($P < 0.05$). However, WP steers had similar accretion of visceral tissues (kg/d). At harvest, SF steers had lower yield grades and higher marbling scores compared with CF and WP steers; PF steers were intermediate ($P < 0.01$). In conclusion PF steers had greater gains in empty body mass during the growing period as compared to WP and SF steers at equal MEI. During finishing, PF steers had less accretion of visceral organ mass compared with SF and WP steers. This resulted in lower gains for WP steers but was overcome by increased DMI in SF steers.

Key Words: Beef Cattle, Body Composition, Carcass, Feedlot Performance, Growth

INTRODUCTION

Age, weight, previous diet, breed type, and body composition upon entering the feedlot are all factors taken into account when predicting potential finishing performance of feeder cattle (Coleman and Evans, 1986; 1993). After weaning, calves are often placed on a growing diet to achieve adequate frame size before entering into a finishing program while some cattle may go directly to finishing. Rate of gain in the finishing phase can be influenced by plane of nutrition and energy density of the diet during the growing phase. Steers that are fed to have high rates of gain during the growing period are fatter at all measures of carcass composition upon feedlot entry compared with steers

that have been nutritionally restricted (Baker et al., 1992; Sainz et al., 1995; Hersom et al., 2004a). Cattle that have a higher percentage of body fat upon feedlot entry are generally assumed to be less efficient and to have reduced gains during the finishing phase resulting in a negative correlation between predicted ME allowable ADG and initial body fat content (NRC, 1996).

In contrast, it has been reported that cattle grazing wheat pasture at higher rates of gain during the growing period did not experience decreased performance during the finishing period compared with steers that were grazed on dormant native winter range (Choat et al., 2003; Hersom et al., 2004a). Despite being fatter at feedlot entry, ADG was similar to nutritionally restricted steers. In order to determine if these results were unique to cattle grazed on wheat pasture, we designed an experiment to test the hypothesis that steers managed for similar rates of gain on different diets during the growing period would have different performance during the finishing phase. The objective was to determine the effects of winter growing program on subsequent finishing performance, carcass merit, body composition, and maintenance energy requirements. Additionally these growing programs were compared to steers that were placed on a finishing diet immediately after weaning.

MATERIALS AND METHODS

Experimental Animals and Treatments

A total of 260 British crossbred steers were utilized for the experiment. Fifty steers (average initial BW = 239 ± 33.5 kg) from the Oklahoma State University cow herd were weaned in the fall of 2003. The remaining 210 steers (average initial BW =

236 ± 22.0 kg) were purchased by Colorado Beef to be of similar breed, type, and age. Four randomly selected steers were transported to the Oklahoma Food and Agricultural Products Research and Technology Center (**FAPRTC**) abattoir in Stillwater, OK for an initial serial slaughter group. Remaining steers were blocked by initial weight and randomly allotted to one of four treatment groups for winter feeding. One group of steers were placed in the feedlot (n = 8 pens; 8 steers/pen) immediately on arrival and adapted to a high-concentrate finishing diet fed ad libitum (**CF**). Steers in this treatment underwent a three tier adaptation consisting of a 49, 74, and finally 88% concentrate diet (finisher). Each adaptation diet was fed for 5 d. The three remaining treatment groups were managed on three different growing systems to achieve approximately equal rates of BW gain. One group was grazed as a single group on wheat pasture with unrestricted forage availability (**WP**; n = 64), a second group was fed a sorghum silage-based growing diet (**SF**; n = 8 pens; 8 steers/pen), and the third group was program fed a high-concentrate diet (**PF**; n = 8 pens; 8 steers/pen). The composition of each diet is shown in Tables 3-1 and 3-2.

All pen feeding took place at the Southeastern Colorado Research Center, Lamar, CO, while wheat pasture grazing took place at the Oklahoma State University Wheat Pasture Research Unit. Steers at OSU allocated to the SF, PF, and CF groups were transported from Stillwater, OK to Lamar, CO (688 km), while purchased steers allocated to the WP group were transported from Lamar to Stillwater prior to the beginning of the trial. At both locations, steers were treated for parasites with IVOMEC Plus (Merial, Duluth, GA), vaccinated for Bovine Rhinotracheitis, Bovine Virus Diarrhea (types 1 & 2), Bovine Syncytial Virus, and Parainfluenza$_3$ with Titanium 5 and for Clostridium

Chauvoei-Septicum-Novyi-Sordellii-Perfringens type C & D with Vision 7 (Intervet, Millsboro, DE), and implanted with Component ES (Vetlife, Overland Park, KS). All steers were re-vaccinated for Bovine Rhinotracheitis, Bovine Virus Diarrhea (types 1 & 2), Bovine Syncytial Virus, and Parainfluenza$_3$, and Leptospirosis with Titanium 5 L5 (Intervet, Millsboro, DE) approximately 14 days after the start of the trial.

Steers from all treatment groups were weighed at 28-d intervals. During the growing phase steers in the SF, PF and CF groups were weighed immediately after removal from their feedlot pens. A 4% pencil shrink was applied to weights from SF and CF steers. Due to the restricted amount of feed received by PF steers, weights from that treatment group were pencil shrunk 3% to account for differences in fill. Steers in the WP group were gathered off pasture at approximately 0700 on weigh days, and held in pens for two to three hours prior to weighing. Due to the increased holding time prior to weighing, only a 2% pencil shrink was applied to weights of WP steers. Differences in pencil shrinks were determined by weight of contents of the gastrointestinal tract measured during the serial slaughter.

At the end of the growing phase (112 d), six randomly selected steers from each of the WP, SF, and PF treatment groups were transported to the FAPRTC abattoir in Stillwater, OK for slaughter. Remaining steers in the WP group were shipped from Stillwater, OK to Lamar, CO (688 km). Final weight off of wheat pasture in Stillwater was considered as the final growing phase weight for the WP group. Remaining steers from these three treatment groups were adapted to the same high-concentrate finishing diet as CF steers (Table 3-1) and placed in the feedlot (n = 8 pens; 8 steers/pen). Steers in the WP and SF groups were adapted to the finishing diet as described above for the CF

treatment group while PF steers immediately received the 74% concentrate diet for 5 d followed by the 88% concentrate finisher.

Steers on the growing diets (WP, SF, and PF) were re-implanted with Revalor-S at the start of the finishing program. Calf-fed steers were re-implanted with Revalor-S at d 84 of the finishing period. During the finishing phase steers in all treatment groups were weighed immediately after removal from their feedlot pens and a 4% pencil shrink was applied to all weights. After the finishing phase, steers from all treatment groups were slaughtered at a common 12th-rib fat of 1.27 cm as determined by ultrasound. Six randomly selected steers from each treatment group were transported to the FAPRTC abattoir for the final serial slaughter group. Remaining steers in all treatments were slaughtered commercially at the Swift plant in Cactus, TX and complete carcass data was collected the National Cattleman's Beef Association's carcass data collection service.

Determination of Net Energy Requirements

A group of similar steers were used for the determination of ME contents of the diets for each of the four treatment groups. Steers in the CF, SF, and PF groups (n = 5 steers/diet) were fed individually in stalls at the Oklahoma State University Nutrition Physiology Research Center, Stillwater, OK. Steers in the WP group (n = 5 steers) were grazed on wheat pasture at the Oklahoma State University Wheat Pasture Research Unit. Diet samples were collected daily, composited, and analyzed for DM, NDF, ADF, CP, and insoluble ash. Composition of wheat pasture forage was determined to be 90.9% OM, 44.5% NDF, 23.5% ADF, and 21.99% CP on a DM basis. Total feces and urine were collected for determination of fecal and urinary energy and N loss for the CF, SF, and PF treatments. Fecal and urine grab samples were collected for WP steers. Fecal

output was estimated using chromium oxide as an indigestible marker, and total DMI was estimated as fecal output divided by the percentage of the indigestible portion of NDF of wheat pasture forage. Indigestible NDF of wheat forage was determined by a 96 h *in situ* digestion (done in triplicate) followed by NDF determination of remaining materials. Urine samples from all treatment groups were examined for concentration of creatinine by liquid chromatography (Shingfield and Offer, 1999). Total creatinine excretion per day was calculated for CF, SF, and PF groups. The average creatinine excretion from these groups and the creatinine concentration of urine samples from WP steers were used to determine total urinary output for WP steers. Gaseous energy losses associated with methane for all groups were estimated using the equations of Moe and Tyrrell (1980) and heat of fermentation was estimated as 7% of ME (ARC, 1980). Retained energy (**RE**) was obtained from the energy content of the whole body composition of slaughtered steers and was subtracted from ME intake (**MEI**) for determination of daily heat production (**HP**). Fasting heat production (**FHP**) was estimated as the intercept of the regression of MEI on log HP. Net efficiency was estimated as the slope of the regression of MEI on RE.

Slaughter and Sample Collection

Slaughter procedures and sample collections were similar for all slaughter groups from all treatments as described by Hersom et al. (2004a, 2004b) with modifications. Steers were stunned with captive bolt and exsanguinated. After exsanguination, weights were collected on blood, noncarcass tissues (offal), and hot carcass. Weights of the head, internal organs, visceral tissues (reticulo-rumen, omasum, abomasum, small and large intestine, cecum, and mesenteric/omental fat), and trim were recorded. Contents of the

gastrointestinal tract were removed before weighing. Empty body weight was calculated as hot carcass weight plus total offal weight.

After weighing, visceral components were composited and ground to measure viscera composition. Visceral tissues were ground, mixed, and sub-sampled in triplicate. After sampling visceral components were composited with blood and remaining offal tissues and ground to measure total offal tissue composition. Tissues were ground twice using an Autio grinder (Astoria, OR) through a 10-mm aperture plate, mixed, and sub-sampled in triplicate. After a 48-h chill, carcass characteristics, including maturity, marbling score, 12th-rib fat, 12th-rib LM area, kidney, pelvic, and heart fat, USDA quality grade, and USDA yield grade were determined. The right side of each carcass was then ground, mixed, and sampled in a similar manner as described for offal tissue to determine carcass and whole body composition.

Chemical Analysis

Chemical analyses of body composition components were carried out by the procedures described by Hersom et al. (2004a). Triplicate samples of carcass, offal, and viscera were analyzed for water by lyophilization to a constant weight. Lyophilized samples were further processed to reduce particle size by submersion in liquid nitrogen and grinding using a Waring blender (Waring Products Co., Winsted, CT). Samples were subsequently analyzed for fat (extraction with diethyl ether for 48 h in a Soxhlet apparatus) and fat-free organic matter (**FFOM**; combustion of ether extraction residue, 500°C for 6 h). Energy content of tissues was calculated as weight of ether extracted material x 9.4 kcal/g plus weight of FFOM x 5.55 kcal/g (Ferrell and Jenkins, 1998). For calculation of accretion of body tissue components during the growing phase, initial body

composition of steers slaughtered at the end of the growing phase was estimated as average percent composition of the initial harvest group multiplied by initial body weight. For calculation of accretion of body tissue components during finishing, average composition of steers in each treatment at the end of the growing phase was multiplied by the final growing phase weight of steers from their respective treatment groups to estimate body composition of final harvest steers at the end of the growing phase.

Statistics

Data for performance and carcass characteristics were analyzed as a randomized complete block design using generalized least squares (Proc MIXED, SAS Institute, Cary, NC). Data were analyzed on a pen mean basis and pen was considered the experimental unit. The model for all measurements included treatment as a fixed effect and block (initial weight) as a random effect. Data for energy intake and retention were analyzed as a completely randomized design using generalized least squares (Proc MIXED). Individual animal was considered the experimental unit and the model included treatment as a fixed effect. Regression of MEI on RE and MEI on log HP was carried out using the Proc REG procedure of SAS. Mean separation for all data was accomplished using Least Significant Difference and means were considered to be significantly different at the $P < 0.05$ level when protected by an F-value ($P < 0.10$).

RESULTS

Performance and Carcass Merit

During the growing phase, ADG was greater ($P = 0.009$) for WP and PF steers than for SF steers (Table 3-3). Treatment means were 1.15, 1.10, and 1.18 kg/d for WP,

SF, and PF steers, respectively, and therefore our objective of achieving similar rates of gain was generally met. Dry matter intake was greater ($P < 0.001$) for steers fed silage compared with PF steers, whereas G:F was greater ($P < 0.001$) for PF steers. At the end of growing 12th-rib LM area was smaller for WP steers compared with SF and PF steers ($P < 0.05$). There were no other significant differences carcass characteristics at the end of the growing phase.

Performance during the finishing phase and carcass characteristics are shown in Table 3-4. Initial (average = 376 vs. 239 kg, respectively) and final (average = 579 vs. 559 kg, respectively) weights were greater ($P < 0.001$) for steers that went through a growing program than for steers that were fed as calves. During finishing, DMI was 7.9% greater ($P < 0.001$) for SF steers than for PF steers, with WP steers being intermediate. Steers fed as calves had lower ($P < 0.001$) DMI (8.6 kg/d) compared with all other treatment groups; however, days on feed was 70 to 84 d longer than the three groups that were fed growing diets. Steers in the SF group had 9.2% greater ($P < 0.05$) ADG than PF steers, and PF steers had 12.8% greater ($P < 0.01$) ADG than both WP and CF steers. This resulted in a lower ($P < 0.01$) G:F for WP steers compared with SF, PF and CF steers.

Hot carcass weight did not differ ($P = 0.12$) among treatments. Dressing percent was greater ($P < 0.05$) for WP, PF, and CF steers than for SF steers although numerical differences were small. Calf-fed steers had smaller ($P < 0.05$) LM area compared with SF and PF steers; WP steers were intermediate. This resulted in less desirable USDA yield grades for CF and WP steers compared with SF and PF steers ($P < 0.05$). Steers fed

silage during the growing period had higher ($P < 0.01$) marbling scores compared with CF and WP steers with PF steers being intermediate.

Composition of Gain

Average composition of the initial slaughter group is shown in Table 3-5, and chemical composition and rates of accretion during the growing and finishing phases are shown in Tables 3-6 and 3-7, respectively. Following the growing phase, empty body mass did not differ ($P = 0.16$) among treatments (Table 3-6). However, FFOM (kg) was greater ($P < 0.05$) in the carcass of PF steers than WP and SF steers. Mass (kg) of fat and energy (Mcal) in the offal was greatest ($P < 0.05$) for PF, intermediate for SF, and lowest for WP steers. When expressed per kg of EBW, fat in offal was greater ($P < 0.05$) for PF and SF steers compared with WP steers. A similar trend was observed for fat (g/kg EBW) and energy (Mcal) in the whole empty body. Fat-free organic matter (kg) in the empty body was greatest ($P < 0.05$) for PF, intermediate for WP, and lowest for SF steers. However, no differences ($P = 0.16$) were observed when FFOM was expressed per unit of EBW.

