

**IMPACTS OF LATE GESTATIONAL TALL FESCUE FORAGE SYSTEMS ON
PREWEANING CALVES**

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By

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IMPACTS OF LATE GESTATIONAL TALL FESCUE FORAGE SYSTEMS ON
PREWEANING CALVES

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DEDICATION

To my parents

Kris and Corie Niederecker

Thank you for all of your unconditional love and support

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
LIST OF FIGURES	vii
LIST OF TABLES	viii
ABSTRACT.....	x
Chapter 1	
LITERATURE REVIEW	1
INTRODUCTION.....	1
STOCKPILED TALL FESCUE	2
<i>Nitrogen Application, Forage Yield, and Nutrient Composition</i>	3
<i>Forage Allocation</i>	6
<i>Value of Extending the Grazing Season</i>	7
<i>Animal Performance While Grazing Stockpiled Tall Fescue</i>	8
DEVELOPMENTAL PROGRAMMING	9
<i>Effects of Gestational Nutrition on Cow Organs and Performance</i>	10
<i>Organogenesis</i>	17
<i>Organ Growth and Maturation</i>	19
<i>Fetal Growth</i>	21
<i>Neonatal Offspring Circulating Metabolites and Hormones</i>	23

<i>Offspring Health</i>	24
<i>Offspring Pre-weaning Performance</i>	26
<i>Female Offspring Attainment of Puberty and Fertility</i>	27
<i>Offspring Carcass Characteristics</i>	28
SUMMARY AND CONCLUSIONS	30

Chapter 2

Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on cow and calf performance through weaning	31
ABSTRACT	31
INTRODUCTION.....	32
MATERIALS AND METHODS	33
<i>Animal Management and Forage Systems</i>	33
<i>Animal Measurements</i>	35
<i>Forage Measurements</i>	36
<i>Statistical Analysis</i>	38
RESULTS AND DISCUSSION	39
<i>Cow Performance</i>	39
<i>Calf Performance</i>	42
CONCLUSION	46

Chapter 3

Pre-weaning calf circulating metabolites and hormones in a tall fescue forage system

model of developmental programming	51
ABSTRACT	51
INTRODUCTION.....	52
MATERIALS AND METHODS	53
<i>Animal Management and Forage Systems</i>	53
<i>Forage Measurements</i>	55
<i>Postnatal Sample and Data Collection</i>	57
<i>Chemistry Profile, Metabolite, and Hormone Analyses</i>	58
<i>Statistical Analysis</i>	59
RESULTS AND DISCUSSION	60
<i>Calf Vigor</i>	61
<i>Neonatal Calf Serum Chemistry Profile</i>	61
<i>Neonatal Calf Serum Cortisol and Thyroid Hormones</i>	63
<i>Neonatal Calf Plasma AA</i>	64
<i>Preweaning Calf Circulating BUN and Glucose</i>	68
CONCLUSION	69
LITERATURE CITED	81
APPENDIX.....	91

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 3.1. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf serum urea nitrogen concentrations through weaning in yr 1.	79
Figure 3.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma glucose concentrations through weaning in yr 1.....	80

LIST OF TABLES

<u>Table</u>	<u>Page</u>
Table 2.1. Nutrient composition, digestibility, and yield of stockpiled tall fescue and tall fescue hay offered to beef cows during late gestation in both years	31
Table 2.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on prepartum cow performance in both years	48
Table 2.3. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on postpartum cow performance	49
Table 2.4. Effects of feeding stockpiled tall fescue versus fescue hay during late gestation on calf BW and performance through weaning	50
Table 3.1. Nutrient composition, digestibility, and yield of stockpiled tall fescue and tall fescue hay offered to beef cows during late gestation in both years	71
Table 3.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf weight and vigor measures at birth during yr 2	72
Table 3.3. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation in yr 2 on calf serum chemistry profile at 48 h postnatally	73
Table 3.4. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on circulating calf serum cortisol, triiodothyronine (T ₃), and thyroxine (T ₄) concentrations at 48 h postnatally	74
Table 3.5. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma AA concentrations 48 h postnatally	75
Table 3.6. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma AA expressed as a percentage of total AA at 48 h postnatally .	77

Table 3.7. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma essential AA expressed as a percentage of total essential AA at 48 h postnatally	78
Appendix Table 1. Pre-grazing stockpiled tall fescue forage yield and quality versus hay quality during yr 1.....	91
Appendix Table 2. Post-grazing stockpiled tall fescue forage yield, quality, and utilization rates during yr 1	92
Appendix Table 3. Pre-grazing stockpiled tall fescue forage yield and quality versus hay quality during yr 2.....	93
Appendix Table 4. Post-grazing stockpiled tall fescue forage yield, quality, and utilization rates during yr 2	94

IMPACTS OF LATE GESTATIONAL TALL FESCUE FORAGE SYSTEMS ON PREWEANING CALVES

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ABSTRACT

A 2-yr experiment was conducted researching the impact of common lower Midwestern beef cattle winter forage systems on late gestation, spring-calving beef cows and their subsequent calves. We hypothesized that cows grazing stockpiled tall fescue (STF) during late gestation would have increased nutrient intake compared to cows fed summer-baled tall fescue hay (HAY), which would result in improved fetal growth and development, as well as subsequent calf performance and metabolic status. Overall, cows consuming HAY lost more BCS prepartum than cows consuming STF. In yr 2 HAY cows gained more BW prepartum than STF cows, but there was no difference between forage systems in yr 1. Calves born to cows consuming HAY weighed less at birth than calves born to STF cows, suggesting decreased fetal growth. Despite this, in yr 2 there were no differences in calf vigor measures at birth or in triiodothyronine, thyroxine, or cortisol concentrations at 48 h. Additionally, calves born to HAY cows tended to weigh less at d 80 than STF in yr 1, but in yr 2 there was no difference. During yr 1 blood urea nitrogen (BUN) was greater at 48 h for calves born to cows consuming STF and plasma glucose concentrations tended to be greater through weaning for STF calves. Despite this, impacts of late gestation maternal nutrition on calf amino acid concentrations at 48 h varied. In conclusion, grazing stockpiled tall fescue in late gestation appears to improve fetal growth and alter perinatal nutrient supply in calves.

CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

It is well documented in the U.S. that feed inputs are the greatest variable cost for cow-calf producers, making up over 70% of their total operating costs (USDA-ERS, 2014). Nutrient requirements of beef cows increase exponentially during the last third of pregnancy, when the majority of the fetal growth occurs (Robinson et al., 1977). For producers, knowing the impact maternal nutrition has on both the cow and her calf is critical when comparing feed input options to meet gestational nutrient requirements. Developmental programming is the theory that the uterine environment, which is affected by maternal nutrition, among other factors, impacts fetal development and can have lasting effects on offspring postnatal growth and health (Barker et al., 1993; Reynolds, 2010). Recent research in beef cattle has shown that maternal nutrition during late gestation can have lifelong impacts on calves postnatally (Stalker et al., 2006; Martin et al., 2007; Funston et al., 2010a).

Missouri ranks second in the U.S. in beef cow numbers, with 1.82 million beef cows that calved in 2014 (USDA-ERS, 2014). Due to the large number of beef cows, cow-calf nutrition is especially relevant in Missouri. In lower Midwestern states such as Missouri, it is common for cow-calf producers to allow their cows to graze pastures while forage is growing and then feed cows summer-baled hay during winter months, which is often poor quality and fails to meet nutrient demands of late gestation in a spring-calving cow (Kallenbach et al., 2003). If grain-based supplementation is used to meet the increasing nutritional requirements of beef cows during gestation, which are further

increased by cold stress for spring-calving cows, feed costs are increased. An alternative option for cow-calf producers is to extend the grazing season by stockpiling fall forage growth, which also may come closer to meeting maternal nutrient requirements during this time.

STOCKPILED TALL FESCUE

Tall fescue is a wind-pollinated, cool-season, perennial grass covering over 15 million acres of land (Bouton and Hopkins, 2003). It belongs to the genus *Festuca* and consists of 80 species growing in cool regions around the world, with 20 species growing in the U.S. (Terrell, 1979). Since the 1940s, tall fescue has become the primary cool-season forage in areas that fluctuate between warm and cool climate conditions (Sleper and West, 1996). This is due to the fact that growth is still possible in poorly drained soils (Buckner et al., 1979). Although abundant moisture is not necessary, tall fescue does require at least 45 cm of rainfall annually (Buckner et al., 1979). The most abundant variety in the U.S. is Kentucky 31, which has many desirable characteristics from a hardiness standpoint, but is infected with an endophytic fungus that can negatively impact livestock (Siegel et al., 1984).

Missouri is an ideal place for tall fescue growth, with an average annual temperature of 12.6°C, average winter temperature of 0.1°C, and average summer temperature of 24.2°C (Missouri Climate Center, 2014). Additionally, over the last 120 yr Missouri has experienced an average of 100 cm of precipitation annually, making abundant fescue growth possible. In addition to its wide availability, tall fescue is known for being temperature and drought resistant, making it an ideal perennial forage grass in Missouri. Because tall fescue is a cool season grass, it has a growth pattern where peak

growth occurs in the spring followed by a second smaller peak of growth in the fall, making forage availability limited in the winter especially (Wolf et al., 1979).

Stockpiling forage consists of allowing forage growth, such as fall forage growth of a cool-season grass, to accumulate or be stockpiled for deferred grazing (Sleper and West, 1996). Tall fescue has many attributes that make it a good candidate for stockpiling pastures. It has a waxy outer cuticle that contributes to the grass's overall hardness and allows it to retain its nutritive value through winter conditions (Hitz and Russell, 1998). Mays and Wasko (1960) reported that of all of the cool-season forages, tall fescue has the most autumn forage growth. Tall fescue also responds well to late summer nitrogen fertilization allowing maximum accumulation of fall forage growth (Poore et al., 2000). When stockpiled forage yield alone is not sufficient as a feed source for livestock, forage production can be increased by fertilization (Taylor and Templeton, 1976)

Nitrogen Application, Forage Yield, and Nutrient Composition

Nitrogen is the most common limiting nutrient in non-legume plants such as tall fescue, and when applied to the soil can increase plant yield (Havlin et al., 2014). Most soil types cannot adequately supply nitrogen needed by plants, so supplemental inorganic or organic nitrogen sources need to be applied to maximize forage yield (Havlin et al., 2005). Forage yield is dependent on amount of nitrogen applied to the soil. Most studies show as amount of nitrogen applied increases, yield increases (Taylor and Templeton, 1976; Balasko, 1977; Collins and Balasko, 1981b). When considering when to apply nitrogen to pasture for stockpiling, most authors conclude higher forage yields with earlier nitrogen application (early August) but lower final nutrient concentration in the stockpiled forage (Poore et al., 2000). Rayburn et al. (1979) reported greater

accumulation of forage when nitrogen was applied in early to mid-August resulting in a DM yield of 1,769 kg/ha compared to mid-September nitrogen application resulting in a DM yield of 1,552 kg/ha. When nitrogen was applied in mid-August at 0, 30, 60, or 90 kg/ha, yield responded in an increasing manner with a DM yield of 1,700 kg/ha when no nitrogen was applied, up to 3,300 kg DM/ha when 90 kg/ha of nitrogen was applied (Collins and Balasko, 1981a). Exact yield response of tall fescue to nitrogen rate is variable dependent on many factors such as nitrogen source, previous application, weather, and location (Poore and Drewnoski, 2010), as well as endophyte infection (Kallenbach et al., 2003) . Prior to nitrogen fertilization, pastures should be mowed to remove the poor quality summer growth and allow for growth of higher quality fall forage (Taylor and Templeton, 1976).