During the growing period PF steers accreted carcass and empty body mass (kg/d) at a greater ($P < 0.05$) than WP and SF steers (Table 3-6), suggesting that a greater percentage of live weight gain for WP and SF steers was due to gastrointestinal tract fill. Similarly, steers in the PF group accreted FFOM at a greater rate (g/d; $P < 0.05$) in the carcass and empty body compared with SF and WP steers. Program-fed steers accreted fat (g/d) and energy (Mcal/d) in offal and empty body at a greater rate ($P < 0.05$) than WP steers; SF steers were intermediate.

Following the finishing phase, mass of carcass, offal, and empty body did not differ ($P > 0.05$) among treatments (Table 3-7). In addition, chemical composition of the carcass and empty body was similar ($P > 0.05$) among growing programs following the finishing phase. In general, offal FFOM was lower ($P < 0.05$) and offal fat was greater ($P < 0.05$) as a proportion of EBW for CF steers compared with steers backgrounded prior to finishing. During the finishing period, carcass and empty body gain were greater ($P < 0.05$) for SF and PF steers than for WP and CF steers. Offal gain was greater ($P < 0.05$) for PF steers compared with WP steers during finishing. Offal gain in CF steers was lower ($P < 0.05$) than PF steers. Gain of FFOM matter followed a similar trend as mass for the carcass, offal, and empty body. In contrast, gain of fat did not differ ($P = 0.28$) among treatments during the finishing period. Energy gain in the carcass and empty body was greatest ($P < 0.05$) for PF, intermediate for WP and SF, and lowest for CF.

Following the growing phase, mass of the viscera was greater ($P < 0.05$) for PF than for WP steers; SF steers were intermediate (Table 3-8). In addition, the visceral component of noncarcass tissue was significantly lower ($P < 0.05$) in FFOM (g/kg EBW) and higher ($P < 0.05$) in fat (kg and g/kg EBW) and energy (Mcal) for PF steers compared with WP and SF steers. Gain of visceral mass, fat, and energy followed a similar trend as mass, being greater ($P < 0.05$) in PF compared with WP and SF steers during the growing phase.

Following the finishing phase, mass of visceral components was similar ($P = 0.74$) among treatments with the exception of FFOM expressed as g/kg EBW (Table 3-9). Fat free organic matter was greatest for SF steers, intermediate for WP and PF steers, and

lowest for CF steers. During finishing, gain of FFOM in viscera was greater ($P < 0.05$) for backgrounded calves compared with calves placed directly on feed.

Energy Intake and Retention

Data for MEI and energy retention are shown in Table 3-10. Consistent with the design of the experiment, MEI (Mcal/d) did not differ ($P = 0.50$) among the WP, SF, and PF treatments during the growing phase. Nevertheless, steers in the PF group had greater ($P < 0.05$) RE (Mcal/d) in the empty body compared with WP steers, with SF steers being intermediate. The same trend in RE observed in the empty body was also observed in individual components (carcass, offal, viscera). Therefore, HP for steers in the PF treatment was significantly ($P < 0.05$) lower than WP and SF steers. During the finishing phase MEI was greater ($P < 0.05$) for SF steers than for PF steers, and PF steers had greater ($P < 0.05$) MEI compared with CF steers. The WP treatment was intermediate to SF and PF steers and significantly greater ($P < 0.05$) than the CF treatment. Consistent with the lowest MEI, CF steers also had the lowest RE (Mcal/d). Steers in the PF treatment had the numerically greatest RE in both the empty body and in the carcass, despite a lower MEI as compared to WP and SF steers. The estimated daily heat production of both PF and CF steers was lower ($P < 0.05$) than WP and SF steers. Steers in the PF group had the lowest FHP numerically but there were no statistical differences. Compared with WP and SF steers, PF steers did have greater net efficiency ($P < 0.05$).

DISCUSSION

Although our goal was to have equal live weight gains during the growing phase for the WP, SF, and PF groups, ADG for the SF treatment were slightly lower than WP

and PF steers. However, results from the companion metabolism trial demonstrate that ME intake was similar among these three treatment groups. Data from the slaughter groups at the end of the growing period points to greater gains on an empty body weight basis for PF steers compared with WP and SF groups, both in mass and retained energy in the empty body. This difference in retained energy was manifested in greater daily accretion of both fat and FFOM in the empty body for PF steers compared with WP and SF treatments.

The increased empty body mass for PF steers was realized in both the carcass and the noncarcass fractions, but chemical components were different between these fractions. In carcass tissues the greater mass and retained energy was due to increased gain of FFOM. However, in offal tissues this increased mass was through greater accretion of fat. This agrees with the work of Smith et al. (1984) that dealt with steers fed either a high-concentrate or alfalfa hay diet. Steers fed the alfalfa hay diet had a slightly higher MEI, but steers fed the high concentrate diet had higher rates of gain, primarily in the fat depots. The visceral tissue alone accounted for a majority of the daily accretion of fat (67%) and energy (52%) in offal tissues for the PF steers. At the end of the growing phase, mass of the viscera was greatest for PF steers, intermediate for SF, and lowest for WP steers. The greater visceral mass of PF steers was due to greater fat accretion, but FFOM accretion was lower for PF steers in the viscera.

Similar ME intakes coupled with differences in RE in the empty body resulted in lower HP for steers in the PF treatment group. This is in agreement with the work of Reynolds et al. (1991) that showed lower heat production for heifers fed 75% concentrate diets compared with heifers fed 75% forage diets. This suggests the steers program-fed a

high-concentrate diet had a lower heat increment and/or maintenance energy requirement as compared to the groups fed a forage-based diet, and thus had more energy available for tissue accretion. Tess et al. (1984) demonstrated that fasting heat production in pigs was predicted most accurately by lean mass of the animal but that adipose tissue mass contributed little. It was furthermore concluded that protein mass of the visceral organ tissue contributed to fasting heat production more than carcass protein mass. In the present study, the greater visceral mass of PF steers was due to greater fat mass as proportion of EBW, but FFOM mass on an EBW basis was lower for PF steers in the viscera. It is therefore logical to assume that the lower mass of FFOM per unit of EBW in visceral tissue for PF steers lead to a decrease in heat production and consequently lower maintenance energy requirements. Again this is in agreement with the work of Reynolds et al. (1991) that showed greater oxygen consumption by the portal-drained viscera accounted for 72% of the decrease in energy available for tissue accretion in heifers fed a 75% forage diet as opposed to a 75% concentrate diet.

Of the three groups that were placed on growing diets, SF steers had the highest DMI during the finishing phase. Steers in the PF treatment were lowest with WP steers being intermediate. However, the greatest gains during finishing were also achieved by steers in the SF treatment group, resulting in SF and PF steers having greater growth efficiency as compared to WP steers. Steers in the WP group were lowest in both ADG and growth efficiency and were fed for an additional 19 d as compared with SF and PF steers. Steers in the CF had the lowest DMI and greatest efficiency during the finishing phase, however their efficiency was comparable to both the SF and the PF treatments. Gains during finishing were lower for CF steers compared to the SF and PF treatments,

but equal to those of WP steers despite the fact that the finishing period for CF steers was 73 d longer. The lower performance of WP steers may be partially attributable to the fact that they underwent an additional transport from Stillwater, OK to Lamar, CO at the end of the growing phase that other treatments did not and thus may have had additional stress. Stress is linked with increases in circulating glucocorticoids in cattle (Weber et al., 2001) which is linked with immune suppression and increased incidence of disease (Burton et al., 2005). Increased incidence of bovine respiratory disease, in turn, has been associated with decreased feedlot performance (Gardner et al., 1999). However differences in incidence of clinical symptoms of respiratory disease were not noted among treatments, and any decrease in performance due to these factors would have been at the subclinical level.

Daily accretion of empty body mass was lowest for WP and CF steers and this was mostly attributable to less accretion of water and FFOM as compared to SF and PF steers. Because SF steers had greater live weight gains during finishing compared with PF steers, some of this difference may be attributed to gut fill. These same differences in mass due to lower accretion of water and FFOM were evident in the carcass tissue fraction suggesting less accretion of muscle mass for WP and CF steers compared with SF and PF steers. Indeed, 12th-rib LM area was found to be smaller in CF steers as compared to SF and PF steers with WP steers being intermediate. Although there were no differences in body composition among treatments at final harvest, the faster rate of water and FFOM accretion by SF and PF steers disagrees with previous work (Sainz et al., 1995) that concluded there was no difference in muscle accretion due to energy intake, only in fat accretion.

Steers in the WP group also had the lowest daily accretion of offal tissues due to less accretion of water and FFOM. Accretion of visceral mass was similar among treatments. Although WP steers were lowest in daily accretion of empty body mass, carcass mass and offal mass, they were not lower in daily accretion of visceral mass. Thus, a greater portion of their total gain and RE was invested in that fraction as compared to other treatments. This may also suggest that WP steers had a higher maintenance energy requirement during the finishing phase compared with PF and CF steers, due to the large energy expenditure of visceral organs (Ferrell and Jenkins, 1985; Burrin et al., 1990).

Previous work has concluded that steers restricted in intake below ad libitum levels (at maintenance vs. full-feeding, Fox et al., 1972; restricted to 70% of controls, Wright and Russel, 1991) during the growing phase have an initial period of increased lean gain when realimented to an ad libitum high-concentrate diet, followed by rapid fat accretion. The initial increased lean gain is thought to be more energetically efficient and to partly contribute to the compensatory gain phenomenon. In the current study there were no significant differences in body composition or carcass composition among treatments at the end of the growing or finishing phases; however, SF and WP steers experienced rapid accretion of visceral tissues during the finishing phase. It is therefore possible that initial lean gain when steers are moved to a high-concentrate diet may be due not to muscle gain, but to accretion of water and FFOM in the viscera.

Among the three treatment groups that were grown, PF steers had the lowest MEI and the highest RE in the empty body, giving the lowest estimate for HP among those groups. Steers in the CF group, although lowest in RE among all treatments, were also

lowest in MEI. This resulted in their estimated HP being comparable to that of the PF steers. Both WP and SF steers had greater HP as compared with PF and CF steers. This would suggest that heat increment, maintenance requirements, or both were higher for these two groups as compared to PF and CF steers. This agrees with the work of Sainz et al. (1995) that showed a 21% reduction in maintenance requirements during the finishing phase for steers limit-fed a high-concentrate diet during the growing phase as compared to steers ad libitum-fed a forage diet during the growing phase. Because MEI was lower for PF and CF steers as compared to SF steers and tended to be lower as compared to WP steers, this is also in agreement with Reynolds et al. (1991) that showed heat production was not only influenced by diet type, but increased with increasing intake. Steers in the SF treatment had similar heat production to that of WP steers but had greater DMI, ADG, and growth efficiency. Because steers in the SF treatment also had the highest MEI, it appears they were able to overcome this handicap of greater heat production with greater DMI during finishing.

As mentioned above steers in the CF group had smaller 12th-rib LM area as compared to SF and PF steers, while WP steers were intermediate. Combined with greater 12th-rib fat for CF steers this resulted in lower yield grades for SF and PF steers compared with WP and CF steers. Despite this the SF treatment resulted in greater marbling scores compared with the WP and CF treatments. Steers in the PF group were intermediate. This may be attributed to SF steers having the highest DMI and thus more energy available for intramuscular fat accretion. It was shown by Wertz et al. (2001) that starting calves on high-concentrate diets earlier in life increased marbling scores. Steers in the CF group exhibited the lowest marbling scores despite having the longest period on

ad libitum, high-concentrate feed. However, steers in the current study were weaned and placed on a finishing diet at an older age as compared to Wertz et al. (2001). Additionally because they were the youngest group to be harvested in this study, physiological maturity may have advanced to a point where CF steers did not have adequate time on feed to develop intramuscular fat (Coleman et al., 1993; Schoonmaker et al., 2004). Because WP steers were also lower in marbling score, it is possible that higher maintenance requirements, as mentioned above, may have resulted in less overall energy availability and thus less intramuscular fat accretion. The current findings are also in contrast with Klopfenstein et al. (2000) who concluded that there were no differences in marbling due to type of backgrounding program or rate of gain during the growing/backgrounding phase when steers were fed to a common depth of 12th-rib backfat.

IMPLICATIONS

Program feeding of a high-concentrate diet during the growing period may result in greater gains and increased retained energy in the empty body and carcass as compared to forage-based growing programs even at similar calculated ME intake. Furthermore, feeding of high-concentrate diets during the growing phase may result in greater, more efficient gains during the subsequent finishing period as compared to forage-based diets due to less accretion of visceral organ mass and lower maintenance energy requirements during finishing. These higher maintenance requirements and diminished availability of energy for gain may result in less carcass fat and protein accretion per day. However, if

greater visceral mass and increased GIT capacity leads to increased DMI during finishing, gains may not be decreased.

LITERATURE CITED

ARC. 1980. The Nutritional Requirements of Ruminant Livestock. Commonwealth Agricultural Bureaux, Oxon, U.K.

Baker, R. D., N. E. Young, and J. A. Lewis. 1992. The effect of diet in winter on the body composition of young steers and subsequent performance during the grazing season. Anim. Prod. 54:211-219.

Burrin, D. G., C. L. Ferrell, R. A. Britton and M. L. Bauer. 1990. Level of nutrition and visceral organ size and metabolic activity in sheep. Br. J. Nutr. 64:439-448.

Burton, J. L., S. A. Madsen, L. C. Chang, P. S. Weber, K. R. Buckham, R. van Dorp, M. C. Hickey, B. Earley. 2005. Gene expression signatures in neutrophils exposed to glucocorticoids: a new paradigm to help explain "neutrophil dysfunction" in parturient dairy cows. Vet. Immunol. Immunopathol. 105:197-219.

Choat, W. T., C. R. Krehbiel, G. C. Duff, R. E. Kirksey, L. M. Lauriault, J. D. Rivera, B. M. Capitan, D. A. Walker, G. B. Donart, and C. L. Goad. 2003. Influence of grazing dormant native range or winter wheat pasture on subsequent finishing cattle performance, carcass characteristics, and ruminal metabolism. J. Anim. Sci. 81:3191-3201.

Coleman, S. W., and B. C. Evans.1986. Effect of nutrition, age, and size on compensatory growth in two breeds of steers. J. Anim. Sci. 63:1968-1982.

Coleman, S. W., B. C. Evans, and J. J. Guenther. 1993. Body and carcass composition of Angus and Charolais steers as affected by age and nutrition. J. Anim. Sci. 71:86-95.

Ferrell, C. L. and T. G. Jenkins. 1985. Cow type and the nutritional environment: nutritional aspects. J. Anim. Sci. 61:725-741.

Ferrell, C. L. and T. G. Jenkins. 1998. Body composition and energy utilization by steers of diverse genotypes fed a high-concentrate diet during the finishing period: I. Angus, Belgian Blue, Hereford, and Piedmontese sires. J. Anim. Sci. 76:637-646.

Fox, D. G., R. R. Johnson, R. L. Preston, and T. R. Dockerty, and E. W. Klosterman. 1972. Protein and energy utilization during compensatory growth in beef cattle. J. Anim. Sci. 34:310-318.

Gardner, B. A., H. G. Dolezal, L. K. Bryant, F. N. Owens, and R. A. Smith. 1999. Health of finishing steers: effects on performance, carcass traits, and meat tenderness. J. Anim. Sci. 77:3168-3175.

Hersom, M. J., G. W. Horn, C. R. Krehbiel, and W. A. Phillips. 2004a. Effect of live weight gain of steers during winter grazing: I. Subsequent feedlot performance, carcass characteristics and body composition. J. Anim. Sci. 82:262-272.

Hersom, M. J., C. R. Krehbiel, and G. W. Horn. 2004b. Effect of previous live weight gain of steers during the winter grazing: II. Visceral organ mass, cellularity and oxygen consumption. J. Anim. Sci. 82:184-197.

Klopfenstein, T., R. Cooper, D. J. Jordon, D. Shain, T. Milton, C. Calkins, and C. Rossi. 2000. Effects of backgrounding and growing programs on beef carcass quality and yield. Proc. Am. Soc. Anim. Sci., 1999. Available at http://www.asas.org/jas/symposia/proceedings/0942.pdf. Accessed 6/2/2006.

Moe, P. W. and H. F. Tyrrell. 1980. Methane production in dairy cows. In L. E. Mount (Ed.) Energy Metabolism. European Association of Animal Production Publ. No. 26. p.59. Butterworths, London.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. National Academy Press. Washington D.C.

Reynolds, C. K., H. F. Tyrrell, and P. J. Reynolds. 1991. Effect of diet forage-to-concentrate ratio and intake on energy metabolism in growing beef heifers: whole body energy and nitrogen balance and visceral heat production. J. Nutr. 121:994-1003.

Sainz, R. D., F. De la Torre, and J. W. Oltjen. 1995. Compensatory growth and carcass quality in growth restricted and refed beef steers. J. Anim. Sci. 73:2971-2979.

Schoonmaker, J. P., M. J. Cecava, F. L. Fluarty, H. N. Zerby, and S. C. Loerch. 2004. Effect of source and amount of energy and rate of growth in the growing phase on performance and carcass characteristics of early- and normal-weaned steers. J. Anim. Sci. 82:273-282.

Shingfield, K. J., and N. W. Offer. 1999. Simultaneous determination of purine metabolites, creatinine and pseudouridine in ruminant urine by reverse-phase high-performance liquid chromatography. J. Chromatogr. B. 723:81-94.

Smith, S. B., R. L. Prior, C. L. Ferrell, and H. J. Mersmann. 1984. Interrelationships among diet, age, fat deposition and lipid metabolism in growing steers. J. Nutr. 114:153-162.

Tess, M. W., G. E. Dickerson, J. A. Nienaber, and C. L. Ferrell. 1984. The effects of body composition of fasting heat production in pigs. J. Anim. Sci. 58:99-110.

Weber, P. S., S. A. Madsen, G. W. Smith, J. J. Ireland, and J. L. Burton. 2001. Pre-translational regulation of neutrophil L-selectin in glucocorticoid-challenged cattle. Vet. Immunol. Immunopathol. 83:213-240.

Wertz, A. E., L. L. Berger, P. M. Walker, D. B. Faulkner, F. K. McKeith, and S. Rodriguez-Zas. 2001. Early weaning and post weaning nutritional management affect feedlot performance of Angus X Simmental heifers and the relationship of 12^{th} rib fat and marbling score to feed efficiency. J. Anim. Sci. 79:1660-1669.

Wright, I. A. and A. J. F. Russel. 1991. Changes in the body composition of beef cattle during compensatory growth. Anim. Prod. 52:105-113.

Table 3-1. Dry matter composition of diets

	Diet		
Item[a]	SF	PF	CF
Ingredient			
Steam flaked corn	25.94	60.88	76.14
Sorghum silage	62.56	23.52	11.76
CCDS[b]	3.00	3.00	3.00
Yellow grease	-	3.50	3.50
Soybean meal	7.08	5.80	2.26
Supplement	1.42	3.30	3.35
Nutrients			
DM, % of as-fed	38.50	54.14	63.46
CP	12.58	14.90	13.34
Non-protein nitrogen[c]	0.98	3.12	3.13
NDF	32.46	20.55	14.66
NE_m, Mcal per kg[d]	0.32	0.42	0.45
NE_g, Mcal per kg[e]	0.20	0.28	0.31
Calcium	0.82	0.91	0.78
Phosphorus	0.23	0.28	0.28
Potassium	1.34	0.97	0.72
Magnesium	0.25	0.26	0.26

[a]Percentage of dry matter unless stated otherwise.
[b]Condensed corn distiller's solubles.
[c]Crude protein equivalent.
[d]Net energy for maintenance. Calculated from NRC (1996).
[e]Net energy for gain. Calculated from NRC (1996).

Table 3-2. Dry matter composition of diet supplements

	Diet		
Ingredient[a]	SF	PF	CF
Limestone	55.32	35.16	27.75
Urea	11.24	32.17	31.82
Salt	17.59	7.58	7.47
Min Ad	9.60	20.94	27.87
Potassium chloride	-	-	1.04
Mineral oil	2.01	2.04	2.01
Colorado Beef TM[b,c]	1.33	0.86	0.80
Rumensin 80[d]	1.24	0.53	0.53
Tylan 100[e]	0.33	0.14	0.14
Vitamin A premix[f]	0.21	0.09	0.09
Vitamin E premix[g]	1.14	0.49	0.48

[a]SF = silage fed PF = Program fed CF = Ad libitum concentrate fed
[b]Percentage of dry matter.
[c]Colorado Beef trace mineral premix: Cobalt, 340 ppm; Copper, 7.7%; Manganese, 6%; Zinc, 22.4%; and Selenium, 300 ppm.
[d]Monensin, 176.4 g per kg.
[e]Tylosin, 220.5 g per kg.
[f]110,250,000 IU vitamin A per kg.
[g]198,450 IU vitamin E per kg.

Table 3-3. Effect of treatment on performance during the growing period (d 1 to 112)

	Treatment[a]				
Item	WP	SF	PF	SEM[b]	*P*-value
Performance					
Initial wt, kg	253[c]	237[d]	234[d]	2.87	<0.001
Final wt, kg	382	369	377	3.76	0.51
DMI, kg/d	-	7.7[c]	6.1[d]	0.20	<0.001
ADG, kg	1.15[c]	1.10[d]	1.18[c]	0.02	0.01
G:F	-	0.143[c]	0.198[d]	0.007	<0.001
Carcass characteristics					
HCW, kg	220	220	232	8.7	0.55
Dressing %	59.0	53.8	63.5	3.3	0.16
12th-rib fat	0.40[c]	0.62[d]	0.53[cd]	0.06	0.08
LM area	57.5[c]	67.3[d]	64.1[cd]	2.5	0.04
KPH, %	0.3	0.6	0.5	0.10	0.24
Marbling Score[e]	245	273	305	20.6	0.15

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed.
[b]Standard error of mean, n = 8 for performance, n = 6 for carcass characteristics.
[c,d]Within a row and tissue, means without a common superscript letter differ (P < 0.05).
[e]200 = USDA Traces[00], 300 = USDA Slight[00]

Table 3-4. Effect of treatment on performance during the finishing phase and carcass characteristics at slaughter

	Treatment[a]					
Item	WP	SF	PF	CF	SEM[b]	*P*-value
Performance						
Days on feed	123	104	104	196	-	-
Initial wt, kg	382[c]	369[d]	377[cd]	239[e]	3.76	<0.001
Final wt, kg	584[c]	581[c]	571[cd]	559[d]	6.22	<0.001
DMI, kg/d	10.4[cd]	10.9[c]	10.1[d]	8.6[e]	0.24	<0.001
ADG, kg	1.64[c]	2.02[d]	1.85[e]	1.63[c]	0.04	<0.001
G:F	0.156[c]	0.186[d]	0.186[d]	0.190[d]	0.005	<0.001
Carcass characteristics						
HCW, kg	386	379	376	371	4.4	0.12
Dressing %	65.9[c]	65.1[d]	65.9[c]	66.3[c]	0.27	0.01
12th-rib fat	1.35[c]	1.27[c]	1.24[c]	1.63[d]	0.048	<0.001
LM area	86.5[cd]	89.7[c]	89.0[c]	84.5[d]	1.29	0.02
KPH, %	3.0	3.0	3.0	3.1	0.05	0.41
Yield grade	3.19[c]	2.76[d]	2.94[d]	3.39[c]	0.08	<0.001
Marbling Score[f]	409[c]	449[d]	423[cd]	401[c]	9.8	0.01

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed.
[b]Standard error of mean, n = 8 for performance, n = 6 for carcass characteristics.
[c,d,e]Within a row and tissue, means without a common superscript letter differ (P < 0.05).
[f]200 = USDA Traces[00], 300 = USDA Slight[00]

Table 3-5. Chemical composition of the initial harvest group

	Tissue component			
	Carcass	Offal	Viscera	Empty body
Mass, kg	140.2	76.0	18.23	216.3
Water, kg	72.0	42.0	10.71	114.0
FFOM, kg[a]	33.4	18.7	2.76	52.1
FFOM, g/kg	237.2	247.0	153.26	240.6
Fat, kg	25.6	11.2	4.47	36.9
Fat, g/kg	181.5	146.1	242.45	168.9
Energy, Mcal[b]	425.8	209.6	57.38	635.4

[a]Fat-free organic matter

[b]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g

Table 3-6. Effect of winter growing program on chemical composition and composition of gain during the growing phase

	Carcass				Offal				Empty body			
	Treatment[a]				Treatment				Treatment			
	WP	SF	PF	SEM[b]	WP	SF	PF	SEM	WP	SF	PF	SEM
Chemical composition												
Mass, kg	222.0	212.1	237.2	7.83	114.2	110.5	116.6	3.85	336.2	322.6	353.8	10.77
Water, kg	128.3^{cd}	118.0^{c}	130.3^{d}	3.72	69.0	64.3	66.5	2.49	197.3	182.4	196.8	5.15
FFOM, kg[e]	46.6^{c}	45.9^{c}	53.7^{d}	2.45	23.5	21.8	23.3	1.12	70.1^{cd}	67.7^{c}	77.0^{d}	2.76
FFOM, g/kg	209.4	216.5	225.9	5.62	205.8	196.7	201.3	9.26	208.1	209.5	217.8	3.66
Fat, kg	33.6	36.2	40.0	3.03	16.8^{c}	19.9^{cd}	22.3^{d}	1.64	50.3	56.1	62.3	3.98
Fat, g/kg	151.2	169.0	168.3	9.90	146.6^{c}	180.6^{d}	189.6^{d}	10.84	149.8^{c}	172.9^{d}	174.1^{d}	7.66
Energy, Mcal[f]	573	595	674	36.7	288^{c}	308^{cd}	339^{d}	14.7	862^{c}	903^{cd}	1013^{d}	48.5
Energy, Mcal/kg	2.59	2.79	2.84	0.08	2.52^{c}	2.79^{d}	2.90^{d}	0.07	2.56^{c}	2.79^{d}	2.86^{d}	0.07
Composition of gain												
Mass, kg/d	0.81^{c}	0.80^{c}	0.96^{d}	0.044	0.39	0.39	0.42	0.031	1.20^{c}	1.19^{c}	1.38^{d}	0.065
Water, g/d	542^{cd}	485^{c}	564^{d}	24.9	264	245	250	21.7	806	730	814	37.4
FFOM, g/d	139^{c}	152^{c}	207^{d}	16.0	53	52	58	9.6	192^{c}	204^{c}	265^{d}	16.7
Fat, g/d	87	126	149	22.0	57^{c}	89^{cd}	105^{d}	12.8	144^{c}	215^{cd}	255^{d}	28.1
Energy, Mcal/d	1.59^{c}	2.03^{cd}	2.55^{d}	0.235	0.83^{c}	1.12^{cd}	1.32^{d}	0.104	2.42^{c}	3.15^{cd}	3.87^{d}	0.30

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed

[b]Standard error of mean, n = 4 for initial harvest, n = 6 for intermediate and final harvest

[c,d]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$)

[e]Fat-free organic matter

[f]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g

Table 3-7. Effect of winter growing program on chemical composition and composition of gain during the finishing phase

	Carcass					Offal					Empty body				
	Treatment[a]					Treatment					Treatment				
	WP	SF	PF	CF	SEM[b]	WP	SF	PF	CF	SEM	WP	SF	PF	CF	SEM
Chemical composition															
Mass, kg	376.0	357.1	383.4	361.1	14.62	175.0	165.5	175.3	166.6	6.44	551.1	522.5	558.7	527.6	20.56
Water, kg	182.5	173.5	182.3	170.2	6.07	89.6	87.8	90.0	83.8	3.15	272.1	261.4	272.2	254.0	8.96
FFOM, kg[f]	86.8	84.3	89.6	88.1	4.04	35.4^{c}	32.2^{cd}	35.5^{c}	29.7^{d}	1.15	122.2	116.5	125.1	117.8	4.74
FFOM, g/kg	231.3	236.0	234.3	243.8	7.20	202.3^{c}	194.6^{cd}	204.1^{c}	178.3^{d}	5.79	222.1	223.1	224.9	223.1	5.88
Fat, kg	84.5	81.7	91.8	84.0	8.03	43.4	39.6	43.1	46.8	3.27	127.9	121.3	134.8	130.9	10.78
Fat, g/kg	223.0	227.6	236.0	232.6	15.60	247.6^{cd}	239.3^{c}	240.9^{c}	281.8^{d}	13.17	230.9	231.3	237.5	248.4	13.75
Energy, Mcal[g]	1276	1235	1360	1279	86.5	605	551	602	605	33.3	1881	1786	1961	1884	115.7
Energy, Mcal/kg	3.38	3.45	3.52	3.54	0.13	3.45	3.33	3.40	3.64	0.11	3.40	3.41	3.48	3.57	0.11
Composition of gain															
Mass, kg/d	1.18^{c}	1.46^{d}	1.57^{d}	1.23^{c}	0.071	0.45^{c}	0.56^{de}	0.64^{e}	0.52^{cd}	0.031	1.63^{c}	2.02^{d}	2.21^{d}	1.75^{c}	0.94
Water, g/d	395^{c}	567^{d}	586^{d}	553^{d}	38.6	143^{c}	246^{d}	270^{d}	244^{d}	17.5	537^{c}	813^{d}	856^{d}	796^{d}	53.5
FFOM, g/d	312^{c}	383^{d}	383^{d}	304^{c}	23.9	88^{cd}	107de	131^{e}	69^{c}	8.8	400^{c}	490^{d}	513^{d}	373^{c}	24.7
Fat, g/d	402	451	525	317	61.6	211	195	216	190	24.8	613	646	742	508	82.2
Energy, Mcal/d	5.51^{cd}	6.37^{cd}	7.06^{d}	4.67^{c}	0.610	2.47	2.43	2.76	2.17	0.221	7.98^{cd}	8.80^{cd}	9.82^{c}	6.84^{d}	0.794