Additionally, weather conditions throughout the winter months have varying effects on stockpiled forage yield as winter progresses. Kallenbach et al. (2003) conducted a study in southern Missouri and data reveal that herbage mass did not change from mid-December through mid-March. In opposition, Taylor and Templeton (1976) collected data in Kentucky and reported a decrease in yield as winter progressed. Conflicting data further solidify that stockpile tall fescue yield and its ability to maintain herbage is highly dependent on location as well as weather conditions. Overall Taylor and Templeton (1976) concluded that tall fescue yield in spring is not compromised by stockpiling forage if the stockpile is grazed prior to spring growth, and that stockpiled forage is best incorporated into an annual grazing scheme if utilized late fall and early winter.

When considering any forage as a winter feed source, nutritional value is of utmost importance. It has been reported that stockpiled tall fescue is often higher quality than much of the summer-harvested hay commonly fed to beef cows in Missouri (Kallenbach et al., 2003). Curtis et al. (2008) reported that stockpiled tall fescue fed to fall calving cow-calf pairs from December through February was 76.4% digestible and was 12.8% CP (DM basis) on average over 2 yr. Another Missouri study reported stockpiled tall fescue utilized to have an average CP of 13.0% and that it was 79% digestible (Curtis and Kallenbach, 2007). Hitz and Russel (1998) reported stockpiled tall fescue interseeded with alfalfa to average 63.8% NDF, 38.3% ADF, and 14.3% CP (DM basis) in Iowa over 3 yr. When comparing stockpiled tall fescue to tall fescue hay, tall fescue hay has averaged 7.8% CP, 76.8% NDF, and 43.2% ADF on a DM basis if hay is baled at a mature stage (Fieser and Vanzant, 2004). Although CP and fiber content of summer-baled tall fescue can vary, other studies utilizing tall fescue hay versus stockpiled tall fescue also reported tall fescue hay to be of less nutritive value than stockpiled tall fescue (Curtis et al., 2008; Meyer et al., 2009).

Drewnoski et al. (2007) measured that nutritive value of different fractions of stockpiled tall fescue and reported the green fractions in endophyte-infected stockpiled tall fescue were 87.3% digestible (DM basis) and the brown fractions are decreased to 61.1% digestible (DM basis). Authors also evaluated the NDF, ADF, and CP of the fractions and reported that the green fraction had a nutritive value of 48.2% NDF, 22.2% ADF, and 12.3% CP on average on a DM basis (Drewnoski et al., 2007). The nutritive value of the brown fractions of stockpiled tall fescue were 70.1% NDF, 35.5% ADF, and 8.3% CP on a DM basis (Drewnoski et al., 2007). Taylor et al. (1976) reported that in

November, tall fescue was over 75% green fraction, and by February the green fraction declined to 20% but these vary based on weather as well as location. In another study, the green portion of grass had 11.6% CP compared to 6.6% CP in the brown portion on a DM basis when forage accumulation occurred from August 15 until November 1 in Kentucky (Taylor and Templeton, 1976).

Forage Allocation

Stockpiled tall fescue is best managed by utilizing a strip-grazing or front-grazing system to reduce forage waste (Poore and Drewnoski, 2010). Researchers at the University of Missouri determined that allocating stockpiled tall fescue pastures in 3-d strips resulted in 40% more grazing days per acre than 14-d allocations and allowed a 70% forage utilization rate (Gerrish, 2004). A 14-d allocation provided at most a 50% forage utilization rate, and that did not include how winter weather conditions negatively affected forage utilization (Gerrish, 2004). Excessive rain, snow, or ice accumulation can decrease forage utilization due to trampling as well as snow cover (Meyer et al., 2009).

Curtis et al. (2008) conducted a study evaluating forage allocation to fall cow-calf pairs and reported that calf ADG/ha was greatest at the greatest forage allocation of 4.50% of cow-calf pair BW per d. As expected, ADG was the least at the lowest forage allocation of 2.25% BW, and animal performance increased linearly with increasing forage allocations (Curtis et al., 2008). Although there was increased ADG with increased allocation, land requirements also increased (Curtis et al., 2008). Authors concluded that due to comparable calf weaning BW, reduced land requirements, and that fact that cows regained lost BW the subsequent spring, providing reduced allocations of 2.25% of cow calf BW daily to cow-calf pairs was optimal. Another study researched

stocking rate and type of allocations when stocker cattle were put into a year-round grazing system (continuous), rotational grazing system, or a short duration pasture subdivision (strip-grazing) system. Average daily gain was reduced in steers allocated short duration pasture during yr 1 of the 6-yr study (Hart et al., 1988). Authors noted that reduced ADG was due to limited forage by a fixed allocation schedule in yr 1, and that once forage allocation was managed by visual availability there were no differences in steer ADG among forage systems (Hart et al., 1988). With no differences in steer ADG, frequent allocations would be optimal in order to maximize land use efficiency and minimize forage waste.

Value of Extending the Grazing Season

Due to the cost of harvesting and baling or purchasing hay, extending the grazing season can be a cost-effective solution (D'Souza et al., 1990). Additionally, stockpiling tall fescue reduces the need for stored feed as well as labor during harvest, further reducing costs (Adams et al., 1994). When comparing an extended grazing system to a conventional continuous grazing system, D'Souza et al. (1990) reported that the extended grazing system had lower inputs, which can increase profitability. Poore et al. (2000) put together case simulations based on research and surveys from producers evaluating the economic benefits of stockpiling tall fescue, but did note that economics are very site and animal specific. In the simulation, assumptions included yield, animal DMI, average costs and labor, equipment costs, grazing efficiency based on allocation frequency, and hay losses from harvest, storage, and feeding. The cost per animal per day was the lowest for animals consuming daily allocations of stockpiled tall fescue at $\$0.74 \cdot \text{head}^{-1} \cdot \text{day}^{-1}$. Two-week stockpiled tall fescue allocations resulted in a cost of $\$0.95 \cdot \text{head}^{-1} \cdot \text{day}^{-1}$,

and feeding hay was the most expensive per animal on a daily basis at $\$1.25 \cdot \text{head}^{-1} \cdot \text{day}^{-1}$ (Poore et al., 2000). When evaluating the economics of grazing beef cows, Bishop-Hurley and Kallenbach (2001) reported that tall fescue hay costed about 30% more per cow than feeding stockpiled tall fescue, with the cost per cow of feeding hay at $\$129.72$ and stockpiled tall fescue at $\$67.44$ per cow over winter. Although there are limited data evaluating the actual costs of feeding hay versus stockpiled tall fescue, these previous studies suggest that with proper management grazing stockpiled tall fescue is more cost effective.

Animal Performance While Grazing Stockpiled Tall Fescue

Grazing stockpiled tall fescue has had varying effects on animal performance, dependent on many factors such as animal age, nutrient requirements, stocking rate, and endophyte level, just to name a few. Stocker cattle grazing stockpiled tall fescue that was endophyte-infected, endophyte free, or contained a non-toxic novel endophyte had no differences in calf ADG over the grazing season between treatments (Drewnoski et al., 2007). Contrary to previous data, when stocker cattle were grazing endophyte-infected tall fescue established in September versus a novel variety, calves grazing endophyte-infected tall fescue had reduced ADG (Beck et al., 2008). The reason for the difference in animal performance could be due to feeding stockpiled tall fescue in the fall and early winter. (Kallenbach et al., 2003) suggested that endophyte concentration in Kentucky 31 tall fescue decreases by 85% over winter, falling below the toxicity threshold for livestock.

Hitz and Russell (1998) reported that mid-gestation beef cows grazing stockpiled tall fescue interseeded with alfalfa gained BW and BCS over winter. Similar results were

reported in late gestation beef cows, which have increased nutrient demands, consuming stockpiled tall fescue gained BW and BCS during year 1 and lost less BW, BCS, and 12th rib fat over the winter during yr 2 when compared to their counterparts fed summer-baled hay (Meyer et al., 2009). Despite differences in cow performance during late gestation, birth and weaning weights of calves did not differ between those born to cows fed stockpiled tall fescue or hay (Meyer et al., 2009).

Curtis et al. (2008) evaluated the impact allocation of stockpiled tall fescue to fall calving cows and their calves the winter following parturition, when cow nutrient requirements would be at their highest due to lactation. Grazing stockpiled tall fescue from December through February had varying effects on cow BW change dependent on year. Cows grazing stockpiled tall fescue lost less BW than cows consuming hay during yr 2, but during yr 1, cows consuming hay lost less BW and BCS (Curtis et al., 2008). After calving, cows losing BW during winter (indicating that they were not meeting nutrient requirements) experienced compensatory gain once grazing spring forage growth began, showing cows can easily recover any lost BW and BCS (Curtis et al., 2008) . Despite this, the fetal impact of feeding stockpiled tall fescue may be different.

DEVELOPMENTAL PROGRAMMING

During gestation there are critical developmental periods when the fetus is vulnerable to maternal stressors (Nathanielsz, 2006). Potential maternal stressors include, but are not limited to, environmental temperature, toxins, disease, stress, and nutrient intake (Fowden et al., 2006). When a fetus develops in a nutrient restricted environment, organ growth and development can be negatively affected (Nathanielsz, 2006). Because of this, offspring may not grow to reach their genetic potential and consequences could

include reduced future offspring health and performance (Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009).

In ruminants, the nutrient demands of the fetus increase exponentially as pregnancy progresses (NRC, 2000). For spring-calving cows in the Midwest, the most demanding periods of gestation occur during winter when forage availability is scarce. During this nutritionally demanding time many producers rely on stored forage, which is often poor in quality. When this is the sole nutrient source for pregnant beef cows, it often fails to meet the nutrient requirements of gestation. Nutrient restriction of beef cows during gestation has had varying effects on dam and offspring performance, which depends on many variables such as stage of gestation, level of supplementation, or supplement type.

Effects of Gestational Nutrition on Cow Organs and Performance

Fetal nutrient requirements during early and mid-gestation are minimal, making up less than 12% of the dam's total requirements (NRC, 2000). From a production standpoint, early gestation occurs at a time when cow nutrient requirements are greatest and mid-gestation occurs during late lactation and after weaning when cows' nutrient demands are at their lowest (NRC, 2000). Mohrhauser et al. (2014) conducted a mid-gestation nutrient restriction study where cows either remained in a positive energy balance, maintaining condition while grazing native range through supplementation of a soybean meal-based supplement, or cows were in a negative energy balance, losing 1 BCS through limit-feeding mature brome hay with a wheat middlings-based protein supplement. The treatments occurred from d 102 to 193 of gestation and, as expected,

cows in a negative energy balance lost BW and BCS, whereas the cows in a positive energy status gained BW and BCS (Mohrhauser et al., 2014). These results hold true in other studies where cattle fed below nutrient requirements during early or mid-gestation lost BW and BCS compared to those fed to meet nutrient requirements (Armstrong et al., 2001; Long et al., 2010).