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed

[b]Standard error of mean, n = 4 for initial harvest, n = 6 for intermediate and final harvest

[c,d,e]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$)

[f]Fat-free organic matter

[g]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g

Table 3-8. Effect of winter growing program on viscera chemical composition and composition of gain during the growing phase

	Treatment[a]			
	WP	SF	PF	SEM[b]
Chemical composition				
Mass, kg	25.51[c]	26.52[cd]	30.81[d]	1.56
Water, kg	14.51	13.90	15.25	0.72
FFOM, kg[f]	2.77	2.75	2.83	0.13
FFOM, g/kg	108.8[c]	104.7[c]	92.6[d]	3.8
Fat, kg	7.95[c]	9.55[c]	12.30[d]	0.84
Fat, g/kg	310.9[c]	357.9[d]	396.7[e]	12.1
Energy, Mcal[g]	90.1[c]	105.1[c]	131.4[d]	8.4
Energy, Mcal/kg	3.53 [c]	3.95 [d]	4.24 [d]	0.11
Composition of gain				
Mass, kg/d	0.073[c]	0.095[c]	0.123[d]	0.011
Water, g/d	40.04	41.51	49.35	5.261
FFOM, g/d[e]	1.47	3.61	3.38	1.054
Fat, g/d	33.90[c]	48.97[c]	70.52[d]	6.359
Energy, Mcal/d[f]	0.33[c]	0.48[c]	0.68[d]	0.062

[a]Treatments were WP = wheat pasture, SF = silage fed, and PF = program fed for a 112 d growing period.
[b]Standard error of mean, n = 6.
[c,d,e]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).
[f]Fat-free organic matter.
[g]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g.

Table 3-9. Effect of winter growing program on viscera chemical composition and composition of gain during the finishing phase

	Treatment[a]				
Item	WP	SF	PF	CF	SEM[b]
Chemical composition					
Mass, kg	49.64	45.44	46.84	44.52	3.47
Water, kg	17.90	17.56	16.34	16.46	0.87
FFOM, kg	4.36	4.17	4.09	3.57	0.28
FFOM, g/kg	87.75[cd]	92.04[c]	89.65[cd]	79.91[d]	3.42
Fat, kg	26.90	23.29	26.07	24.08	2.49
Fat, g/kg	540.2	511.9	539.8	539.2	17.8
Energy, Mcal	277.1	242.1	267.7	246.1	24.7
Energy, Mcal/kg	5.57	5.32	5.57	5.51	0.15
Composition of gain					
Mass, kg/d	0.188	0.188	0.177	0.148	0.024
Water, g/d	22.62[cd]	39.71[e]	20.61[c]	36.75[de]	5.06
FFOM, g/d	11.93[c]	14.35[c]	13.87[c]	5.96[d]	1.83
Fat, g/d	151.7	135.9	141.7	103.5	19.8
Energy, Mcal/d	1.49	1.36	1.41	1.01	0.19

[a]Treatments were WP = wheat pasture, SF = silage fed, and PF = program fed for a 112 d growing period.
[b]Standard error of mean, n = 6.
[c,d,e]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).
[e]Fat-free organic matter.
[f]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g.

Table 10. Energy intake and retention in the empty body (Mcal/d) by steers during growing and finishing phases

	Treatment[a]					
	WP	SF	PF	CF	SEM[b]	*P*-value
Growing phase				--		
ME intake	12.89	13.25	12.63	--	0.37	0.497
Retained energy	2.42[c]	3.15[cd]	3.87[d]	--	0.30	0.015
Carcass	1.59[c]	2.03[cd]	2.55[d]	--	0.24	0.040
Offal	0.83[c]	1.12[cd]	1.32[d]	--	0.10	0.020
Viscera	0.33[c]	0.48[c]	0.68[d]	--	0.06	0.004
Heat production	10.47[c]	10.10[c]	8.76[d]	--	0.48	0.053
Finishing phase						
ME intake	28.36[cd]	29.96[c]	27.07[d]	23.42[e]	0.79	<0.001
Retained energy	7.98[cd]	8.80[cd]	9.82[c]	6.84[d]	0.79	0.087
Carcass	5.51[cd]	6.37[cd]	7.06[c]	4.67[d]	0.61	0.060
Offal	2.47	2.43	2.76	2.17	0.22	0.350
Visceral	1.49	1.36	1.41	1.01	0.19	0.330
Heat production	20.37[c]	21.16[c]	17.25[d]	16.57[d]	0.93	0.004
Fasting heat production[f]	0.78	0.76	0.75	--	0.03	0.099
Net efficiency[g]	0.36 [c]	0.34 [c]	0.46 [d]	--	0.06	0.043

[a]Treatments were WP = wheat pasture, SF = silage fed, and PF = program fed for a 112 d growing period.
[b]Standard error of mean, n = 6.
[c,d,e]Within a row, means without a common superscript letter differ ($P < 0.05$).
[f]Calculated as the intercept of the regression of log heat production on ME intake
[g]Calculated as the slope of RE on ME intake

CHAPTER IV

EFFECTS OF WINTER GROWING PROGRAM ON VISCERAL ORGAN MASS, CELLULARITY, AND OXYGEN CONSUMPTION OF BEEF STEERS DURING GROWING AND FINISHING[1,2]

M. P. McCurdy*, G. W. Horn[*], J. J. Wagner[†], and C. R. Krehbiel[1*,3]

[*]Department of Animal Science, Oklahoma State University, Stillwater, 74078

[†]Southeastern Colorado Research Center, Colorado State University, Lamar, 81052

[1]Approved for publication by the Director of the Oklahoma Agric. Exp. Sta. This material is based in part upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No.?

[2]The authors wish to thank Donna Perry, Kim Whittet, and Joan Summers for their help in collection and analysis of samples, Scott Schaeffer and Jim Kountz for animal care and sample preparation, the Southeastern Colorado Research Center and staff and animal

caretakers, and numerous undergraduate and graduate students who assisted on harvest dates.

[3]Corresponding author: Dept. of Anim. Sci., 208 Anim. Sci. Bldg., Stillwater, OK 74078 phone: 405/744-8857; fax: 405/7447390; E-mail: clint.krehbiel@okstate.edu).

ABSTRACT: The purpose of this study was to investigate the effects of winter growing program on organ mass, cellularity, and oxygen consumption of beef steers. A total of 46 steers were utilized for the experiment. Four steers were randomly selected as an initial harvest group. Remaining steers were blocked by weight and randomly allotted to one of four treatment groups: 1) ad libitum fed high-concentrate diet (**CF**); 2) grazed on wheat pasture (**WP**); 3) fed a sorghum silage-based growing diet (**SF**); or 4) program fed a high-concentrate diet (**PF**). Steers in the WP, SF, and PF groups were managed to achieve approximately equal rates of BW gain. After the growing phase (112 d) steers in the WP, SF, and PF treatments were adapted to a high-concentrate diet for finishing. Steers from all treatment groups were harvested at a backfat of 1.27 cm as estimated by ultrasound. In addition, six steers from each treatment group were randomly selected for harvest at the end of the growing and finishing phases. At each harvest, weights were collected on all individual organs. During the growing phase, WP, SF, and PF treatments gained 1.21, 1.10, and 1.18 kg/d, respectively, with SF steers differing from the WP and PF groups ($P < 0.05$). At the end of the growing phase, liver and small intestine weights (g/kg EBW) were greatest for WP steers ($P < 0.01$). Silage-fed steers had the heaviest ($P < 0.05$) reticulo-rumens. Mesenteric fat mass was greatest for PF, intermediate for SF, and lowest for WP steers ($P < 0.01$). Mass of the total gastrointestinal tract (**GIT**) was

greater for PF steers as compared to WP steers ($P < 0.05$); SF steers were intermediate. Mass of total splanchnic tissues (**TST**) did not differ among treatments. At final harvest, liver weights remained greatest (g/kg EBW; $P < 0.01$) for WP steers. Mass of the reticulo-rumen, mesenteric fat, and GIT was similar among treatments and WP steers had less decrease in GIT and TST mass as a portion of BW than PF and CF steers ($P < 0.05$); SF steers were intermediate. There were no differences in cellularity (protein:DNA) or oxygen consumption of small intestine or liver tissue on an equal weight basis ($\mu L \cdot min^{-1} \cdot g^{-1}$) at the end of either period; thus energy expenditure of splanchnic organs was dependent on mass. A lesser proportion of the gain of PF steers was attributed to the growth of splanchnic organs during finishing, which may have resulted in decreased maintenance energy requirements during finishing.

Key Words: Beef Cattle, Cellularity, Oxygen Consumption, Visceral Organs

INTRODUCTION

The plane of nutrition during the growing phase can determine the maintenance requirement of cattle in the subsequent finishing phase (Ferrell and Jenkins, 1986; Hersom et al., 2004a), and increased gain in the feedlot by previously restricted cattle has been attributed to decreased maintenance energy requirement (Fox et al., 1972; Sainz et al. 1995). Depending on the quality and energy density of the diet, maintenance requirements can account for more than half of the metabolizable energy intake of beef cattle (Beef Cattle NRC, 1996). Due to high rates of protein synthesis, visceral organs comprise a large portion of the energy expenditure for maintenance even though they

represent a small percentage of body weight (McBride and Kelly, 1990). Maintenance requirements increase with visceral organ mass (Ferrell and Jenkins, 1998), which is in turn dependent on plane of nutrition (Sainz and Bentley, 1997).

Differences have been reported in visceral organ mass and in individual mass of metabolically important organs due to DMI, physical form of the diet, and energy density of the diet (Sainz and Bentley, 1997; Hersom et al., 2004b). Forestomach mass appears to respond to physical form of the diet and fiber content (Sainz and Bentley, 1997; Hersom et al., 2004b), liver mass appears to be dependent on nutrient load, and increases with DMI and higher energy density of the diet (Carstens et al., 1991; Sainz and Bentley, 1997; Hersom et al., 2004b), while small intestinal mass appears to be dependent on both (Sainz and Bentley, 1997).

The following study was designed to compare steers managed for similar rates of gain on different diets during the growing period. The objective of the experiment was to characterize the effect of winter growing diet on mass, cellularity, and oxygen consumption of metabolically important visceral organs during the growing and finishing phases.

MATERIALS AND METHODS

A total of 46 steers were utilized for the experiment. Steers were randomly selected from a larger population of steers used to determine performance, body composition, and carcass characteristics (McCurdy et al., 2006). Four steers were transported to the Oklahoma Food and Agricultural Products Research and Technology Center (**FAPRTC**) abattoir in Stillwater, OK for an initial serial slaughter group. Remaining steers were blocked by weight and randomly allotted to one of four treatment

groups for winter feeding. One group of steers were placed in the feedlot (n = 6) immediately after weaning and fed a high-concentrate finishing diet ad libitum (**CF**). The three remaining treatment groups were managed on three different growing programs to achieve approximately equal rates of BW gain. One group was grazed on wheat pasture with unrestricted forage availability (**WP**; n = 12), a second group was fed a sorghum silage-based growing diet (**SF**; n = 12), and the third group was program fed a high-concentrate diet (**PF**; n = 12). Steers were housed with the larger population of steers described above (McCurdy et al., 2006).

At the end of the growing phase (112 d), six randomly selected steers from each of the WP, SF, and PF treatment groups were transported to the FAPRTC abattoir in Stillwater, OK for slaughter. Remaining steers from these treatment groups were adapted to the same high-concentrate finishing diet as CF steers and placed in the feedlot. After the finishing phase, steers from all treatment groups were slaughtered at a common backfat of 1.27 cm as estimated by ultrasound. Steers were transported to the FAPRTC abattoir for slaughter.

Harvest and Sample Collection

Slaughter procedures and sample collections were similar for all serial slaughter groups from all treatments as described by Hersom et al. (2004a, 2004b) with modifications. Steers were stunned with captive bolt and exsanguinated. After exsanguination, weights of blood, noncarcass tissues (offal), and hot carcass were measured. Individual weights of blood, head, hide, internal organs, viscera (reticulo-rumen, omasum, abomasum, small and large intestine, cecum, and mesenteric/omental fat), and trim were recorded. Contents of the GIT were removed before weighing.

Empty body weight was calculated as hot carcass weight plus total offal weight. Total splanchnic tissue was calculated as GIT plus mesenteric/omental fat, liver, spleen, and pancreas.

After collection of weights, additional tissue samples were collected from the center lobe of the liver and duodenum (18 cm distal to the pyloric sphincter) to estimate in vitro oxygen consumption of the tissues. Samples were collected immediately after organ masses were recorded, and as close to time of evisceration as possible (approximately 30 min). Collected tissue samples were placed in ice-cold Krebs-Hensleit saline with glucose (**KHS**; Kelly et al., 1993) and transported to the laboratory.

Additional samples were obtained from the duodenum and liver for determination of DNA, RNA, and protein content. Samples were dissected into approximately 1 g pieces and snap frozen in liquid nitrogen within 30 min of exsanguination. Frozen samples were then placed on dry ice for transport to the lab, where they were placed into storage at -80°C for further analysis.

In Vitro O_2 Consumption

When tissue samples for determination of O_2 consumption reached the laboratory they were transferred to fresh KHS at 37°C and bubbled with 95% oxygen gas (Kelly et al., 1993). All visible adipose tissue was removed from the small intestine, which was cut longitudinally to the lumen. Small cross-sections were excised to accumulate 50 mg for analysis (Burrin et al., 1990). A 50 mg sample of liver tissue was excised and lightly scored with a scalpel (Burrin et al., 1990). Rates of O_2 consumption were measured as previously reported by Hersom et al., 2004b, using a Clark-style electrode (YSI model 5300, Yellow Springs Instruments, Yellow Springs, OH) positioned within a

thermostatically controlled cell chamber at 37°C (Yellow Springs Instruments, Yellow Springs, OH). Triplicate tissue samples were placed in unoxygenated KHS solution in the O_2 electrode chamber and allowed to acclimate to the chamber for 1 min, after which O_2 consumption was measured over 5 min (Kelly et al., 1993).

GIT Cellularity

Frozen tissue samples obtained from the duodenum and liver were used for approximation of cell number and activity by determining cell contents of DNA, RNA, and protein. Subsamples of 0.30g of frozen tissue (for both duodenum and liver) were sliced from 1.0 g samples. Samples were incubated at room temperature in TRIzol reagent (Invitrogen, Carlsbad, CA) for 10 min. Samples were homogenized using a Virtishear homogenizer (VirTis Co., Gardiner, NY). Determination of DNA, RNA, and protein concentrations were carried out using the TRIzol reagent extraction procedures.

Statistics

All data for organ mass, cellularity, and oxygen consumption were analyzed as a completely randomized design using generalized least squares (Proc MIXED, SAS Institute, Cary, NC). Individual animal was considered the experimental unit for all data. The model for all measurements included treatment as a fixed effect. Mean separation was accomplished using Least Significant Difference and means were considered to be significantly different at the $P < 0.05$ level when protected by an F-value ($P < 0.10$).

RESULTS

Winter growing performance, subsequent finishing performance, carcass characteristics, and body composition data were previously reported by McCurdy et al. (2006).

Growing phase organ mass

Mass of individual organs and body components for the growing phase is shown in Table 4-1. At the end of the growing phase there were no differences in empty body weight (kg, **EBW**) or in carcass tissue content of the empty body (g/kg EBW; McCurdy et al., 2006). There were no differences ($P > 0.10$) between treatment groups for weight of blood, head, hide, heart, lungs, or esophagus (g/kg EBW). However, significant differences in several components of the viscera and TST were observed. Reticulo-rumen mass (g/kg EBW) was greater ($P < 0.05$) for SF steers compared with WP steers, with PF steers being intermediate. The remaining parts of the forestomach complex (omasum and abomasum) did not differ ($P > 0.10$) among treatments. Small intestine mass (g/kg EBW) was greater ($P < 0.01$) for WP steers compared with other treatments, whereas large intestine and cecum mass were not affected ($P > 0.10$) by growing diet.

Notable differences were observed in mass of visceral fat (mesenteric and omental; g/kg EBW; Table 4-1). Steers in the PF treatment group had greater visceral fat ($P < 0.05$) compared with SF steers, and SF steers had greater ($P < 0.05$) visceral fat compared with steers in the WP group. Owing primarily to the visceral fat mass, PF steers had greater ($P < 0.05$) mass (g/kg EBW) of visceral tissues than WP steers; SF steers were intermediate.

At the end of the growing phase WP steers had the greatest ($P < 0.01$) liver mass (g/kg EBW) compared with the other treatment groups (Table 4-1). The same differences

were observed for kidney mass with WP steers having greater ($P < 0.01$) mass at the end of the growing phase compared with the other treatments. Other splanchnic tissues (pancreas and spleen) did not differ ($P > 0.10$) among treatment groups. Mass of TST (g/kg EBW) also did not differ significantly due to treatment.

Finishing phase organ mass

Mass of individual organs and body components at the end of finishing is shown in Table 4-2. At the end of finishing there were no differences in EBW (kg) or in carcass tissue content of the empty body (g/kg EBW; McCurdy et al., 2006). There were no significant differences between treatments for weight of blood, head, or hide (g/kg EBW). Steers in the SF treatment had heavier ($P < 0.05$) feet and ears compared with PF steers. Steers in the WP treatment had lesser heart mass (g/kg EBW; $P < 0.05$) compared with SF and PF groups; CF steers were intermediate. Steers in the CF treatment had the lowest ($P < 0.01$) lung mass among all treatments. After finishing, mass of kidneys (g/kg EBW) was similar ($P > 0.10$) among WP and other growing treatment groups; however, WP steers had greater ($P < 0.05$) kidney mass than CF steers. Steers in the SF treatment had greater ($P < 0.05$) kidney mass than the PF and CF groups.

Mass of visceral tissues did not differ ($P > 0.10$) among treatments at the end of the finishing phase (Table 4-2). Across the finishing period, steers in the WP group showed less decrease in visceral mass ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) compared with PF steers ($P < 0.05$), with SF and CF steers being intermediate. Mass of reticulo-rumen was not different ($P > 0.10$) due to treatment, signifying that WP steers had the lowest decrease in rumen mass ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) of all treatments from the end of the growing phase to the end of the finishing phase. Mass of the omasum (g/kg EBW) was not significantly

different among treatments; however, abomasal mass was greater ($P < 0.05$) for SF steers compared with CF and PF steers; WP steers were intermediate.

Small intestinal mass (g/kg EBW) was not significantly different among treatments at the end of the finishing phase with WP steers experiencing a greater decrease ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) in small intestine mass ($P < 0.05$) from the end of the growing phase to the end of the finishing phase compared with SF and PF groups (Table 4-2). Large intestinal mass was greater ($P < 0.05$) for WP steers at the end of the finishing phase compared with PF and CF steers, with SF steers being intermediate. Thus, across the finishing period, WP and SF steers had less ($P < 0.01$) decrease in large intestinal mass as a percentage of EBW ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) compared with PF and CF steers. Mass of visceral fat did not differ among treatments at the end of the finishing phase, and WP steers had a larger increase ($P < 0.05$) in visceral fat mass ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) compared with PF steers. Steers in the SF and CF treatments were intermediate.

At the end of finishing phase, liver mass (g/kg EBW) remained larger ($P < 0.05$) for WP steers compared with all remaining treatments (Table 4-2). This difference was evident despite the fact that WP steers had the greatest ($P < 0.05$) decrease in liver mass ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) over the finishing period compared with other treatments. Numerically, steers in the WP group had the largest TST and had the lowest ($P < 0.05$) decrease in TST ($g \cdot kg\ EBW^{-1} \cdot d^{-1}$) over the finishing period compared with PF and CF groups; SF steers were intermediate.

Tissue O_2 consumption

There were no significant differences in oxygen consumption of tissues among treatments at the end of the growing phase (Table 4-3). Duodenum and liver showed no

differences in oxygen consumption on an equal weight basis ($\mu L \cdot min^{-1} \cdot g^{-1}$) due to diet ($P$ = 0.86 and P = 0.85, respectively). Therefore oxygen consumption by total organs was dependent on mass. Duodenum and liver oxygen consumption followed trends in mass of the liver and small intestine (ml/min); however, differences were not statistically significant among treatments (P = 0.38 and P = 0.27, respectively).

At the end of the finishing phase, there were no differences ($P > 0.10$) in oxygen consumption due to treatment by duodenum (P = 0.50) or liver tissues (P = 0.33) on an equal wet weight basis ($\mu L \cdot min^{-1} \cdot g^{-1}$; Table 4-3). Oxygen consumption by total organs was related to organ mass, although differences were not different among treatments for duodenum (P = 0.74) or liver (P = 0.11).

Tissue cellularity

Data of cellular content of duodenum and liver tissues for both phases is presented in Table 4-4. There were no differences ($P > 0.37$) among treatment groups in RNA, DNA, or protein concentration (mg/g) of the duodenal tissue at the end of the growing or finishing phases, despite the fact that WP steers had larger small intestinal mass at the end of the growing phase. There was also no difference in the ratio of RNA:protein or protein:DNA at the end of either phase. Similarly, there were no differences ($P > 0.45$) among treatments in cellular parameters for liver tissue.

DISCUSSION

At the end of the growing phase, several components of the GIT were shown to be responsive to diet type. Previous work in lambs (Wester et al., 1995; Fluharty and McClure, 1997; Noziere et al., 1999) and steers (Sainz and Bentley, 1997; Hersom et al.,

2004b) has shown that reticulo-rumen mass is responsive to both energy density and physical form of the diet. Hersom et al. (2004b) showed restrictions in both DMI and ME intake of growing diets resulted in larger reticulo-rumen mass. Steers that were grazed on dormant native range vs. wheat pasture had larger rumen mass, presumably from a lower energy density of the forage and correspondingly higher DMI. These findings are supported by Jones et al. (1985) and Sainz and Bentley (1997) in steers which demonstrated greater reticulo-rumen mass due to greater DMI of a low-energy forage diet compared with a high-concentrate diet. Increases in reticulo-rumen mass among steers fed high-concentrate diets ad libitum or limit-fed were not observed by Sainz and Bentley (1997), but were demonstrated in lambs by Fluharty and McClure (1997). Although not as large of a difference, Hersom et al. (2004b) also showed steers that were grazed on wheat pasture with restricted forage availability (high-stocking density) had larger reticulo-rumens compared with steers grazed for ad libitum intake on wheat pasture (low-stocking density) demonstrating that reticulo-rumen mass increased due to lower ME intake even with lower DMI. This is supported by the work of Wester et al. (1995) in lambs that demonstrated increased reticulo-rumen mass in limit-fed vs. ad libitum-fed growing diets. Noziere et al. (1999) showed opposite results with restricted-fed (40% of maintenance) lambs having smaller reticulo-rumen mass compared with lambs fed at maintenance, but the different results in this study may be due to the severe nature of the restriction. In the current study the larger reticulo-rumen mass of the SF steers as compared with the PF steers agrees with the aforementioned findings regarding lower energy density and consequently larger DMI resulting in increased mass. However

it is not evident as to why WP steers exhibited the smallest reticulo-rumen mass. A high rate of passage for wheat pasture grazed cattle might have contributed to the response.

It is also not evident why WP steers had the lowest decrease of reticulo-rumen mass as a proportion of EBW during the finishing phase resulting in similar mass among treatments at the end of the finishing phase. Drouillard et al. (1991) and Noziere et al. (1999) both reported similar mass of forestomachs after realimentation to a high concentrate diet in previously restricted lambs. However, in the present study no treatment group was restricted in MEI. At the end of the growing phase reticulo-rumen mass was not significantly different between the WP and the PF steers. During finishing DMI was not significantly different between these groups, however WP steers had greater growth of reticulo-rumen tissue.

Although the rate of oxygen consumption by ruminal epithelium was not reported for the present experiment, previous work has shown that there were no differences in oxygen consumption of this tissue due to diet in steers (Hersom et al., 2004b) or lambs (McLeod and Baldwin, 2000). In fact it appears that there is little difference in metabolism of rumen epithelial tissue on an equal weight basis due to dietary effects (Baldwin and McLeod, 2000), and thus energy expenditure of the rumen tissue appear to be dependent on mass.

In the present experiment, greater small intestine mass for WP steers compared with both SF and PF steers might provide further evidence of a greater rate of passage and nutrient flow to the small intestine for wheat pasture-grazed steers. Burrin et al. (1990) reported decreased small intestinal mass in lambs due to decreased DMI. Drouillard et al (1991) reported that small intestinal mass was reduced by energy

restriction and these differences persisted after realimentation to feed. This disagrees with the work of both Wester et al. (1995) and Fluharty and McClure (1997) who reported no differences in small intestinal mass of lambs due to DMI or MEI restriction. However, Wester et al. (1995) and Sainz and Bentley (1997) showed that small intestinal mass increased in previously restricted lambs and steers, respectively, when realimented to feed. Additionally it was reported by Jones et al. (1985) that high-concentrate diets resulted in greater small intestinal mass in steers compared with steers fed forage diets. Thus it appears that small intestinal mass is dependent on both nutrient load and physical form of the diet (Sainz and Bentley, 1997; Mcleod and Baldwin, 2000), responding to the amount and energy density of digesta that is presented to post-stomach tissues.

During finishing WP steers had the greatest decrease in small intestine mass as a proportion of EBW which resulted in similar small intestine mass among treatments at the end of the finishing phase. Previous work in lambs (Wester et al., 1995; Noziere et al., 1999) and steers (Sainz and Bentley, 1997) showed an increase in small intestinal mass in previously-restricted animals. This is most likely due to increased intake following restriction and thus more digesta and nutrients presented to the small intestine. Although steers in the current study were not restricted during the growing period, total nutrients available to the small intestine would most likely have been greater during finishing. This agrees with the work of Drouillard et al. (1991) that showed a decrease in small intestinal mass when previously restricted lambs were realimented to a high-concentrate diet.

Despite the WP steers having a significantly greater mass of small intestine at the end of the growing phase, there were no significant differences in cellularity of the

duodenal tissue before or after finishing. Although Hersom et al. (2004b) reported differences in RNA content of duodenal tissue in steers, there were no differences in DNA or protein concentration among treatments. These results are consistent with other studies in steers (Sainz and Bentley, 1997) and lambs (Noziere et al., 1999) and suggest that changes in small intestinal mass occur through changes in hyperplasia rather than hypertrophy. Additionally there were no differences in oxygen consumption of the duodenal tissue at the end of the growing or the finishing phases. Studies in lambs have also demonstrated no differences in oxygen consumption of the small intestinal tissue due to diet (Wester et al., 1995; McLeod and Baldwin, 2000) and it appears that energy demand of the small intestine varies with mass.

In the present experiment, differences in visceral fat were large and the most visibly evident of all differences in TST components at the end of the growing phase. The PF group had greater mass than the SF group and the SF group had greater mass than the WP group. It has been demonstrated in both lambs (Fluharty and McClure, 1997) and steers (Jones et al., 1985; Hersom et al., 2004b) that mesenteric fat increases with increasing energy intake. However in the current study ME intake did not differ among treatments at the end of the growing phase (McCurdy et al., 2006). Therefore differences occurred due to diet type with the more energy-dense PF diet resulting in greater accretion of mesenteric fat. Because of the large difference in mass of visceral fat, steers in the PF group had the greatest visceral mass. Steers fed silage were intermediate in mesenteric fat and had the largest reticulo-rumens, resulting in greater visceral mass than WP steers. Although WP steers had the greatest small intestine mass of the three groups,

they had the least mass of reticulo-rumen and visceral fat, and therefore had the lowest total visceral mass at the end of the growing phase.

During the finishing phase all treatment groups experienced an increase in visceral fat mass as a percentage of EBW. As previously mentioned, visceral fat increases with increasing energy intake (Jones et al., 1985; Fluharty and McClure, 1997; Hersom et al., 2004b). Visceral fat mass was similar among treatments at the end of the finishing phase and therefore WP steers had a greater increase in mass during finishing compared with SF and PF steers. Mass of the total viscera did not differ among treatments at the end of the finishing period. Due to the accretion of reticulo-rumen and mesenteric fat tissue by WP steers during finishing, WP steers had the lowest decrease in total visceral mass as a proportion of EBW. Thus a greater portion of the empty body weight gain of WP steers during finishing was attributed to gain of the visceral tissues.