Another factor researched recently is maternal re-alimentation after a nutrient restriction during various stages of gestation. From a production standpoint, this is likely to occur in times such as immediately after weaning when cows nutrient requirements decrease dramatically making it easier to meet her nutrient requirements or when spring forage growth starts to occur after a winter of consuming poor quality hay. On d 30 of gestation, cows were randomly assigned to either meet NRC recommendations for NE or consume 60% of NE recommendations for maintenance and fetal growth; then on d 85, cows from each treatment were a) slaughtered, b) remained on control or nutrient restricted diet, or c) realimented to the control diet meeting NRC requirements for NE (Camacho et al., 2014). Then on d 140 remaining cows were either slaughtered, remained on the control diet, or were realimented to the control diet, and finally on d 254 all remaining cows were slaughtered. Overall cows either were slaughtered on d 85 (control or restricted), d 140 (control, restricted, or restricted and realimented at d 85), or on d 254 (control, restricted and realimented at d 85, or restricted and realimented at d 140). At d 85, regardless of nutritional treatment, all cows had lost BW from initiation through d 85 (Camacho et al., 2014). By d 140, continually restricted dams had decreased BW compared to control dams. When cows were slaughtered at d 254 of gestation, BW and carcass measures were not different among treatments; authors suggest this is potentially

due to pregnant cows either being less sensitive to nutrient restriction or compensatory gain. Interestingly, dam gravid uterus weight was not impacted by maternal nutrient restriction during gestation which is likely due to minimal fetal requirements during early and mid-gestation (Camacho et al., 2014). Authors reported changes in some maternal organs and suggested that even though fetal demands during this time are minimal, a nutrient restriction during early to mid-gestation may have changed how the dam utilized nutrients during the rest of gestation (Camacho et al., 2014).

Wood et al. (2013) conducted a study investigating the effects of moderate nutrient restriction from approximately d 167 of gestation until slaughter at approximately d 250 of gestation on visceral organ weight. When cows were restricted to 85% of NRC total NE, BW and ADG decreased when compared to cows fed to 140% of NE recommendations, but there were no differences in body composition (Wood et al., 2013). Fetal weight, total internal fat, and mass of all measured organs other than the rumen were not different between treatments (Wood et al., 2013). Authors reported no differences in circulating beta-hydroxybutyric acid, urea, or total cholesterol at any time point. Similar to Camacho et al. (2014), results suggest that cattle are less sensitive to a nutrient restriction or that cows in this study were not restricted to a severe enough level given they were only restricted to 85% of NRC requirements.

During late gestation, cows are at their second greatest nutritionally demanding period from a production standpoint, behind lactation (NRC, 2000). Taking into consideration that a majority of fetal growth occurs during this time, an insufficiency in maternal nutrition can potentially have negative consequences on dam performance. Supplementation to meet or exceed nutrient requirements has proven to have positive

effects on cattle performance in general, and this holds true for pregnant beef cows supplemented during late gestation. Late gestational protein supplementation to spring-calving cows is common in areas such as the Sandhills of Nebraska where cows are consuming low protein forages through winter. During late gestation cows grazed native range and were either supplemented with a protein supplement (sunflower meal, cottonseed meal, and urea) or were not supplemented (Stalker et al., 2006; Martin et al., 2007). Cows supplemented during late gestation maintained BW and BCS, whereas cows not supplemented during late gestation lost BW and BCS indicating a difference in nutrient supply due to supplementation (Stalker et al., 2006; Martin et al., 2007). In a similar supplementation study, late gestation beef cows either grazed native range or corn residue through winter leading into calving and were either given a dried distillers grains with solubles-based protein supplement or were not supplemented (Larson et al., 2009, Funston, 2010). Authors reported a forage system by supplementation interaction for cow pre-calving BW where cows grazing corn residue during late gestation that were also supplemented were heavier than their counterparts. Additionally, cows supplemented during late gestation had increased BCS pre-calving compared to non-supplemented cows. Despite this, there were no differences in cow pregnancy rates at the subsequent breeding (Larson et al., 2009, Funston, 2010).

Similar cow performance results were observed when cows were managed to enter late gestation with a previously achieved BCS of 4 (low BCS) or 6 (high BCS) and were either supplemented with dried distillers grains with solubles or not supplemented during late gestation. Cows that started late gestation with a low BCS continued to have reduced BW and BCS at calving and through weaning when compared to cows starting

late gestation with a BCS of 6 (Bohnert et al., 2013). Non-supplemented cows also had reduced BW and BCS at calving compared to supplemented cows (Bohnert et al., 2013). Additionally, Freetly et al. (2000) conducted a study where cows were fed to maintain a BCS of 5.5 from mid-gestation until breeding (H-H-H), lose BCS during mid-gestation but regain it in late gestation (L-H-H), or lose BCS in both mid and late gestation but gain it back after 28 d of lactation (L-L-H) (Freetly et al., 2000). When cows were losing BCS during mid- and late gestation, they weighed less at both parturition and 58-d postpartum than cows maintaining BCS throughout gestation. Contrary to Bohnert et al. (2013), authors reported that cows losing BCS during the second and third trimester of pregnancy regained that BCS during lactation, as there were no differences in cow BW at weaning (Freetly et al., 2000).

How nutrition during gestation affects dam performance is not uniform for all ruminants. When ewes were fed to a similar restriction level as Camacho et al (2013), more severe results were present in sheep than reported in cattle (Scheaffer et al., 2004; Meyer et al., 2010a). Scheaffer et al. (2004) conducted a study where primiparous ewes were restriction at 60% or 100% of NRC requirements from d 50 to d 90 or d 50 to d 130 of gestation (Scheaffer et al., 2004). At slaughter, spleen, heart, liver, kidneys, small intestine, and total digestive tract were reduced in nutrient restricted ewes when compared to ewes fed to meet requirements from d 50 to 90 or from d 50 to 130 of gestation (Scheaffer et al., 2004). Additionally, ewe BW, ADG, and carcass weight was reduced in restricted ewes. Despite this, there were no differences in total internal organ BW (Scheaffer et al., 2004). Numerous other studies in sheep report that there is increased sensitivity to a nutrient restriction occurring during gestation (Munoz et al.,

2008; Carlson et al., 2009; Meyer et al., 2013). Results suggest that ewes are potentially more sensitive to a nutrient restriction during pregnancy when compared to cattle, indicating that using ewes as a model for maternal nutrition during gestation research might not reflect what is actually happening in cattle at similar stages of gestation.

Effects of Maternal Nutrition on Fetal Development

Maternal Recognition of Pregnancy. Maternal recognition of pregnancy is the signaling between the dam and embryo to ensure maintenance of the corpus luteum which secretes progesterone in order to maintain pregnancy (Roberts et al., 1996). The embryo begins to interrupt the luteolytic process around 3 to 4 d before the corpus luteum starts to regress (Roberts et al., 1996). In ruminants, results suggest that trophoblastin, a member of the interferon tau family, secreted by the embryo suppresses the signal for prostaglandin production (McCracken et al., 1999). Forero et al. (1980) conducted a study to determine the impact of cow nutrient availability post-calving as well as the impact of limiting CP on pregnancy rates. Cows limited in CP from 10 to 85 d post-calving had reduced pregnancy rates when compared to cows given excess CP (Forero et al., 1980). These results could be indicating that reduced nutrition during the days leading up to maternal recognition of pregnancy could be a factor contributing to failure to establish pregnancy and could increase early embryonic loss. Abecia (1999) conducted a similar study where ewes were either fed 50% of their energy requirement or 150% of their energy requirement from 2 wk prior to breeding through 15 d post-breeding (Abecia et al., 1999). At pregnancy check, ewes limited in energy had a reduced pregnancy rates when compared to ewes exceeding their energy requirement. Many other studies show

similar results where nutrient restriction pre-breeding and immediately following resulted in decreased pregnancy rates (Cantrell et al., 1982; Hancock et al., 1985; Rakestraw, 1986). Many of these studies concluded pregnancy was not established possibly due to a failure in maternal recognition of pregnancy but the exact mechanism requires further research.

Placental Growth and Vascularity. Maternal recognition of pregnancy is then followed by placental formation, which requires communication and acceptance between maternal cells and the blastocyst (Cross et al., 1994). The placenta is a temporary organ that functions in nutrient exchange between dam and fetus (Vonnahme and Lemley, 2011). The fetal placenta is attached to maternal wall via cotyledons and this caruncle-cotyledon unit is called a placentome, which is site of nutrient and waste transport between dam and fetus in ruminant species (Vonnahme and Lemley, 2011). When considering the importance of the placenta and its role in nutrient transport, adequate placental vascularization is essential to maximize nutrients available to the fetus (Vonnahme and Lemley, 2011).

Vonnahme et al. (2007) conducted a study examining the impact of cow nutrient restriction (68% of NE_m and 86.7% of MP NRC requirements) from d 30 to 125 of gestation followed by realimentation to the control diet on placental vascularity and reported that capillary area density was not different at d 125 of gestation between restricted cows and cows meeting NRC requirements. By d 250 of gestation cows restricted from d 30 to 125 of gestation then realimented had a decreased capillary area density when compared to cows meeting NRC recommendations during that time (Vonnahme et al., 2007). Control cows meeting the NRC requirements also had a greater

capillary number density when compared to cows restricted from d 30 to 125 of gestation (Vonnahme et al., 2007). Uterine artery resistance was measured at d 130 of gestation in cows that were either provided 100% or 60% of NRC recommendations from d 50 to 130 of gestation and authors reported that restricted cows had smaller placentas that showed increased vascular resistance (Vonnahme et al., 2013). Smaller placentas with increased vascular resistance could indicate reduced maternal placental gravid uterine artery blood flow. The decreased maternal gravid uterine blood flow and increased vascular resistance potentially indicate a smaller vascular bed and thus less area for nutrient transport (Vonnahme et al., 2013). Less blood flow available to the fetus due to decreased placental vascularization could negatively impact fetal development and organogenesis due to less nutrients available to the fetus which could lead to negative consequences postnatally.

Organogenesis. Organogenesis is the differentiation and development of organs and occurs at the same time as placental development (Funston et al., 2010b). The primary germ layers in early development (ectoderm, endoderm, and mesoderm) differentiate into fetal organs which develop to function in organ systems (Fowden et al., 2006). Cells keep dividing, remain undifferentiated, or become differentiated (Nathanielsz, 1999). Cells differentiating into the wrong cell type could hurt organ function and cells differentiating too early may result in fewer cells within an organ, which would consequently result in smaller organs. Maternal nutrition during gestation may play a role in this cell differentiation and thus organ size and function postnatally.

Underwood (2008) conducted a study evaluating the impact of cow nutrition from d 135 to 195 of gestation. Cows were either managed on native range or improved

pastures during the 60-d period with native range ranging from 6.5 to 5.4% CP and improved pasture ranging from 11.1% early in the grazing season to 6% CP in the late grazing season. Steers born to cows grazing native range had less 12th rib back fat at slaughter than their counterparts, yet when steer adipocyte diameter from the same location was measured there were no differences between treatments (Underwood et al., 2008). These combined results indicate differences in steer 12th rib back fat thickness were likely due to cell number, not cell size, which could be a consequence of less adipocyte differentiation.