In the present experiment, steers in the WP group had greater liver mass at the end of the growing phase compared with the SF and PF groups, and this was likely due to the higher protein content of wheat pasture compared with the other growing diets (McCurdy et al., 2006). Previous work also shows that liver mass is responsive to CP content of the diet in lambs (Drouillard et al., 1991; Wester et al., 1995; Fluharty and McClure, 1997) and in steers (Hersom et al., 2004b). Liver mass has also been shown to increase in response to increasing energy intake (Burrrin et al., 1990; Sainz and Bentley, 1997). However, in the present study MEI did not differ among treatments, and presumably energy load presented to the liver was not different during the growing phase.

During the finishing phase, WP steers had the sharpest decline in liver mass per unit of EBW among all treatments. Nevertheless, at the end of the finishing phase WP

steers still had greater liver mass compared with all other treatments. Hersom et al. (2004b) demonstrated that steers grazed on wheat pasture with a low stocking density had greater liver mass at the end of the growing phase compared with steers grazed on wheat pasture with a high stocking density and steers grazed on dormant native winter range. It was thought this difference resulted from the greater nitrogen intake for those steers. Similar results were observed in the current study with the WP steers compared with other treatment groups. However, in contrast to the present study, differences in liver mass no longer existed at the end of the finishing phase in the Hersom et al. (2004b) experiment. Similarly, differences in liver mass have been reported in lambs following a period of energy or protein restriction (Wester et al., 1995; Noziere et al., 1999), but these differences no longer existed following a period of feed repletion on a common high-concentrate diet.

Although liver mass was significantly larger for WP steers at the end of both the growing and finishing phases, there were no differences in RNA, DNA, or protein concentrations of the liver tissue at either time point. Most researchers have reported that increases in liver mass in ruminants occur through hypertrophy and that dietary effects that increase liver size increase the protein:DNA ratio of the tissue (Burrin et al., 1992; Sainz and Bentley, 1997; Noziere et al., 1999). In these studies differences in liver mass were due to differences in DMI and MEI.

In the present experiment, there were no differences in oxygen consumption of liver tissue due to treatment and oxygen consumption of the whole liver tended to vary with organ mass. This agrees with the work of Hersom et al. (2004b) in steers and Burrin et al. (1990) in lambs who reported no difference in oxygen consumption of liver tissue

due to dietary treatment on an equal weight basis. It was reported by Wester et al. (1995) that oxygen consumption of liver was increased 25% in lambs due to protein or energy restriction in the diet over controls. However, because of the decrease in liver mass in diet-restricted groups, oxygen consumption on a total organ basis was only 68% of controls. Therefore, it is likely that even if subtle differences exist in energy expenditure on an equal weight basis for liver tissue due to dietary differences, organ mass is still the primary determinant of liver energy expenditure.

At the end of the growing phase, PF steers had the greatest visceral fat mass, SF steers had the heaviest reticulo-rumens, and WP steers had the largest livers. Because of the differences in these individual components, TST mass was statistically similar. At the end of finishing WP steers had the greatest mass of TST numerically, but statistically TST mass was not different among treatments. However, because of the growth in total visceral mass and liver mass remaining larger for WP steers during the finishing period, this treatment exhibited less decline in TST mass per unit of EBW compared with PF and CF steers; SF steers were intermediate. Therefore it is likely that the differences in finishing phase performance demonstrated in our previous study (McCurdy et al., 2006) were due to differences in energy demand and growth dynamics of visceral or total splanchnic tissues.

IMPLICATIONS

Dietary effects including intake level, physical form of the diet, and caloric density play a major role in determining mass of the portal-drained viscera and liver. Changes in organ mass due to previous diet during the growing phase may contribute to

differences in splanchnic organ mass during finishing. It does not appear however that diet has a major effect on metabolism or oxidative capacity of tissues in the gastrointestinal tract or liver on a cellular level. Therefore differences in energy expenditure of visceral organs seem to be driven primarily by differences in organ mass. Compared with grazing or forage-based diets, feeding higher concentrate diets during the growing phase may lead to decreased growth of splanchnic organs during the finishing phase. Due to the considerable energy expenditure of splanchnic organs, this may result in altered maintenance energy requirements and consequently lead to differences in performance.

LITERATURE CITED

Baldwin, R. L., VI, and K. R. McLeod. 2000. Effect of diet forage:concentrate ratio and metabolizable energy intake on isolated rumen epithelial cell metabolism in vitro. J. Anim. Sci. 78:771-783.

Burrin, D. G., R. A. Britton, C. L. Ferrell, and M. L. Bauer. 1992. Level of nutrition and visceral organ protein synthetic capacity and nucleic acid content in sheep. J. Anim. Sci. 70:1137-1145.

Burrin, D. G., C. L. Ferrell, R. A. Britton and M. L. Bauer. 1990. Level of nutrition and visceral organ size and metabolic activity in sheep. Br. J. Nutr. 64:439-448.

Carstens, G. E., D. E. Johnson, M. A. Ellenberger, and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. J. Anim. Sci. 69:3251-3264.

Drouillard, J. S., T. J. Klopfenstein, R. A. Britton, M. L. Bauer, S. M. Gramlich, T. J. Wester, and C. L. Ferrell. 1991. Growth, body composition, and visceral organ mass and metabolism in lambs during and after metabolizable protein or net energy restrictions. J. Anim. Sci. 69:3357-3375.

Ferrell, C. L. and T. G. Jenkins. 1998. Body composition and energy utilization by steers of diverse genotypes fed a high-concentrate diet during the finishing period: I. Angus, Belgian Blue, Hereford, and Piedmontese sires. J. Anim. Sci. 76:637-646.

Ferrell, C. L., L. J. Koong, and J. A. Nienaber. 1986. Effect of previous nutrition on body composition and maintenance energy costs of growing lambs. Br. J. Nutr. 56:595-605.

Fluharty, F. L. and K. E. McClure. 1997. Effects of dietary energy intake and protein concentration on performance and visceral organ mass in lambs. J. Anim. Sci. 75:604-610.

Fox, D. G., R. R. Johnson, R. L. Preston, and T. R. Dockerty, and E. W. Klosterman. 1972. Protein and energy utilization during compensatory growth in beef cattle. J. Anim. Sci. 34:310-318.

Hersom, M. J., G. W. Horn, C. R. Krehbiel, and W. A. Phillips. 2004a. Effect of live weight gain of steers during winter grazing: I. Subsequent feedlot performance, carcass characteristics and body composition. J. Anim. Sci. 82:262-272.

Hersom, M. J., C. R. Krehbiel, and G. W. Horn. 2004b. Effect of previous live weight gain of steers during the winter grazing: II. Visceral organ mass, cellularity and oxygen consumption. J. Anim. Sci. 82:184-197.

Jones, S. D. M., R. E. Rompala, and L. E. Jeremiah. 1985. Growth and composition of the empty body in steers of different maturity types fed concentrate or forage diets. J. Anim. Sci. 60:427-433.

Kelly, J. M., B. W. McBride, and L. P. Milligan. 1993. In vitro ouabain-sensitve respiration and protein synthesis in ruminal epithelial papillae of Hereford steers fed either alfalfa or bromegrass hay once daily. J. Anim. Sci. 71:2799-2808.

McBride, B. W. and J. M. Kelly. 1990. Energy cost of absorption and metabolism in the ruminant gastrointestinal tract and liver: a review. J. Anim. Sci. 68:2997-3010.

McCurdy, M. P., G. W. Horn, C. R. Krehbiel, J. J. Wagner. 2006. Effects of winter growing programs on subsequent feedlot performance, carcass characteristics and body composition of beef steers. J. Anim. Sci. In Press

McLeod, K. R. and R. L. Baldwin VI. 2000. Effects of diet forage:concentrate ratio and metabolizable energy intake on visceral organ growth and in vitro oxidative capacity of gut tissues in sheep. J. Anim. Sci. 78:760-770.

Noziere, P. D. Attaix, F. Bocquier, and M. Doreau. 1999. Effects of underfeeding and refeeding on weight and cellularity of splanchnic organs in ewes. J. Anim. Sci. 77:2279-2290.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. National Academy Press. Washington D.C.

Sainz, R. D. and B. E. Bentley. 1997. Visceral organ mass and cellularity in growth-restricted and refed beef steers. J. Anim. Sci. 75:1229-1236.

Sainz, R. D., F. De la Torre, and J. W. Oltjen. 1995. Compensatory growth and carcass quality in growth restricted and refed beef steers. J. Anim. Sci. 73:2971-2979.

Wester, T. J., R. A. Britton, T. J. Klopfenstein, G. A. Ham, D. T. Hickok, and C. R. Krehbiel. 1995. Differential effects of plane of protein or energy nutrition on visceral organs and hormones in lambs. J. Anim. Sci. 73:1674-1688.

Table 4-1. Mass of visceral organs in steers from different winter growing programs during the growing phase

	Initial	Final				Change[b]			
		Treatment[a]				Treatment			
Item		WP	SF	PF	SEM[c]	WP	SF	PF	SEM
EBW, kg	216	336	323	354	10.7	119	106	137	10.7
Carcass									
kg	140	220	212	237	7.8	730[de]	642[d]	866[e]	69.9
g/kg EBW	649	660	657	671	6.4	103.6	79.3	197.0	56.93
Blood									
kg	8.7	14.9	13.2	14.6	0.80	55.3	40.36	53.0	7.1
g/kg EBW	40.1	44.4	40.9	41.3	1.98	38.1	7.2	10.6	17.70
Feet and Ears									
kg	7.3	10.2	9.0	9.8	0.32	25.9[d]	14.8[e]	22.5[de]	2.84
g/kg EBW	33.9	30.4	27.9	27.9	1.09	-31.7	-53.7	-53.5	9.74
Hide									
kg	19.5	28.9	28.8	26.6	2.55	84.5	83.0	96.9	8.09
g/kg EBW	89.9	86.6	89.6	75.3	7.86	-29.7	-3.5	-13.2	70.18
Head									
kg	9.2	12.5	12.2	13.2	0.50	29.5	27.1	35.9	4.49
g/kg EBW	42.6	37.2	37.9	37.4	0.80	-47.8	-42.2	-46.5	7.17
Trim[g]									
kg	3.6	6.2	7.0	6.6	0.89	23.1	30.9	27.0	7.95
g/kg EBW	16.2	18.2	21.9	18.7	2.59	17.7	50.9	22.0	23.15
Heart									
kg	1.0	1.7	1.7	1.8	0.12	5.6	5.5	6.5	1.03
g/kg EBW	4.8	4.9	5.1	5.0	0.26	1.3	2.3	1.7	2.30
Lungs									
kg	3.7	5.3	5.0	5.4	0.31	14.6	11.3	15.7	2.74
g/kg EBW	16.9	15.8	15.4	15.4	0.80	-10.6	-14.0	-14.0	7.17
Esophagus									
kg	0.2	0.3	0.3	0.3	0.02	0.7	0.6	0.8	0.17
g/kg EBW	1.0	0.9	0.9	0.9	0.05	-1.1	-1.2	-1.2	0.47
Kidney									

kg	0.7	1.0[d]	0.8[e]	0.8[e]	0.04	3.2[d]	0.9[e]	1.0[e]	0.32
g/kg EBW	3.2	3.1[d]	2.4[e]	2.3[e]	0.07	-0.8[d]	-6.7[e]	-8.2[e]	0.60
Reticulo-rumen									
kg	4.9	6.5	7.5	7.7	0.45	14.0	22.5	25.1	4.01
g/kg EBW	22.9	19.3[d]	23.1[e]	21.7[de]	0.92	-32.4[d]	2.3[e]	-10.1[de]	8.17
Omasum									
kg	2.1	2.5	2.8	2.9	0.30	2.8	6.2	7.0	2.7
g/kg EBW	9.9	7.2	8.8	8.3	0.80	-24.0	-9.8	-14.1	7.16
Abomasum									
kg	1.0	1.4	1.3	1.5	0.12	4.0	3.2	4.6	1.10
g/kg EBW	4.4	4.2	4.0	4.1	0.31	-2.3	-3.2	-2.4	2.80
Small Intestine									
kg	3.5	5.4[d]	4.0[e]	4.5[e]	0.21	16.8[d]	4.2[e]	8.8[e]	1.85
g/kg EBW	16.3	16.1[d]	12.4[e]	12.8[e]	0.58	-2.3[d]	-35.3[e]	-32.0[e]	5.16
Large Intestine									
kg	2.0	2.7	2.4	2.9	0.17	6.8	3.8	8.10	1.56
g/kg EBW	9.1	8.1	7.4	8.2	0.43	-8.7	-15.5	-8.0	3.87
Cecum									
kg	0.5	0.5	0.4	0.4	0.05	-0.2	0.9	0.7	0.43
g/kg EBW	2.4	1.4	1.3	1.2	0.12	-8.4	-10.0	-10.4	1.08
Mesenteric fat									
kg	4.2	6.5[d]	8.1[d]	10.9[e]	0.81	20.7[d]	34.9[d]	59.4[e]	7.2
g/kg EBW	19.5	19.5[d]	25.0[e]	30.6[f]	1.87	-0.6[d]	49.0[e]	99.0[f]	16.65
Total viscera[h]									
kg	18.2	25.5[d]	26.5[de]	30.8[e]	1.56	64.9[d]	74.0[de]	112.3[e]	13.97
g/kg EBW	84.5	75.7[d]	82.0[de]	87.0[e]	2.77	-78.7[d]	-22.4[de]	22.1[e]	24.76
Pancreas									
kg	0.2	0.3	0.3	0.4	0.03	0.9	1.2	1.4	0.25
g/kg EBW	0.9	0.9	1.0	1.0	0.09	-0.1	1.0	0.9	0.76
Spleen									
kg	0.5	1.0	0.7	0.8	0.18	4.3	1.5	3.0	1.62
g/kg EBW	2.3	2.9	2.1	2.3	0.51	5.3	-2.4	0.2	4.54
Liver									
kg	3.2	6.4[d]	5.1[e]	5.5[e]	0.33	28.1[d]	16.7[e]	19.8[e]	2.96

g/kg EBW	15.0	19.0[d]	15.8[e]	15.4[e]	0.60	36.0 [d]	7.3 [e]	3.9 [e]	5.40
TST[i]									
kg	22.2	33.2	32.6	37.5	1.91	98.3	93.3	136.4	17.04
g/kg EBW	102.7	98.5	100.8	105.7	3.17	-37.6	-16.5	27.1	28.33

[a]WP=Wheat pasture, SF=Silage fed, PF=Program fed.
[b]Change expressed as g/d for carcass and organ mass, and mg·kg EBW^{-1}·d^{-1} for carcass and organ proportional mass.
[c]Standard error of mean, n=4 for initial harvest, n=6 for final harvest.
[d,e,f]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).
[g]Trim = tail, spinal cord, and tissue cut from the carcass in the abattoir.
[h]Gastro-intestinal tract; includes reticulo-rumen, omasum, abomasums, small intestine, large intestine, cecum, and mesenteric/omental fat.
[i]Total splanchnic tissues; includes GIT, liver, pancreas, and spleen.