Zhu et al. (2004) compared ewes fed a beet pulp-based diet formulated to meet 100% NRC requirements with restricted ewes fed to 50% of the NRC requirements from d 28 to 78 of gestation, after which ewes were slaughtered and fetuses were removed. Authors reported fetuses from the restricted ewes had decreased muscle fasciculi area and decreased ratio of secondary to primary muscle fiber (Zhu et al., 2004). Vonnahme et al. (2003) then used the fetuses from the same study. On d 78 of development, fetal organs such as the liver, kidneys, and lungs from restricted ewes were reduced in mass when compared to fetal organs from control ewes. Fetal body mass was also decreased, which could be due to reduced cell number or cells differentiating too early (Vonnahme et al., 2003). Trahair et al. (1997) conducted a similar study but nutrient restriction started 2 mo prior to mating, and authors reported organ weights such as the fetal small intestine and total gastrointestinal tract were decreased in fetuses from restricted ewes. Using beef cows, Meyer et al. (2010b) compared a nutrient restriction of 68.1% of NE_m and 86.7% of MP to a control group meeting NE_m and MP requirements for gestating beef cows where treatments started 30 d post-breeding and cattle were slaughtered and fetuses were

harvested on d 125 of gestation (Meyer et al., 2010b). Results indicated no differences in fetal gastrointestinal organ weight between fetuses from nutrient restricted and control cows (Meyer et al., 2010b). Data reveal that fetal organ mass is not always altered by a nutrient restriction during early to mid-gestation, and potentially further solidify that cows are less sensitive to a nutrient restriction during early to mid-gestation than sheep.

Organ Growth and Maturation. Organ growth is the increase in mass due to both cell hyperplasia and hypertrophy (Owens et al., 2014). During fetal development, most organ growth occurs through hyperplasia. Fetal growth is dependent on the nutritional, hormonal, and metabolic status of the dam and can be negatively impacted by lack of nutrients available in the fetal environment (Desai and Hales, 1997). Fetal growth is exponential during late gestation, when over 70% of growth occurs (Robinson et al., 1977). Organ maturation is the process of tissues undergoing structural and functional changes to prepare for life outside of the womb (Fowden et al., 2006). Maturation of fetal organs starts around 75 to 80% of the way through gestation and increases leading up to parturition (Fowden et al., 2006). These processes are often glucocorticoid dependent, and an increase in fetal circulating glucocorticoid concentrations can be observed in all species studied so far in the days leading up to birth (Fowden et al., 2006). Organs such as the lungs and liver are highly dependent on glucocorticoids in order for functional gas exchange and enzyme activity, respectively, at birth (Kitterman et al., 1981). Researchers observing glucocorticoid influence on organ maturation revealed early glucocorticoid administration can cause early organ maturation which could be positive in premature offspring, but can result in negative consequences such as hypertension and renal failure if this happens in full term offspring (Fowden et al., 2006).

Fowden et al. (1993) researched the role of cortisol in regulating gluconeogenic enzymes utilizing ewes with twin lambs where 20 fetuses and dams were catheterized between d 115 and 130 of gestation. Cortisol was administered to 1 twin from d 122 to 125 of gestation followed by slaughter of ewes and collection of fetal tissues. Fetal cortisol infusion from d 122 to 125 of gestation increased fetal cortisol levels sixfold, as well as numerous hepatic enzymes. After assessing the relationship between plasma cortisol and liver enzymes, data revealed a significant positive correlation between plasma cortisol and enzyme activity. Fowden et al. (1993) concluded cortisol enhances the ability of fetal livers and kidneys to produce glucose following birth. These data are supported by Fowden et al. (1990) who researched cortisol's influence on glucose-6-phosphatase. Lemley et al. (2014) reported that nutrient restriction in ewes (60% NRC recommendations) starting on d 40 of gestation resulted in decreased maternal cortisol concentrations throughout gestation, which could lead to a decrease in fetal cortisol levels and potentially result in organ less maturation.

Maturation continues after birth and intake of colostrum is essential in this process (Burrin et al., 1997). When fetal sheep were infused with colostrum at d 117 to 119 of gestation, colostrum infusion increased growth of most organs, especially the gastrointestinal system (Trahair and Sangild, 2000). Additional research in pigs supports the role of colostrum in organ development immediately following birth (Burrin et al., 1997). Nutrient restriction of ewes to 60% of NRC requirements from d 40 of gestation through parturition resulted in decreased yield and total nutrients compared to ewes meeting or exceeding requirements during that time (Meyer et al., 2011). Given the importance of colostrum in organ development postnatally, a reduction in colostrum

quality and yield due to maternal nutrition can potentially negatively impact offspring organ development. Overall, little is known about the mechanisms leading to maturation in ruminants, but research does demonstrate the importance of glucocorticoids and colostrum, which both can all be altered by maternal nutrition.

Fetal Growth. Final fetal growth is measured through birth weight, and reduced calf birth weight as result of cow nutrient restriction during gestation may indicate that the calf did not meet its genetic potential for fetal growth. This altered fetal growth or development may have lasting consequences later in life (Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009). Maternal nutrient restriction during early to mid-gestation has less of an impact on birth weight than a restriction later in gestation. Meyer et al. (2010a) reported no differences in fetal BW from cows nutrient restricted to 68% of NE and 87% of MP requirements during the first 125 d of gestation compared to cows meeting NRC recommendations. Fahey et al. (2005) reported no differences in birth BW in lambs born to ewes nutrient restricted to 50% of NRC recommendations from d 30 to 70 of gestation or d 55 to 95 of gestation compared to control ewes fed to meet NRC recommendations. Yet, when ewes were restricted to 50% of NRC recommendations from d 85 to 115 of gestation, lamb birth BW was reduced compared to lambs born to ewes meeting requirements throughout gestation (Fahey et al., 2005). These data potentially indicate that sheep are more sensitive to a nutrient restriction than cattle and that offspring are more sensitive later in gestation but results may vary due to exact timing of restriction as well as extent of restriction.

Freetly et al. (2000) conducted a study to determine the impacts of a nutrient restriction during different periods of gestation, combining both mid and late gestation.

There were 3 gestational treatments: cows maintained a BCS of 5.5 through the second and third trimester (H-H), cows lost BCS during the second trimester but regained BCS in the third (L-H), or cows lost BCS in both the second and third trimester (L-L). In this study, there were no differences in birth BW between calves born to H-H cows or L-H cows, but calves born to L-L cows weighed less at birth than their counterparts (Freetly et al., 2000). Contrary to Freetly's results, Stalker et al. (2006) and Martin et al. (2007) reported no difference in birth weight between calves born to cows either consuming native range only or native range plus a CP supplement from d 170 of gestation through calving. Interestingly, when looking at prepartum energy source during late gestation, Radunz et al. (2010) reported calves born to cows consuming hay during late gestation were lighter at birth than those born to cows consuming corn or dried distillers grains. Authors concluded that late gestation dietary energy source can alter fetal growth (Radunz et al., 2010).

There have been multiple studies evaluating the impact of poor nutrition during late gestation on birth weight, but results have varied. About half of the studies indicate that poor nutrition during late gestation reduces birth weight (Corah et al., 1975; Bellows and Short, 1978; Houghton et al., 1990; Freetly et al., 2000), and the other half indicate no difference in birth weight (Stalker et al., 2006; Martin et al., 2007; Funston et al., 2010b). The conflicting results indicate the impact of a nutrient restriction during gestation on offspring fetal growth is dependent on many factors which may include time and duration of nutrient restriction, age, breed, and extent of nutrient restriction, among others.

Neonatal Offspring Circulating Metabolites and Hormones. There are limited data indicating the impact of maternal nutrition during gestation on circulating calf metabolites and hormones preweaning, yet calf metabolites can be used to estimate calf nutrient supply perinatally. Increased metabolites at birth and before suckling reflect nutrients available to the fetus prepartum, whereas metabolites after suckling would not only reflect prepartum nutrients but would also be impacted by cow colostrum quality postpartum and calf intake. Bull et al. (1991) reported that blood urea nitrogen (**BUN**) concentrations were affected by maternal CP intake during the last 150 d of gestation, where calves born to heifers restricted in CP had reduced BUN concentrations during the first 72 h postnatally compared to calves born to dams receiving adequate CP. Additionally, BUN levels peaked at 12 h of age then decreased by 72 h of age. Interestingly, the authors also observed a temperature effect where BUN was increased for calves housed at low temperatures postnatally. Other serum constituents such as creatinine, total protein, cholesterol, and total bilirubin were not different between treatments. Authors speculated that protein deficiency as well as cold stress to the calf after birth results in altered BUN levels during the first 3 d of life (Bull et al., 1991).

Thyroid hormones play an important role in development in addition to energy metabolism (McNabb and King, 1993), and concentrations in the blood can be used as an indicator of available nutrients (Fowden and Forhead, 2004). Additionally, circulating cortisol prior to birth enhances the ability of fetal liver and kidneys to produce glucose postnatally and aids in organ maturation (Fowden et al., 1993). Camacho et al. (2012) investigated neonatal hormone changes in lambs born to dams that were assigned to a control diet meeting NRC recommendations, a restricted diet at 60% of NRC

requirements, or an increased diet at 140% of requirements starting on d 40 of gestation. Authors reported restricted ewes gave birth to lambs with decreased triiodothyronine concentrations compared to control ewes. There were no differences in thyroxine or cortisol concentrations at birth in lambs born to restricted ewes compared to control ewes. Despite this, lambs born to ewes exceeding their nutrient requirements had increased thyroxine and decreased cortisol concentrations compared to lambs born to restricted or control ewes diet (Camacho et al., 2012). Circulating triiodothyronine, thyroxine, and cortisol from d 3 to 19 were not affected by ewe nutrient intake. Although circulating hormone concentrations can be a good indication of nutrient provided to the fetus, little is known about what the average concentrations should be, especially in calves.

Offspring Health. Calf health is critical in all types of beef cattle operations and stages of production, as a compromise in health of any kind results in added labor and expenses for a producer. Unfortunately, there is limited research on how maternal nutrition during gestation impacts progeny health. Corah et al. (1975) conducted 2 experiments with individually fed heifers fed to 65% of 1970 NRC requirements for DE or meeting requirements for the last 100 d of gestation. In experiment 2 of this study, cows were restricted to 44% of DE requirements 100 d prepartum, then 30 d prior to expected parturition, cows were either allocated to remain nutrient restricted or were fed to exceed DE requirements. Results revealed increased morbidity and mortality in calves born to energy restricted first-calf heifers throughout late gestation when compared to heifers fed to meet requirements (Corah et al., 1975). A 10% calf death loss at birth was reported in nutrient restricted heifers (3% in control heifers) and 10% death loss of calves born to nutrient restricted cows (0% in cows fed to exceed requirements the last 30 d)

(Corah et al., 1975). Additionally, 19% of calves born to continuously restricted cows died between birth and weaning, whereas no calves born to cows fed to requirements for 30 d prior to parturition died prior to weaning (Corah et al., 1975). It is important to note that calf numbers were low in this study with 51 calves at weaning in experiment 1 and 35 total at weaning (14 calves from restricted dams) in experiment 2. Birth weights were reduced for calves born to nutrient restricted heifers and cows, which could be a driving factor for increased morbidity and mortality (Corah et al., 1975). Further research is necessary to determine the exact mechanism reducing health in calves, but they may not have had fully developed organs reducing immune function at birth, or reduced passive transfer resulting in decreased postnatal health.