Table 4-2. Mass of visceral organs in steers from different winter growing programs during the finishing phase

	Initial					Final					Change[b]				
	Treatment[a]					Treatment					Treatment				
Item	WP	SF	PF	CF	SEM[c]	WP	SF	PF	CF	SEM	WP	SF	PF	CF	SEM
EBW, kg	336	323	354	216	10.7	639	602	640	604	25.2	303[d]	280[d]	286[d]	388[e]	25.3
Carcass															
kg	220	212	237	140	7.8	376	357	383	361	14.6	1252[d]	1393[d]	1406[d]	1842[e]	124.2
g/kg EBW	660	657	671	649	6.4	588	593	600	598	4.7	-58.4[d]	-62.1[d]	-67.8[d]	-25.9[e]	35.42
Blood															
kg	14.9	13.2	14.6	8.7	0.80	20.2[de]	19.1[d]	21.7[e]	18.5[d]	0.79	43.2[d]	56.4[de]	67.8[e]	94.5[f]	7.24
g/kg EBW	44.4	40.9	41.3	40.1	1.98	31.7	31.9	34.2	30.8	1.45	-104.6[d]	-87.3[de]	-68.5[de]	-48.5[d]	13.61
Feet and Ears															
kg	10.2	9.0	9.8	7.3	0.32	14.2	14.6	12.9	13.0	0.68	32.4[d]	54.4[e]	29.5[d]	66.3[e]	5.73
g/kg EBW	30.4	27.9	27.9	33.9	1.09	22.3[de]	24.2[d]	20.5[e]	21.5[de]	1.01	-66.0[d]	-36.2[e]	-72.4[d]	-64.3[d]	9.02
Hide															
kg	28.9	28.8	26.6	19.5	2.55	42.0	40.5	43.4	44.2	2.36	106.1[d]	112.6[d]	161.6[e]	225.4[f]	17.03
g/kg EBW	86.6	89.6	75.3	89.9	7.86	66.0	67.5	68.8	72.7	4.00	-168.4[de]	-212.4[d]	-62.7[f]	-88.1[ef]	34.22
Head															
kg	12.5	12.2	13.2	9.2	0.50	16.7	16.8	17.0	17.0	0.90	34.1[d]	44.2[d]	36.0[d]	86.6[e]	7.52
g/kg EBW	37.2	37.9	37.4	42.6	0.80	26.2	28.6	26.5	28.1	0.97	-90.1	-95.1	-104.2	-74.6	8.25
Trim[g]															
kg	6.2	7.0	6.6	3.6	0.89	9.2[de]	8.5[d]	11.8[e]	11.0[de]	0.98	25.1[d]	14.00[d]	49.6[e]	56.3[e]	7.56
g/kg EBW	18.2	21.9	18.7	16.2	2.59	14.5	14.0	18.5	18.4	1.62	-31.3[d]	-76.9[f]	-2.3[de]	11.1[e]	11.65
Heart															
kg	1.7	1.7	1.8	1.0	0.12	2.3[d]	2.5[de]	2.8[e]	2.5[de]	0.13	5.3[d]	8.5[e]	10.1[ef]	12.6[f]	1.00
g/kg EBW	4.9	5.1	5.0	4.8	0.26	3.6[d]	4.2[e]	4.4[e]	4.1[de]	0.17	-11.6[d]	-8.8[d]	-5.4[d]	-4.3[e]	1.42
Lungs															
kg	5.3	5.0	5.4	3.7	0.31	9.0[d]	7.8[d]	8.5[d]	6.3[e]	0.44	29.8	27.7	29.2	32.4	3.91
g/kg EBW	15.8	15.4	15.4	16.9	0.80	14.1[d]	13.0[d]	13.2[d]	10.5[e]	0.47	-14.8[d]	-23.3[de]	-21.6[d]	-33.4[e]	4.07
Esophagus															

kg	0.3	0.3	0.3	0.2	0.02	0.5 [d]	0.3 [e]	0.4 [e]	0.3 [e]	0.02	1.2 [d]	0.5 [e]	0.5 [e]	1.63 [d]	0.18
g/kg EBW	0.9	0.9	0.9	1.0	0.05	0.7 [d]	0.6 [e]	0.6 [e]	0.5 [e]	0.03	-1.2 [d]	-3.2 [e]	-3.1 [e]	-2.2 [e]	0.39
Kidney															
kg	1.0	0.8	0.8	0.7	0.04	1.2 [d]	1.1 [d]	1.1 [de]	1.0 [e]	0.05	1.0 [d]	3.4 [e]	2.6 [e]	4.9 [f]	0.38
g/kg EBW	3.1	2.4	2.3	3.2	0.07	1.8 [de]	1.9 [d]	1.7 [ef]	1.6 [f]	0.06	-11.7 [d]	-5.8 [e]	-6.4 [e]	-8.2 [f]	0.51
Reticulo-rumen															
kg	6.5	7.5	7.7	4.9	0.45	10.7	9.8	9.9	9.4	0.77	33.9 [de]	23.0 [d]	20.7 [d]	48.1 [e]	6.61
g/kg EBW	19.3	23.1	21.7	22.9	0.92	16.7	16.3	15.3	15.5	0.82	-21.2 [d]	-66.6 [e]	-62.2 [e]	-38.7 [d]	0.74
Omasum															
kg	2.5	2.8	2.9	2.1	0.30	3.6	3.2	3.1	3.4	0.28	9.0 [d]	3.8 [de]	1.7 [e]	17.4 [f]	2.39
g/kg EBW	7.2	8.8	8.3	9.9	0.80	5.6	5.4	4.8	5.7	0.36	-13.2 [d]	-33.7 [e]	-34.9 [e]	-22.1 [d]	3.00
Abomasum															
kg	1.4	1.3	1.5	1.0	0.12	1.7	1.7	1.6	1.5	0.11	2.7 [d]	4.1 [d]	1.4 [d]	7.6 [e]	0.99
g/kg EBW	4.2	4.0	4.1	4.4	0.31	2.7 [de]	2.9 [d]	2.5 [e]	2.5 [e]	0.12	-12.2 [d]	-11.1 [d]	-16.3 [e]	-10.7 [d]	1.02
Small Intestine															
kg	5.4	4.0	4.5	3.5	0.21	6.2	5.4	5.7	4.9	0.39	6.1 [d]	13.7 [d]	11.5 [d]	25.1 [e]	3.45
g/kg EBW	16.1	12.4	12.8	16.3	0.58	9.6	8.9	8.8	8.1	0.41	-52.5 [d]	-33.4 [e]	-38.1 [e]	-42.2 [e]	3.52
Large Intestine															
kg	2.7	2.4	2.9	2.0	0.17	5.2 [d]	4.4 [de]	4.2 [e]	4.0 [e]	0.33	20.2	19.0	12.3	20.6	2.85
g/kg EBW	8.1	7.4	8.2	9.1	0.43	8.1 [d]	7.2 [de]	6.4 [e]	6.7 [e]	0.41	0.1 [d]	-0.1 [d]	-17.1 [e]	-12.6 [e]	3.26
Cecum															
kg	0.5	0.4	0.4	0.5	0.05	0.8	0.9	0.7	0.7	0.07	2.5 [d]	4.7 [e]	3.0 [de]	3.4 [de]	0.59
g/kg EBW	1.4	1.3	1.2	2.4	0.12	1.2	1.5	1.2	1.1	0.11	-2.2 [d]	2.1 [e]	0.1 [de]	-7.0 [f]	1.11
Mesenteric fat															
kg	6.5	8.1	10.9	4.2	0.81	21.6	19.9	21.7	20.6	2.14	122.0	113.5	103.6	105.0	19.02
g/kg EBW	19.5	25.0	30.6	19.5	1.87	33.6	33.1	32.9	34.1	2.64	115.5 [d]	78.5 [de]	27.0 [e]	74.8 [de]	22.82
Total viscera [h]															
kg	25.5	26.5	30.8	18.2	1.56	49.6	45.4	46.8	44.5	3.47	196.3	181.9	154.1	227.2	30.13
g/kg EBW	75.7	82.0	87.0	84.5	2.77	77.6	75.4	71.9	73.6	3.50	15.8 [d]	-64.1 [de]	-145.4 [e]	-56.3 [d]	28.65
Pancreas															
kg	0.3	0.3	0.4	0.2	0.03	0.6	0.5	0.6	0.5	0.04	2.2 [de]	1.2 [d]	1.9 [de]	2.4 [e]	0.36

g/kg EBW	0.9	1.0	1.0	0.9	0.09	0.9	0.8	0.9	0.8	0.06	0.2 [d]	-3.2 [f]	-2.1 [ef]	-1.1 [de]	0.50
Spleen															
kg	1.0	0.7	0.8	0.5	0.18	1.3 [d]	1.0 [e]	1.1 [de]	0.9 [e]	0.08	2.2 [d]	2.9 [de]	2.7 [d]	4.7 [e]	0.62
g/kg EBW	2.9	2.1	2.3	2.3	0.51	2.0	1.6	1.8	1.5	0.15	-8.4	-4.2	-5.2	-4.0	1.21
Liver															
kg	6.4 [d]	5.1 [e]	5.5 [e]	3.2	0.33	8.3 [d]	7.3 [e]	7.5 [de]	6.9 [e]	0.36	15.8 [d]	20.7 [d]	19.5 [d]	35.1 [e]	3.18
g/kg EBW	19.0 [d]	15.8 [e]	15.4 [e]	15.0	0.60	13.0 [d]	12.1 [e]	11.7 [e]	11.4 [e]	0.32	-48.2 [d]	-36.3 [e]	-36.6 [e]	-18.5 [f]	2.64
TST [i]															
kg	33.2	32.6	37.5	22.2	1.91	59.8	54.1	56.0	52.8	3.76	216.5	206.8	178.3	269.3	32.85
g/kg EBW	98.5	100.8	105.7	102.7	3.17	93.5	89.8	86.2	87.3	3.52	-41.1 [d]	-106.1 [d]	-188.0 [e]	-79.1 [d]	28.59

[a]WP=Wheat pasture, SF=Silage fed, PF=Program fed.

[b]Change expressed as g/d for carcass and organ mass, and mg·kg $EBW^{-1}\cdot d^{-1}$ for carcass and organ proportional mass.

[c]Standard error of mean, n=6.

[d,e,f]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).

[g]Trim = tail, spinal cord, and tissue cut from the carcass in the abattoir.

[h]Gastro-intestinal tract; includes reticulo-rumen, omasum, abomasums, small intestine, large intestine, cecum, and mesenteric/omental fat.

[i]Total splanchnic tissues; includes GIT, liver, pancreas, and spleen.

Table 4-3. Oxygen consumption by tissues from steers before and after placement into thefeedlot

Item	Treatment[a]				SEM[b]	*P*-value
	WP	SF	PF	CF		
Growing phase						
Duodenum						
$\mu L \cdot min^{-1} \cdot g^{-1}$	3.43	2.78	2.94	-	0.86	0.87
Whole organ, ml/min	19.10	10.58	13.15	-	4.29	0.38
Liver						
$\mu L \cdot min^{-1} \cdot g^{-1}$	5.29	4.75	4.79	-	0.76	0.85
Whole organ, ml/min	33.55	24.76	25.80	-	4.02	0.27
Finishing phase						
Duodenum						
$\mu L \cdot min^{-1} \cdot g^{-1}$	1.54	1.80	1.26	1.96	0.37	0.50
Whole organ, ml/min	8.98	9.74	7.04	9.76	2.11	0.74
Liver						
$\mu L \cdot min^{-1} \cdot g^{-1}$	3.44	3.25	2.58	2.59	0.41	0.33
Whole organ, ml/min	28.88	24.18	18.78	17.68	3.45	0.11

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed
[b]Standard error of mean, n = 6.
[c,d]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).

Table 4-4. Cellularity of organs from steers before placement into the feedlot and at final harvest

	Treatment[a]					
Item	WP	SF	PF	CF	SEM[b]	*P*-value
Duodenum						
End of growing						
RNA, mg/g	4.38	3.68	4.06	-	0.70	0.78
DNA, mg/g	10.69	8.93	9.26	-	1.18	0.55
Protein, mg/g	117.14	130.89	121.33	-	8.12	0.49
RNA:Protein	0.038	0.027	0.034	-	0.006	0.37
Protein:DNA	11.97	16.15	13.86	-	2.08	0.39
Total Organ RNA, g	23.92	14.60	18.17	-	3.50	0.20
Total Organ DNA, g	57.60	37.06	42.27	-	6.60	0.11
Total Organ Protein, g	631.53	525.88	545.04	-	46.36	0.26
End of finishing						
RNA, mg/g	9.15	8.58	7.96	8.11	0.84	0.75
DNA, mg/g	9.57	9.96	10.33	10.87	1.28	0.90
Protein, mg/g	123.75	134.06	141.03	140.38	9.57	0.56
RNA:Protein	0.078	0.067	0.058	0.060	0.009	0.47
Protein:DNA	14.94	15.55	15.22	13.79	2.97	0.98
Total Organ RNA, g	56.10	45.67	46.41	39.51	5.45	0.22
Total Organ DNA, g	59.02	54.58	57.03	52.32	8.15	0.94
Total Organ Protein, g	739.85	722.15	796.16	704.75	69.29	0.81
Liver						
End of growing						
RNA, mg/g	8.84	8.35	8.49	-	0.83	0.91
DNA, mg/g	2.63	2.03	2.49	-	0.45	0.63
Protein, mg/g	191.98	191.47	190.59	-	8.79	0.99
RNA:Protein	0.046	0.044	0.046	-	0.005	0.96
Protein:DNA	85.03	124.92	93.62	-	22.81	0.45
Total Organ RNA, g	56.51	45.52	45.64	-	5.57	0.31
Total Organ DNA, g	17.11	10.67	13.42	-	2.61	0.25
Total Organ Protein, g	1232.11	1033.38	1041.77	-	85.84	0.21
End of finishing						
RNA, mg/g	9.97	8.03	8.37	8.53	1.07	0.60
DNA, mg/g	2.07	1.81	2.21	2.13	0.32	0.83
Protein, mg/g	194.68	186.77	189.33	196.55	9.39	0.87
RNA:Protein	0.052	0.043	0.045	0.045	0.006	0.73
Protein:DNA	106.80	111.01	100.95	105.58	18.15	0.98
Total Organ RNA, g	83.79	58.56	63.34	57.63	8.63	0.15
Total Organ DNA, g	17.30	13.15	16.21	14.66	2.44	0.65
Total Organ Protein, g	1622.11	1352.22	1444.76	1349.40	108.50	0.27

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed
[b]Standard error of mean, n = 6.
[c,d]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$).