Bohnert et al. (2013) reported that when cows entered late gestation at a BCS of 4, there was increased mortality at birth and weaning in calves compared to calves born to cows entering late gestation with BCS of 6 (Bohnert et al., 2013). The authors speculated this was due to decreased immunoglobulin in colostrum, but there was no difference in serum immunoglobulin G concentrations in calves between 24 and 48 h, contradicting their hypothesis. Authors did not measure immunoglobulin concentrations in colostrum (Bohnert et al., 2013). Additionally, research has indicated reduced percentage of calves weaned in calves born to cows that were consuming native range during late gestation and not supplemented, reflecting reduced health (Stalker et al., 2006).

Conversely, Larson et al. (2009) reported that protein supplementation of cows grazing winter range or corn residue during late gestation had no effect on progeny health preweaning. Despite this, 23% of calves born to dams that were not supplemented during

late gestation were treated for respiratory and gastrointestinal disease from weaning to slaughter compared to 3% of calves born to CP supplemented dams (Larson et al., 2009). Additionally, there were no differences in morbidity or mortality through weaning in the corresponding heifer calves (Funston et al., 2010b). Bovine respiratory disease is the main cause of a majority of feedlot morbidity and results in decreased ADG and lowered carcass quality which decrease potential profits (Gardner et al., 1999). When researching effects of prepartum energy source in cows during late gestation, authors reported no differences in passive transfer of immunity (classified through Immunoglobulin G concentration) between 24 and 72 h after birth or morbidity and mortality from birth through slaughter in calves born to cows fed hay, limited corn, or limited dried distillers grains starting on d 160 of gestation (Radunz et al., 2012). Overall, calf health is of utmost importance and may be altered by nutrition during gestation, which has the potential to increase medication costs and decrease calf survival.

Offspring Prewaning Performance. Cow nutrition during gestation has proven to not only impact the calf at birth, but also offspring performance through weaning. Researchers conducted a late gestation protein supplementation study where late gestation beef cows either grazed native range or corn residue through calving and were either given a dried distillers grains with solubles based protein supplement or not supplemented (Larson et al., 2009; Funston, 2010). Authors reported bull calves born to cows that grazed winter range and were not supplemented weighed less at weaning than calves born to supplemented cows (Larson et al., 2009). The heifer calves born to cows grazing winter range or corn residue that were not supplemented also weighed less than heifer calves born to supplemented cows (Funston et al., 2010b). In a similar late

gestation supplementation study, both heifer and steer calves born to non-supplemented cows weighed less at weaning, and steer progeny from unsupplemented cows had reduced preweaning ADG when compared to calves born to supplemented cows (Stalker et al., 2006; Martin et al., 2007). Like previous studies, Bohnert et al. (2013) reported calves born to cows supplemented with dried distillers grains with solubles during late gestation weighed more at weaning when compared to non-supplemented cows, but there were no differences in weaning weights of calves born to cows starting late gestation at a BCS of 4 compared to calves born to cows starting late gestation at a BCS of 6 (Bohnert et al., 2013).

Conversely, when cows were: 1) restricted during the second trimester and realimented to meet requirements in the third trimester 2) restricted in both the second and third trimester or 3) meeting requirements in both trimesters, there were no differences in progeny weaning weight (Freetly et al., 2000). Data reveal a decrease in birth weights and 28-d weights in calves born to cows restricted from the second trimester through the first 28 d of lactation (Freetly et al., 2000). Overall, an increased nutritional plane in late gestation has varying effects on offspring preweaning performance dependent on many factors including but not limited to BCS entering late gestation, protein supplementation, species of ruminant, and length of dam gestational nutrient restriction.

Female Offspring Attainment of Puberty and Fertility. Maternal nutrition during gestation has shown to have life-long impacts on future reproductive performance of daughters. In ruminants, primordial follicles develop in utero without further production postnatally and therefore any reduction in primordial follicle development can lead to

reduced fertility later in life (Fortune, 1994). Funston et al. (2010b) reported heifers born to protein supplemented dams during late gestation tended to reach puberty earlier than heifers born to non-supplemented dams. In a similar study, Martin et al. (2007) reported no differences in age at puberty when dams were supplemented with a protein supplement during late gestation or not. Despite this, calves born to protein supplemented dams had an increased pregnancy rate after their first breeding season compared to heifers born to non-supplemented dams (Martin et al., 2007). Similarly, Funston et al. (2010b) reported a tendency for heifer pregnancy rates to be affected by dam supplementation, where a 91% pregnancy rate was observed in heifers born to supplemented dams and a 77% pregnancy rate in heifers born to non-supplemented dams (Funston et al., 2010b). Martin et al. (2007) suggested that fertility was impacted by dam nutritional influence on fetal ovarian follicle maturation.

Grazul-Bilska et al. (2009) investigated the potential causes of reduced fertility in offspring born to restricted dams using sheep as a model. Ewe restriction to 60% of NRC requirements from d 50 to 135 of gestation resulted in decreased fetal ovarian weight in lambs from restricted ewes (Grazul-Bilska et al., 2009). Additionally, maternal nutrient restriction tended to decrease cellular proliferation in primordial follicles of these fetuses, which may reduce future reproductive performance (Grazul-Bilska et al., 2009). Late gestational nutrition may reduce future heifer fertility and lengthen time until puberty, potentially resulting in life-long impacts in fertility of heifers born to nutrient restricted dams.

Offspring Carcass Characteristics. Recent research has demonstrated varying impacts of maternal nutrition on future offspring carcass characteristics. Muscle

development during the fetal stage is critical due to the fact that there is minimal to no increase in muscle fiber number after birth (Du et al., 2010). Because muscle fiber numbers increase in utero, fetal muscle development is likely vulnerable to a nutrient deficiency. Muscle potentially may be more sensitive than other organs because organs such as the heart or brain have a higher rank when partitioning nutrients to the fetus (Zhu et al., 2004). Much of muscle fiber development occurs during early to mid-gestation, and a maternal nutrient restriction during this time may alter carcass characteristics (Du et al., 2010). Lambs born to ewes that were nutrient restricted to 50% of NRC requirements from d 28 to 78 of gestation had decreased secondary myofibers than muscle from control fetuses (Zhu et al., 2004). Wether lambs born to ewes nutrient restricted to 50% of NRC requirements had increased live weights at slaughter but also had increased kidney and pelvic fat when compared to wethers born to control ewes (Zhu et al., 2006; Ford et al., 2007). Authors suggest maternal nutrient restriction during early to mid-gestation negatively affects muscle development and can lead to increased fat deposition and insulin resistance later in life (Zhu et al., 2004; Zhu et al., 2006). Despite this, no differences in marbling scores were observed in calves born to cows that entered late gestation with a BCS of 4 (likely restricted during mid-gestation to accomplish this) when compared to calves born to cows with a BCS of 6 entering late gestation (Bohnert et al., 2013). Although marbling scores were not different, more calves born to cows starting late gestation at a BCS of 6 (likely not restricted during mid-gestation) tended to grade choice and have less days on feed (Bohnert et al., 2013).

When cow nutritional status differed during late gestation, calves born to protein supplemented cows had improved quality grades and a tendency for increased HCW at

slaughter but no differences in yield grade compared to calves born to non-supplemented cows (Larson et al., 2009). In opposition, Stalker et al. (2006) reported no differences in HCW, dressing percentage, marbling score, 12th rib back fat thickness, percent grading choice, or yield grade of steers if dams were supplemented during late gestation.

SUMMARY AND CONCLUSIONS

In conclusion, there are critical fetal developmental windows that can be impacted by the maternal environment. Poor nutrition early in gestation can have negative consequences on maternal recognition of pregnancy, placental growth, vascularity, and fetal organ development. Poor maternal nutrition later in gestation may reduce fetal growth and maturation leading up to calving. Proper cow nutrition during gestation is critical as calves provided the nutrients to develop to meet their genetic potential at birth are likely larger at weaning, have increased fertility in heifers, and improved carcass quality. Much of the late gestation beef cattle research in this area comes from the Sandhills of Nebraska where low protein forages are supplemented with CP. Despite this wealth of knowledge, little is known about how cow late gestation nutrition in production systems in other areas of the U.S. such as the lower Midwest or fescue belt impacts cows prepartum and their subsequent calves through weaning.

CHAPTER 2

Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on cow and calf performance through weaning

ABSTRACT

We hypothesized that cows grazing stockpiled tall fescue during late gestation would have increased nutrient intake compared to cows fed summer-baled tall fescue hay, which would result in improved fetal development and subsequent calf performance. Multiparous, spring-calving, crossbred beef cows (yr 1: n = 48, initial BW = 678 ± 12 kg, initial BCS = 5.8 ± 0.1 , initial age = 5.7 ± 0.3 yr; yr 2: n = 56, initial BW = 640 ± 10 kg, initial BCS = 5.6 ± 0.1 , initial age = 4.9 ± 0.4 yr) were allocated by BW, BCS, age, service sire, and expected calving date to 1 of 2 forage systems during late gestation: strip-graze endophyte-infected stockpiled tall fescue pasture (STF) in 4.05 ha pastures or consume ad libitum endophyte-infected summer-baled tall fescue hay (HAY) in uncovered dry lots. There were 4 replications per forage system, which were initiated mid-November on d 188 ± 2 of gestation. Cow-calf pairs were managed together from 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum through weaning. Data were analyzed with forage system, year, and their interaction as fixed effects; calf date of birth (cow and calf measures) and sex (calf measures) were included when $P < 0.25$. Forage system did not affect ($P \geq 0.38$) initial cow measures. There was an interaction of forage system x year ($P \leq 0.001$) for overall prepartum cow BW change where in yr 2 cows consuming HAY gained more BW prepartum than STF cows but no differences ($P = 0.14$) in BW change during year 1. Despite this, cows consuming HAY lost ($P \leq 0.01$) more BCS prepartum than cows consuming STF in both years. Forage system did not affect ($P \geq$

0.33) cow 12th rib fat thickness change during late gestation. At the subsequent breeding (both years) or weaning (yr 1 only), there were no differences ($P \geq 0.52$) in cow BCS or BW. Calves born to cows consuming HAY weighed less ($P = 0.03$) at birth than calves born to STF cows. At 80 d of age calves born to HAY cows tended ($P \leq 0.07$) to weigh less than STF in yr 1, but in yr 2 there were no differences ($P = 0.52$) between forage systems. By weaning in yr 1, there were no differences ($P \geq 0.37$) in calf BW in yr 1. Additionally, there were no forage system effects ($P \geq 0.13$) for calf preweaning ADG. In conclusion, grazing STF during late gestation increases cow nutrient availability and may improve fetal growth.

INTRODUCTION

Nutrient requirements of beef cows increase exponentially during the last third of pregnancy, when about 70% of fetal growth occurs. These increasing fetal nutrient demands make up over 30% of the dam's total nutrient requirements during this time (NRC, 2000). Because of this, prenatal calves are potentially sensitive to late gestational nutrition. Developmental programming is the theory that the maternal environment during gestation, which is affected by maternal nutrition among other factors, impacts fetal development and can have lasting effects on offspring postnatally (Barker et al., 1993; Reynolds, 2010). Much of the beef cattle data in this area comes from research conducted in the Sandhills of Nebraska, where low protein forages are supplemented with CP-based supplements. These data have demonstrated improved calf performance due to dam late gestation protein supplementation (Stalker et al, 2006; Martin et al., 2007; Larson et al., 2009).