APPENDIX A

DIGESTIBILITY OF EXPERIMENTAL DIETS

MATERIALS AND METHODS

A group of 20 steers (average BW = 384 ± 16.6 kg) were used to determine digestibility of experimental diets (Table A-1). Steers in the CF, SF, and PF groups (n = 5 steers/diet) were adapted to treatment diets in individual pens over a period of 35 d after which they were moved into metabolism stalls and acclimated to the stalls for an additional 5 d prior to the beginning of sample collections. Daily diet samples and total feces were collected over a 5 d period, composited, and analyzed for DM, OM, NDF, ADF, N, and gross energy. Total urine was collected for a 5 d period and analyzed for determination of N, creatinine, and gross energy.

Steers in the WP group (n = 5 steers) were grazed on wheat pasture from mid-November to mid-March. Forage clippings and fecal and urine spot samples were collected over a 5 d period in early January and analyzed for the components mentioned above. Total fecal output was estimated using chromium oxide as an indigestible marker, and total DMI was estimated as fecal output divided by the percentage of the indigestible portion of wheat pasture forage. The average total creatinine excretion from the other treatment groups and the creatinine concentration of spot urine samples from WP steers were used to determine total urinary output for WP steers.

Table A-1. Composition and digestibility of experimental diets

Item	Treatment[a] WP	SF	PF	CF	SEM[b]	*P*-value
Dry Matter						
Intake, kg	37.19[c]	31.21[c]	38.73[cd]	46.01[d]	2.97	0.023
Fecal output, kg	9.27	10.67	9.36	8.17	0.74	0.171
%Digestibility[f]	74.94[c]	65.28[d]	75.87[c]	82.21[e]	1.31	<0.0001
Organic Matter[g]						
Intake, kg	33.80[c]	28.85[c]	36.50[cd]	43.96[d]	2.73	0.010
Fecal output, kg	6.96[c]	9.36[d]	8.13[cd]	7.08[c]	0.62	0.051
%Digestibility	79.28[c]	67.13[d]	77.78[c]	83.89[e]	1.21	<0.0001
Digestible OM Intake, kg	26.84[c]	19.50[d]	28.37[c]	36.89[e]	2.24	0.001
Nitrogen						
Intake, g	1308.4[c]	668.7[d]	874.5[d]	929.3[d]	90.3	0.001
Fecal output, g	312.7[c]	214.7[d]	199.8[d]	190.3[d]	21.2	0.003
Urinary output, g	542.3[c]	173.2[d]	278.5[e]	218.1[de]	31.3	<0.0001
%Digestibility	75.89[c]	67.44[d]	77.24[c]	79.48[c]	1.33	<0.0001
%Retention	32.49[c]	40.82[c]	45.26[cd]	55.81[d]	5.04	0.034
NDF						
Intake, kg	16.55[c]	12.87[d]	8.13[e]	6.60[e]	1.23	<0.0001
Fecal output, kg	6.21[c]	6.45[c]	5.18[cd]	4.28[d]	0.49	0.022
%Digestibility	62.28[c]	49.18[d]	36.35[e]	35.09[e]	2.87	<0.0001
ADF						
Intake, kg	8.74[c]	10.40[c]	5.57[d]	3.87[d]	0.75	<0.0001
Fecal output, kg	4.56[c]	4.83[c]	3.51[cd]	2.65[d]	0.46[d]	0.014
%Digestibility	47.84[cd]	52.77[c]	36.82[de]	32.54[e]	5.04	0.041

[a]WP = Wheat pasture, SF = Silage fed, PF = Program fed, CF = Ad libitum concentrate fed
[b]Standard error of mean, n = 5
[c,d,e]Within a row and tissue, means without a common superscript letter differ ($P < 0.05$)
[f]All percentages for digestibility and retention of dietary components are calculated on an apparent basis
[g]Organic matter, Nitrogen, NDF, and ADF are calculated on a dry matter basis

APPENDIX B

ADDITIONAL PROBABILITY VALUES
FOR EXPERIMENTAL DATA

Table B-1. Probability values for data items contained in Tables 3-6 and 3-8

	Component			
Item	Carcass	Offal	Empty body	Viscera
Chemical composition				
Mass, kg	0.11	0.55	0.16	0.07
Water, kg	0.07	0.48	0.10	0.43
FFOM, kg[a]	0.07	0.51	0.08	0.90
FFOM, g/kg	0.15	0.79	0.16	0.02
Fat, kg	0.34	0.09	0.14	0.01
Fat, g/kg	0.38	0.03	0.06	<0.001
Energy, Mcal[b]	0.17	0.08	0.11	0.01
Energy, Mcal/kg	0.12	0.01	0.02	<0.001
Composition of gain				
Mass, kg/d	0.04	0.69	0.09	0.01
Water, g/d	0.10	0.81	0.25	0.43
FFOM, g/d	0.02	0.88	0.02	0.32
Fat, g/d	0.17	0.05	0.04	0.003
Energy, Mcal/d	0.04	0.02	0.01	0.004

[a]Fat-free organic matter.

[b]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g.

Table B-2. Probability values for data items contained in Tables 3-7 and 3-9

	Component			
Item	Carcass	Offal	Empty body	Viscera
Chemical composition				
Mass, kg	0.55	0.57	0.54	0.74
Water, kg	0.39	0.51	0.42	0.49
FFOM, kg[a]	0.82	0.005	0.56	0.25
FFOM, g/kg	0.66	0.02	0.99	0.10
Fat, kg	0.83	0.50	0.84	0.72
Fat, g/kg	0.94	0.11	0.79	0.61
Energy, Mcal[b]	0.78	0.60	0.77	0.71
Energy, Mcal/kg	0.81	0.20	0.69	0.64
Composition of gain				
Mass, kg/d	0.002	0.003	0.001	0.63
Water, g/d	0.01	<0.001	0.002	0.03
FFOM, g/d	0.04	<0.001	0.001	0.02
Fat, g/d	0.14	0.86	0.28	0.37
Energy, Mcal/d	0.06	0.35	0.09	0.33

[a]Fat-free organic matter.

[b]Ether extract material x 9.4 kcal/g + fat-free organic matter x 5.55 kcal/g.

Table B-3. Probability values for data items contained in Table 4-1

	Component	
Item	Final	Change
Carcass		
kg	0.11	0.11
g/kg EBW	0.33	0.33
Blood		
kg	0.31	0.31
g/kg EBW	0.42	0.42
Feet and Ears		
kg	0.04	0.04
g/kg EBW	0.22	0.21
Hide		
kg	0.76	0.43
g/kg EBW	0.42	0.42
Head		
kg	0.38	0.38
g/kg EBW	0.84	0.83
Trim[g]		
kg	0.79	0.79
g/kg EBW	0.56	0.56
Heart		
kg	0.75	0.75
g/kg EBW	0.95	0.96
Lungs		
kg	0.52	0.52
g/kg EBW	0.93	0.92
Esophagus		
kg	0.52	0.59
g/kg EBW	0.99	0.96
Kidney		
kg	<0.001	<0.001
g/kg EBW	<0.001	<0.001
Reticulo-rumen		
kg	0.16	0.16
g/kg EBW	0.03	0.03
Omasum		
kg	0.52	0.52
g/kg EBW	0.38	0.39
Abomasum		
kg	0.71	0.70
g/kg EBW	0.97	0.96
Small Intestine		
kg	<0.001	<0.001
g/kg EBW	<0.001	<0.001
Large Intestine		
kg	0.16	0.16
g/kg EBW	0.35	0.36
Cecum		
kg	0.51	0.54

g/kg EBW	0.42	0.38
Mesenteric fat		
kg	0.01	0.01
g/kg EBW	0.003	0.003
Total viscera[h]		
kg	0.07	0.07
g/kg EBW	0.04	0.04
Pancreas		
kg	0.44	0.42
g/kg EBW	0.53	0.41
Spleen		
kg	0.48	0.48
g/kg EBW	0.50	0.48
Liver		
kg	0.04	0.04
g/kg EBW	0.001	0.001
TST[i]		
kg	0.18	0.18
g/kg EBW	0.29	0.29

Table B-4. Probability values for data items contained in Table 4-2

	Component	
Item	Final	Change
Carcass		
kg	0.55	0.02
g/kg EBW	0.31	<0.001
Blood		
kg	0.05	<0.001
g/kg EBW	0.40	0.05
Feet and Ears		
kg	0.22	<0.001
g/kg EBW	0.10	0.04
Hide		
kg	0.71	<0.001
g/kg EBW	0.67	0.02
Head		
kg	0.99	<0.001
g/kg EBW	0.40	0.11
Trim[g]		
kg	0.10	0.002
g/kg EBW	0.12	<0.001
Heart		
kg	0.07	<0.001
g/kg EBW	0.03	0.01
Lungs		
kg	0.002	0.86
g/kg EBW	<0.001	0.03
Esophagus		
kg	0.002	<0.001
g/kg EBW	0.01	0.002
Kidney		
kg	0.02	<0.001
g/kg EBW	0.01	<0.001
Reticulo-rumen		
kg	0.73	0.03
g/kg EBW	0.60	<0.001
Omasum		
kg	0.66	<0.001
g/kg EBW	0.34	<0.001
Abomasum		
kg	0.38	0.002
g/kg EBW	0.06	0.002
Small Intestine		
kg	0.19	0.01
g/kg EBW	0.11	0.01
Large Intestine		
kg	0.08	0.17
g/kg EBW	0.04	0.002
Cecum		
kg	0.11	0.08

g/kg EBW	0.10	<0.001
Mesenteric fat		
kg	0.93	0.89
g/kg EBW	0.99	0.06
Total viscera[h]		
kg	0.74	0.41
g/kg EBW	0.70	0.01
Pancreas		
kg	0.10	0.15
g/kg EBW	0.27	0.004
Spleen		
kg	0.03	0.05
g/kg EBW	0.19	0.20
Liver		
kg	0.06	0.002
g/kg EBW	0.01	<0.001
TST[i]		
kg	0.59	0.29
g/kg EBW	0.49	0.01

VITA

Matthew Pierce McCurdy

Candidate for the Degree of

Doctor of Philosophy

Dissertation: EFFECT OF WINTER GROWING PROGRAM ON SUBSEQUENT FEEDLOT PERFORMANCE, CARCASS MERIT, BODY COMPOSITION, ORGAN MASS, AND OXYGEN CONSUMPTION OF BEEF STEERS

Major Field: Animal Nutrition

Biographical:

Personal Data: Born in Cuero, Texas on September 15, 1977, the son of Robert and Mary McCurdy

Education: Graduated from Cuero High School in Cuero, Texas in May, 1996; received Bachelor of Science degree in Animal Science from Texas A&M University in College Station, Texas in May, 2000; received Master of Science degree in Animal Science from Michigan State University in East Lansing, Michigan in May, 2003. Completed the requirements for the Doctor of Philosophy degree with a major in Animal Nutrition at Oklahoma State University in December, 2006

Experience: Raised on commercial cow-calf ranch near Cuero, Texas; employed as an undergraduate worker by Texas A&M University, Department of Animal Science in meat science extension and ruminant nutrition; employed as a graduate assistant by Michigan State University, Department of Animal Science in ruminant nutrition; graduate assistant with Oklahoma State University, Department of Animal Science, 2003 to present.

Professional Memberships: American Society of Animal Science, American Registry of Professional Animal Scientists

Name: Matthew McCurdy Date of Degree: December 2006

Institution: Oklahoma State University Location: Stillwater, OK

Title of Study: EFFECTS OF WINTER GROWING PROGRAM ON SUBSEQUENT FEEDLOT PERFORMANCE, BODY COMPOSITION, CARCASS MERIT, ORGAN MASS, AND OXYGEN CONSUMPTION IN BEEF STEERS

Pages in Study: 108 Candidate for the degree of Doctor of Philosophy

Major Field: Animal Nutrition

Effect of winter growing program on finishing performance, body composition, carcass merit, organ mass and oxygen consumption of beef steers was investigated. A total of 260 steers were utilized for the experiment. Four steers were randomly selected as an initial harvest group. Remaining steers were blocked by weight and randomly allotted to one of four treatment groups: 1) ad libitum fed high-concentrate diet (**CF**); 2) grazed on wheat pasture (**WP**); 3) fed a sorghum silage-based growing diet (SF); or 4) program fed a high-concentrate diet (**PF**). Steers in the WP, SF, and PF groups were managed to achieve approximately equal rates of BW gain. After 112 d steers in the WP, SF, and PF treatments were adapted to a high-concentrate diet for finishing. Steers from all treatment groups were harvested at a backfat of 1.27 cm. In addition, six steers from each treatment group were randomly selected for harvest at the end of the growing and finishing phases. During the finishing phase DMI was greater ($P < 0.01$) for SF steers (10.9 kg/d) than for PF steers (10.1 kg/d), with WP steers being intermediate (10.4 kg/d). Steers in the SF and PF groups had greater ($P < 0.01$) ADG (2.02 and 1.85 kg/d, respectively) and greater gain:feed (both 0.186) compared with WP steers (1.64 kg/d and 0.156). At the end of the growing phase, liver, kidney and small intestine weights (g/kg EBW) were greatest for WP steers ($P < 0.01$). Silage-fed steers had the heaviest ($P < 0.05$) reticulo-rumens. Mesenteric fat and viscera mass was greatest for PF, intermediate for SF, and lowest for WP steers ($P < 0.01$). At final harvest, liver weights remained greatest (g/kg EBW; $P < 0.01$) for WP steers and mass of total splanchnic tissues was not different. In conclusion, SF and PF steers had greater gains and gain efficiency during finishing compared with WP steers due to greater energy demand of visceral tissue growth during finishing for WP steers. Steers in the SF group had more growth in visceral tissues during finishing as compared to PF steers but compensated with greater intake.

Advisor's Approval: _____Clint Krehbiel_____