Despite this research, little is known about how late gestational nutrition in production systems common to other regions impacts calf performance. In the lower Midwest, it is common for cow-calf producers with spring-calving herds to feed poor quality grass hay that may not meet requirements during winter. Extending the grazing season is potentially more cost-effective than feeding hay given the cost of harvesting or purchasing hay, and may be less costly than grain-based supplementation (D'Souza et al., 1990). Tall fescue is the most widely available cool-season forage in the lower Midwest, and when pastures are stockpiled, it is often higher in quality than grass hay fed to beef cows (Kallenbach et al., 2003). Therefore, we hypothesized that cows grazing stockpiled tall fescue would have increased nutrient intake, which would result in improved fetal development and subsequent calf performance compared to cows consuming HAY during late gestation. Our objectives were to determine the impacts of feeding stockpiled tall fescue versus hay during late gestation on cow performance, fetal growth, and preweaning calf performance.

MATERIALS AND METHODS

The University of Missouri Animal Care and Use Committee approved animal care and use in this study.

Animal Management and Forage Systems

A 2-yr late gestation study was conducted at the University of Missouri Beef Research and Teaching Farm utilizing multiparous, spring-calving, crossbred beef cows (yr 1: n = 48, initial BW = 678 ± 12 [SEM throughout] kg, initial BCS = 5.8 ± 0.1 , initial age = 5.7 ± 0.3 yr; yr 2: n = 56, initial BW = 640 ± 10 kg, initial BCS = 5.6 ± 0.1 , initial

age = 4.9 ± 0.4 yr). Cows were allocated by BW, BCS, age, service sire ($n = 4$), and expected calving date (AI due date: yr 1 = February 8, 2014; yr 2 = February 7, 2015) to 1 of 2 forage systems during late gestation (Table 2.1): endophyte-infected stockpiled tall fescue pasture (**STF**) or endophyte-infected tall fescue hay (**HAY**). There were 4 replications (pens or pastures) per forage system, and the study was initiated on November 15, 2013 (yr 1) and November 14, 2014 (yr 2) at $d188 \pm 2$ of gestation. Cow-calf pairs were managed together from 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum through weaning.

The spring prior to the study's initiation in both years, estrus was synchronized and cows were artificially inseminated using a fixed-time AI 7-day co-sync + controlled internal drug release device protocol. Cows were exposed to bulls (≤ 50 cows per bull) beginning 10 d after AI, resulting in a calving season of 46 d in yr 1 and 79 d in yr 2.

Endophyte-infected tall fescue-based pastures (approximately 4.05 ha each) were used to stockpile the fall growth of forage for the STF forage system. In mid-August of each year, 45 kg of N/ha (as ammonium nitrate) were applied to previously grazed pastures, and pastures were allowed to accumulate forage until study initiation in each year. Stockpiled tall fescue pastures were strip-grazed using electric polytape and lightweight step-in posts. A new strip of forage was allocated approximately every 3.5 d (2x/wk) with a goal utilization of 75 to 80% of available forage. When weather conditions such as excessive ice or snow prevented grazing, cows consuming STF were fed rye haylage (yr 1: 59.7% NDF, 36.6% ADF, 12.3% CP; yr 2: 54.4% NDF, 29.6% ADF, 15.1% CP; all DM basis) until conditions improved. Rye haylage had similar nutrient composition to STF, making it a viable substitution for STF. Feeding rye haylage

was necessary for 17 d (8 d prior to the beginning of calving) in yr 1 and 0 d in yr 2 while cows were grazing STF pasture. At 7.0 ± 1 d (yr 1) and 8.5 ± 0.9 d (yr 2) prior to parturition, cows grazing STF were moved in groups to dry lots adjacent to HAY pens and fed rye haylage to ensure calves born to cows from either forage system were treated similarly postnatally.

Summer-baled, endophyte-infected tall fescue-based grass hay was fed ad libitum in round bale rings with cone chains. Hay was baled into round bales and stored in a barn prior to use. Cows were confined in 18 x 61 m uncovered dry lots that were well-drained, limestone-based, and contained a 9.1 x 9.1 m concrete pad where hay was fed to prevent excessive mud accumulation around the feeders. When the quantity of hay remaining in a feeder appeared to be limiting within 24 h, a new hay bale was weighed and core sampled for nutrient analysis before feeding. Cows in both forage systems had ad libitum access to water and were allowed a mineral and vitamin supplement (Gold Star® MFA Breeder 12 Mineral: MFA, Columbia, MO) to provide the recommended $2 \text{ oz} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$, with additional salt to limit intake when necessary.

Animal Measurements

Prepartum cow data collection was divided into 2 periods: period 1 consisted of d 0 to 35, and period 2 consisted of d 36 to 78 of study. Period 2 ended 1 wk prior to the first expected calving date and 1 d before calving began in both years. Cow performance measurements were taken at the beginning and end of these periods. At these points, cow 2-d BW (without feed and water removal) were recorded, and cows were assigned BCS (1 to 9 scale, 1 = emaciated and 9 = obese) by 3 trained technicians. In addition, 12th rib fat thickness was determined by a trained technician using an Aloka SSD-500V

ultrasound machine (Wallingford, CT). Rib fat measurements were taken at the 12th rib, measuring fat thickness at a location three-quarters down the length of the longissimus dorsi from the backbone end.

After parturition, calves were weighed, tagged, and sex was determined within 8 h of birth. Cow length of gestation was calculated based on d between fixed-time AI breeding date and date of calving for calves conceived by AI. Postpartum cow 2-d BW was recorded and BCS assigned at the subsequent fixed-time AI breeding date (yr 1: May 1, 2014; yr 2 May 7, 2015) and at weaning (yr 1: October 2, 2014). Additionally, calf BW was recorded on approximately 80 d of age (yr 1, 82.7 ± 1.0 d; yr 2, 85.6 ± 1.1 d) and at weaning (yr 1, 225.8 ± 2.1 d of age). To reduce age variation at 80-d BW, calves were split into 2 groups based on conception date (AI or natural service) and calf BW was recorded on 2 separate dates when average calf age was about 80 d in each group. Calf 2-d weaning BW was adjusted to the average age at weaning (225 d). Calf BW was adjusted to 80 d and 225 d by calculating the ADG from birth to actual recorded BW and then multiplying ADG by 80 or 225 and adding calculated gain to calf birth BW. Additionally, calf BW at weaning was calculated using the Beef Improvement Federation's (2015) calculation for 205-d weaning BW accounting for calf sex and dam age. Pregnancy was determined by transrectal ultrasound using an Aloka SSD-500V ultrasound machine 30 d after bull removal. Subsequent cow pregnancy rate was determined by dividing the number of cows determined pregnant after the subsequent breeding season was over by the total number of cows in each forage system.

Forage Measurements

Each STF pasture was sampled 3 times in yr 1 (d -7, 62, and 131 of grazing) and 4 times (d 5, 29, 62, and 119 of grazing) during yr 2. Pre-grazing samples collected on d -7 and 62 of yr 1 as well as d 5, 29, and 62 of yr 2 were used to determine pre-grazing forage yield and quality during late gestation. Post-grazing samples collected on d 62 and 131 of yr 1 as well as d 29, 62, and 119 of yr 2 were used to determine post-grazing forage yield and quality. Our goal was to sample STF pastures every 30 d, but snow and ice accumulation prevented timely sampling (especially in yr 1). At sampling, pre- and post-grazing forage samples were collected before and after each pasture section was offered to cows. Samples were collected using a flail-type harvester pulled by a tractor (Curtis and Kallenbach, 2007). Ten random 0.8 x 4.6 m sample strips were clipped to a height of 2 cm before each new section was offered to determine the pre-grazing nutrient composition and forage yield (Curtis and Kallenbach, 2007). The clipped sections were weighed and subsampled for nutrient analysis. Post-grazing samples of grazed sections were taken in the same manner as pre-grazing samples to estimate forage disappearance and grazing residue nutrient composition. Cow estimated DMI was calculated as the difference in the pre-grazing and post-grazing forage yield using pasture area and grazing days for STF. Estimated DMI of HAY was calculated as total bale weight divided by total number of animals. Waste was estimated to be 18% using results from similar hay feeders (Moore and Sexten, 2015). Pasture utilization was calculated as percentage of forage disappearance $[(\text{pre-grazing DM yield} - \text{post-grazing DM yield})/\text{pre-grazing yield}] \times 100$.

Both hay core samples and clipped STF samples were first dried in a 55°C oven for a minimum of 48 h. Samples were then ground through a 5 mm screen, followed by a 2 mm screen using a Thomas Wiley Mill (Thomas Scientific, Swedensboro, NJ), and finally ground through a 1 mm screen using a Cyclotec sample mill (Model 1093, Cyclotec™ Tecator™, Höganäs, Sweden). Neutral detergent fiber and ADF were sequentially analyzed using an ANKOM Fiber Analyzer (Model 200, ANKOM Technology Corp., Fairport, NY). In vitro true digestibility (**IVTD**) was determined by a 48 h in vitro digestion followed by washing with NDF solution as described by Ankom Technology (Daisy Incubator, ANKOM Technology Corp., Fairport, NY). Nitrogen content of forages was determined by thermoconductivity using an Elementar Nitrogen Analyzer (Vario Macro Cube, Elementar Americas, Mt. Laurel, NJ) and used to calculate CP ($N \times 6.25$). To determine total DM, samples were dried in a 105°C oven for 24 hours, then put into a 500°C oven for 16 h to determine ash content. During yr 2, STF and HAY samples were freeze-dried for analysis of ergovaline concentration (Rottinghaus et al., 1991; Hill et al., 1993). In the STF, ergovaline concentrations ranged from < 25 parts per billion to 140 parts per billion in December and from 30 to 120 parts per billion in January. The ergovaline concentration in HAY was 25 parts per billion.

Statistical Analysis

Cows were removed from the study due to failure to calve (yr 1: n = 1; yr 2: n = 1), twin pregnancy (yr 2: n = 1), calving prematurely (yr 2: n = 1), or calving outside of a 60-d calving window (yr 2: n = 3), resulting in 47 cows included in yr 1 and 50 cows in yr 2. Cows with calving difficulties were included in prepartum data analysis, but

stillborn calves or those that died soon after birth were excluded after birth weight data analysis (yr 1: n = 1; yr 2; n = 2) resulting in 46 calves in yr 1 and 48 calves in yr 2.

Data were analyzed using the MIXED procedure of SAS (SAS version 9.3, SAS Inst. Inc., Cary, NC) with pasture or drylot as the experimental unit. Forage system, year, and their interaction were considered fixed effects. For both cow and calf measures, calf date of birth was included in the model if $P < 0.25$. For calf measures only, calf sex was included in the model if $P < 0.25$. Cow pregnancy rates were compared using chi-squared analysis of the GENMOD procedure of SAS 9.3. Main effects of year were not of interest except for initial cow measures, so these will not be discussed.

RESULTS AND DISCUSSION

Cow Performance

There were no forage system x year interactions ($P > 0.38$) or forage system ($P > 0.41$) main effects for cow initial BW, BCS, or RF (Table 2.2), but cows in yr 1 weighed more ($P = 0.04$) and tended ($P = 0.07$) to have more body condition compared to cows in yr 2. There was a forage system x year interaction ($P = 0.002$) for BW change during period 1, where cows consuming HAY gained more BW ($P \leq 0.001$) than STF cows during yr 2, but no differences were observed in yr 1 (Table 2.2). This was not expected given that STF had increased CP and reduced NDF compared to HAY in both years. Additionally, STF nutrient composition in both years was similar to previous studies (Curtis et al., 2008; Meyer et al., 2010). The fact that HAY cows in yr 2 gained more BW during period 1 may be partially attributed to fill. The IVTD of the HAY was less than STF in yr 2, but during yr 1 the IVTD was similar between forages (Table 2.1). Others

have observed similar outcomes where cows consuming tall fescue hay lost about half as much BW as cows consuming STF, despite hay having less CP and being lower digestibility (Curtis et al., 2008).

During period 2 there was not a forage system x year interaction ($P = 0.90$), but STF cows gained more ($P = 0.006$) BW than cows consuming HAY during late gestation. Period 2 included the last month leading up to calving when the majority of fetal growth occurs (NRC, 2000). Additionally, period 2 in both years occurred from mid-December through January when inclement weather was experienced by cows in both forage systems. These data suggest that cows consuming STF during late gestation fared poor weather better than cows consuming HAY.

There was a forage system x year interaction ($P < 0.001$) for overall prepartum BW change where cows consuming HAY in yr 2 tended to ($P = 0.06$) gain more BW than STF. There were no differences ($P = 0.14$) in overall prepartum cow BW change during yr 1. Body weight gain was expected prepartum, as cows should be gaining fetal weight along with placental and amniotic fluid weight during late gestation. Given the improved nutritive value of STF, we anticipated increased BW gain in cows grazing STF but these results were observed exclusively during period 2. In addition to fill, increased BW gain overall in cows consuming HAY during yr 2 could potentially be due to increased CP in the HAY in yr 2 compared to yr 1 providing more CP to the microbial population. Previous research utilizing STF versus hay in spring-calving cows reported that cows consuming STF gained more BW overall during late gestation than cows consuming hay or hay with a corn-based supplement (Meyer et al., 2009). Differences in results between these studies may be due to longer treatment periods and a later AI calving date in the

Meyer et al. (2009) study. Additionally, overall BW changes included the beginning of lactation (Meyer et al., 2009).

There were no forage system x year interactions ($P \geq 0.15$) for prepartum BCS change (Table 2.2). During period 1, cows consuming STF during late gestation gained ($P = 0.005$) body condition, whereas cows consuming HAY lost condition. During period 2 there were no differences ($P = 0.53$) in BCS change in cows from either forage system. Overall, cows consuming STF lost less ($P = 0.01$) condition prepartum than HAY cows. The lack of differences during period 2 may have been due to inclement weather combined with the fact that any changes in weight during this time were likely due to fetal weight and might not have been apparent in a visual assessment. These data support our hypothesis that BW gain in HAY cows during yr 2 was due to fill, as HAY cows lost BCS despite BW gain. The fact that cows from both forage systems lost BCS overall is not surprising given they were well-conditioned prior to the study's initiation. These data are in agreement with previously reported data where cows consuming STF during late gestation lost less BCS than cows consuming tall fescue hay alone (Meyer et al., 2009). Our data also agree with previous studies where cows consuming low protein forages and supplemented during late gestation had greater BCS pre-calving than non-supplemented cows (Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009). Although the cows in this study were not supplemented, the cows consuming STF did have access to more nutrients during late gestation, reflecting an increased nutritional plane.

There were no forage system x year interactions ($P \geq 0.16$) or forage system main effects ($P \geq 0.33$) for prepartum RF changes overall or during either period (Table 2.2). These data are in agreement with previously reported data where there were no

differences in RF change overall in cows consuming STF during late gestation compared to cows consuming hay only in 1 yr of a 2-yr study (Meyer et al., 2009). Although there were no differences in RF, cows from both forage systems lost RF overall, likely due to the increased nutrient demands of gestation especially over winter. Cows also lost BCS overall, following the same pattern as BF. Despite loss in both BCS and RF overall, cows gained or maintained BW. Body weight gain likely did not follow the same pattern as BCS and RF because cows were gaining fetal weight rather than maternal weight during late gestation. Despite the lack of interaction or forage system effects, there was a year effect where cows in yr 2 lost more RF ($P \leq 0.05$) overall and during both periods. The average age of cows was decreased in yr 2, which likely contributed to the increased loss in RF.

After calving during yr 1, there were no differences ($P \geq 0.35$) in cow BW or BCS at the subsequent breeding or weaning (Table 2.3). These results are in agreement with similar research with late gestation cows consuming STF or hay over winter (Meyer et al., 2009). Cows grazed lush spring pasture before breeding which provided the necessary nutrients to negate any late gestation BW or BCS differences. Cow pregnancy rate was not affected ($P = 0.24$) by late gestation forage system in yr 1. Cows consuming STF during late gestation had a subsequent pregnancy rate of 95.7% (22 of 23) and cows consuming HAY had a pregnancy rate of 87.5% (21 of 24).

Calf Performance

There was not a forage system x year interaction for calf birth BW ($P = 96$), but calves born to cows consuming HAY during late gestation weighed less ($P = 0.03$) at birth than calves born to cow consuming STF (Table 2.4). Calves born to cows

consuming HAY likely had decreased fetal growth due to reduced nutrients available to the fetus during gestation, not allowing these calves to reach their genetic potential for fetal growth in utero. Cows consuming HAY during late gestation lost more BCS compared to cows consuming STF, suggesting that the HAY cows were not meeting the nutrient requirements of late gestation. Additionally, these calves could have had altered fetal development resulting in decreased organ size or function, which could have negative consequences on postnatal health and survivability. In our study, neither cow gestation length nor calf date of birth were impacted by late gestation forage system ($P \geq 0.18$; Table 2.4), indicating that birth BW differences in our study were not due to differences in gestation length or calf birth date relative to forage system initiation.

These results are in agreement with others reporting that maternal nutrient restriction during late gestation resulted in reduced offspring birth BW (Corah et al., 1975; Bellows and Short, 1978; Houghton et al., 1990; Freetly et al., 2005). Despite this, similar research utilizing STF versus hay during late gestation resulted in no differences in offspring birth BW despite improved BW and BCS in cows consuming STF during late (Meyer et al., 2009). Differences in results could have been influenced by cows being fed hay on pasture, allowing them access to higher quality residual forage and forage growth prior to parturition in the previous study (Meyer et al., 2009). Protein supplementation of cows consuming low protein forages during late gestation has also resulted in no change in calf birth BW as result of improved dam nutritional plane due to supplementation (Stalker et al., 2006; Martin et al., 2007; Funston et al., 2010). When comparing winter forage systems, Funston et al. (2010) reported a tendency for heavier heifer calves born to cows grazing corn residue during late gestation compared to cows

grazing winter range. Despite this, winter forage system did not impact birth BW of bull calves (Larson et al., 2009). The impact of maternal nutrition during late gestation on offspring birth BW has had conflicting results, potentially dependent on severity and length of restriction, breed of cattle, and nutrient source.

Adjusted 80-d calf BW tended ($P = 0.08$) to be affected by the forage system x year interaction (Table 2.4). In yr 1 effects of maternal forage system on birth BW continued through 80 d of age, and calves born to cows consuming HAY tended ($P = 0.06$) to weigh less than calves born to cows consuming STF. Despite this, there were no differences ($P = 0.52$) in calf adjusted 80-d BW in yr 2. The fact that calves born to HAY cows in yr 2 did not follow the same trend as yr 1 could be due to increased nutrient value of the HAY in yr 2. Additionally, spring pasture in yr 2 may have provided calves more nutrients, allowing them to reach comparable BW by 80 d of age. Freetly et al. (2000) reported similar results to yr 2 of our study, where calves born to cows restricted in both mid- and late gestation weighed less at birth and d 28 of age, but at d 58 of age there were no differences in calf BW. It is important to note that in Freetly et al. (2000) cows were losing BCS during mid- and late gestation and then fed to regain BCS after the first 28 d of lactation, which is different from our model where all cows were treated similarly after parturition. Lack of calf differences on d 56 of age could be a function of increased nutrients provided to cows that were restricted during both mid and late gestation compared to counterparts (Freetly et al., 2000). In the current study, there tended ($P = 0.06$) to be an interaction for calf ADG from birth through 80 d of age, but no differences ($P \geq 0.13$) were observed between forage systems within year (Table 2.4). The lack of ADG differences suggests that milk production was not altered by late

gestation forage system in our study. Radunz et al. (2010) reported no differences in milk production of cows due to dietary energy source (hay, limit-fed corn, or limit-fed dried distillers grains with solubles) during late gestation. These data are in opposition to Freetly et al. (2000) where calves born to cows restricted in mid- and late gestation had an increased ADG from d 28 to 58 of age compared to calves born to control cows or cows only restricted in mid-gestation. Again, cows restricted during mid and late gestation were fed to gain BCS after the first 28 d of lactation which could have contributed to increased ADG in those calves from d 28 to 58 of age. These data suggest that calves with decreased birth BW as result of decreased maternal nutrition may be smaller at 80 d of age or less when compared to calves born to cows consuming an improved diet, but further research is necessary given previous research and the lack of differences in yr 2.

At weaning (yr 1 only thus far) there were no differences in calf BW adjusted to average age at weaning (d 225; $P = 0.43$) or for 205-d adjusted BW ($P = 0.37$) when using the Beef Improvement Federation's calculation that corrects for dam age and calf sex (Table 2.4). This indicates that potential differences in milk production due to cow age did not change the interpretation of the results. Numerically, calves born to cows consuming STF during late gestation in yr 1 were 8 kg heavier at weaning than calves born to cows consuming HAY; thus, differences in birth BW were not negated in yr 1. Previous work researching CP supplementation of cows grazing low protein forages during late gestation resulted in increased weaning BW of offspring despite lack of differences in birth BW (Stalker et al., 2006; Martin et al., 2007). Similar STF research reported no difference in weaning BW of calves born to cows consuming STF or cows

consuming hay only during late gestation (Meyer et al., 2009). Additionally, our data are in agreement with data reported by Freetly et al. where cows nutrient restricted during mid- and late gestation had lighter calves at birth but no differences in calf weaning BW (Freetly et al., 2000).

Forage system did not affect ($P \geq 0.59$) calf ADG from birth through weaning or d 80 through weaning. This lack of differences in ADG provides support that cow milk production through weaning was not impacted by prepartum forage system. In opposition, calves born to cows consuming low protein forage during late gestation and supplemented with CP had increased ADG compared to calves born to cows that were not supplemented during late gestation (Stalker et al., 2006; Larson et al., 2009).

CONCLUSION

In summary, cows consuming HAY during late gestation lost more BCS prepartum than cows consuming STF. Calves born to cows consuming HAY during late gestation weighed less at birth in both years and tended to weigh less at 80 d of age in yr 1. Results of this study indicate that grazing STF during late gestation increases nutrients provided to cows and allows for normal fetal growth in calves, making STF a better option than summer-baled tall fescue hay alone to feed to spring-calving cows over winter.

Table 2.1. Nutrient composition, digestibility, and yield of stockpiled tall fescue and tall fescue hay offered to beef cows during late gestation in both years

Variable	STF ¹ , yr 1	HAY ² , yr 1	STF ¹ , yr 2	HAY ² , yr 2
DM, %	45.5	91.5	44.7	85.7
DM basis				
CP, %	12.1	6.2	12.4	7.6
NDF, %	61.4	64.9	66.4	68.3
ADF, %	33.4	36.6	37.8	38.3
Ash, %	8.5	9.7	13.7	9.0
IVTD ³ , %	61.4	59.4	64.1	57.7
Estimated DMI, kg/d	11.4	11.6	12.0	13.1
Yield, kg/ha	4,668	--	5,622	--
Forage utilization, %	80.4	--	70.8	--

¹Average STF includes pre-grazing forage samples from all 4 pastures throughout the study in each year.

²Average HAY includes core samples collected from each hay bale prior to feeding.

³In vitro true digestibility.

Table 2.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on prepartum cow performance in both years

Variable	Forage system ¹			P-values		
	STF	HAY	SEM	Forage system	Year	Forage system x year
BW, kg						
Initial BW	663	664	11	0.96	0.04	0.78
BW change period ² 1	-0.2	15.8	1.7	<0.001	0.02	0.002
yr 1	2.4 ^{bc}	5.6 ^b	2.5	--	--	--
yr 2	-2.7 ^c	26.0 ^a	2.4	--	--	--
BW change period 2	17.3	3.0	2.5	0.006	0.001	0.90
BW change overall	17.1	18.8	3.1	0.70	< 0.001	< 0.001
yr 1	9.3 ^c	-1.2 ^c	4.5	--	--	--
yr 2	24.8 ^b	38.9 ^a	4.4	--	--	--
BCS ³						
Initial BCS	5.7	5.7	0.1	0.82	0.07	0.38
BCS change period 1	0.12	-0.12	0.04	0.005	0.13	0.15
BCS change period 2	-0.19	-0.24	0.06	0.53	0.003	0.91
BCS change overall	-0.07	-0.36	0.05	0.01	0.01	0.29
RF ⁴ , cm						
Initial RF	0.77	0.72	0.04	0.41	0.22	0.71
RF change period 1	-0.16	-0.12	0.02	0.33	0.05	0.38
RF change period 2	-0.66	-0.60	0.05	0.50	< 0.001	0.19
RF change overall	-0.21	-0.25	0.03	0.38	0.02	0.16

^{a,b,c} Interactive means within item lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at $d 188 \pm 2$ of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum for management together through weaning.

²Period 1: d 0 to 35 of study; Period 2: d 36-78 of study.

³Body condition scores evaluated on a 1 to 9 scale, where 1 = emaciated and 9 = obese.

⁴12th rib fat thickness.

Table 2.3. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on postpartum cow performance

Variable	Forage system ¹			P-value		
	STF	HAY	SEM	Forage system	Year	Forage system x year
Breeding ²						
BW, kg	596	590	10	0.66	0.19	0.39
BCS ³	5.2	5.2	0.1	0.73	0.76	0.82
Weaning ⁴						
BW, kg	607	596	13	0.56	--	--
BCS	5.5	5.4	0.1	0.52	--	--

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at d 188 ± 2 of gestation and all cows remained in respective forage systems through calving until moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum. Cow-calf pairs were then managed together through weaning.

²May 1, 2014 and May 8, 2015.

³Body condition scores evaluated on a 1 to 9 scale, where 1 = emaciated and 9 = obese.

⁴Only 1 yr of data collection has occurred thus far.

Table 2.4. Effects of feeding stockpiled tall fescue versus fescue hay during late gestation on calf BW and performance through weaning

Variable, kg	Forage system ¹			P-values		
	STF	HAY	SEM	Forage system	Year	Forage system x year
Birth BW	38.2	34.6	0.9	0.03	0.94	0.96
Date of birth, d of study	98.2	95.2	2.5	0.43	0.45	0.86
Cow gestation length ² , d	283	281	0.9	0.18	0.20	0.97
Adjusted 80 d BW	131	127	3	0.30	0.11	0.08
yr 1	130 ^a	119 ^b	4	--	--	--
yr 2	131 ^a	134 ^a	4	--	--	--
ADG, birth to d 80	1.15	1.15	0.03	0.89	0.09	0.06
yr 1	1.15 ^{ab}	1.05 ^b	0.05	--	--	--
yr 2	1.16 ^{ab}	1.24 ^a	0.05	--	--	--
Adjusted 225-d BW ³	254	246	7	0.43	--	--
BIF ⁴ Adjusted 205-d BW	239	231	6	0.37	--	--
ADG, d 80 to 225 ³	0.88	0.87	0.02	0.84	--	--
ADG, birth to d 225 ³	0.96	0.94	0.03	0.59	--	--

^{a,b}Interactive means within item lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at d 188 ± 2 of gestation and all cows remained in respective forage systems through calving until moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum. Cow-calf pairs were then managed together through weaning.

²Fixed-time AI bred cows in both yr.

³Average age of calves at weaning on October 2, 2014. Only yr 1 of calf weaning BW and ADG through weaning has occurred thus far.

⁴Beef Improvement Federation.

CHAPTER 3

Prewaning calf circulating metabolites and hormones in a tall fescue forage system model of developmental programming

ABSTRACT

We hypothesized that cows grazing stockpiled tall fescue (STF) during late gestation would have greater nutrient intake than cows fed summer-baled tall fescue hay, which would result in increased prenatal nutrient supply and ultimately improved fetal development, early neonatal calf vigor, and preweaning metabolic status. Multiparous, spring-calving, crossbred beef cows (yr 1: $n = 48$; initial BW = 678 ± 12 kg, initial BCS = 5.8 ± 0.1 , age = 5.7 ± 0.3 yr; yr 2: $n = 56$, initial BW = 640 ± 10 kg, initial BCS = 5.6 ± 0.1 , age = 4.9 ± 0.4 yr) were allocated to 1 of 2 forage systems during late gestation: endophyte-infected STF pasture or endophyte-infected tall fescue hay (HAY) beginning on d 188 ± 2 of gestation. Cows remained in their respective forage systems until calving, but STF cows were moved to drylots approximately 8.5 d pre-calving and fed harvested forage with similar nutrient composition to STF. Within 1 wk post-partum, all cow-calf pairs were moved to a common pasture through weaning. At 48 h, 80 d, and weaning (225 d), calf jugular blood samples were obtained for analysis. Data were analyzed using a mixed model containing fixed effects of forage system, year, and their interaction. Pasture or drylot was the experimental unit; calf date of birth and sex were included in the model when $P < 0.25$. We previously reported that calves born to cows consuming STF weighed more at birth than HAY calves. Despite this, in yr 2 there were no differences ($P \geq 0.14$) in calf vigor at birth or triiodothyronine, thyroxine, or cortisol concentrations (both yr) at 48 h of age. Calf serum creatinine and albumin were greater

($P \leq 0.05$) in yr 2 for calves born to cows consuming STF. At 48 h postnatally there was a forage system x year interaction ($P = 0.01$) for both branched chain and total essential AA where in yr 1 calves born to cows consuming STF had greater ($P = 0.02$) or tended ($P = 0.06$) to have greater concentrations of total branched chain AA and total essential AA, respectively, than HAY. Despite this, HAY calves tended to ($P = 0.06$) or had greater ($P = 0.02$) concentrations of branched chain and total essential AA in yr 2. There tended ($P = 0.08$) to be a forage system x day interaction for blood urea nitrogen (BUN) concentration during yr 1 where BUN were greater at 48 h for calves born to cows consuming STF compared to HAY, but not at d 80 or 225. Additionally, calf plasma glucose concentrations tended ($P = 0.08$) to be greater for calves born to STF cows through weaning in yr 1. In conclusion, grazing stockpiled tall fescue in late gestation appears to improve fetal growth and alter perinatal nutrient supply in calves.

INTRODUCTION

Maximizing weaning weight and number of calves surviving until weaning is of great economic value for cow-calf producers, especially those who sell their calf crop at weaning. Over 50% of calf death loss occurs during the first 2 d of life (Kroger et al., 1967), and there is an increase in mortality for weak or small calves, especially throughout the winter months (Martin et al., 1975). Research has shown that maternal CP restriction beginning on d 190 of gestation reduces the ability of calves to maintain body temperature if born during cold conditions (Carstens et al., 1987) and that increased maternal nutrition during late gestation can have positive effects on calf performance through weaning (Stalker et al., 2006; Martin et al., 2007; Larson et al., 2009). These data are examples of developmental programming, or the theory that the maternal

environment, which is affected by maternal nutrition and other factors, impacts fetal development and can have lasting effects on the calf postnatally (Barker et al., 1993; Reynolds et al., 2010).

In the lower Midwest it is common for cow-calf producers to feed poor quality summer-baled hay over winter to late gestation spring-calving beef cows. During this time, cows are also experiencing cold stress that further increases their nutrient requirements, and grain-based supplementation to meet these demands may not be used due to increased costs. An alternative to feeding hay is to stockpile tall fescue pastures, which results in forage that is higher quality than most summer-baled hay commonly fed over winter (Kallenbach et al., 2003). We hypothesized that cows grazing stockpiled tall fescue during late gestation would have increased nutrient intake compared with cows fed summer-baled hay, which would result in improved fetal development, early neonatal calf vigor, and preweaning metabolic status.

MATERIALS AND METHODS

The University of Missouri Animal Care and Use Committee approved animal care and use in this study.

Animal Management and Forage Systems

A 2-yr late gestation study was conducted at the University of Missouri Beef Research and Teaching Farm utilizing multiparous, spring-calving, crossbred beef cows (yr 1: n = 48, initial BW = 678 ± 12 [SEM throughout] kg, initial BCS = 5.8 ± 0.1 , initial age = 5.7 ± 0.3 yr; yr 2: n = 56, initial BW = 640 ± 10 kg, initial BCS = 5.6 ± 0.1 , initial age = 4.9 ± 0.4 yr). Cows were allocated by BW, BCS, age, service sire (n = 4), and

expected calving date (AI due date: yr 1 = February 8, 2014; yr 2 = February 7, 2015) to 1 of 2 forage systems during late gestation (Table 2.1): endophyte-infected stockpiled tall fescue pasture (**STF**) or endophyte-infected tall fescue hay (**HAY**). There were 4 replications (pens or pastures) per forage system, and the study was initiated on November 15, 2013 (yr 1) and November 14, 2014 (yr 2) at $d 188 \pm 2$ of gestation. Cow-calf pairs were managed together from 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum through weaning.

The spring prior to the study's initiation in both years, estrus was synchronized and cows were artificially inseminated using a fixed-time AI 7-day co-sync + controlled internal drug release device protocol. Cows were exposed to bulls (≤ 50 cows per bull) beginning 10 d after AI, resulting in a calving season of 46 d in yr 1 and 79 d in yr 2.

Endophyte-infected tall fescue-based pastures (approximately 4.05 ha each) were used to stockpile the fall growth of forage for the STF forage system. In mid-August of each year, 45 kg of N/ha (as ammonium nitrate) were applied to previously grazed pastures, and pastures were allowed to accumulate forage until study initiation in each year. Stockpiled tall fescue pastures were strip-grazed using electric polytape and lightweight step-in posts. A new strip of forage was allocated approximately every 3.5 d (2x/wk) with a goal utilization of 75 to 80% of available forage. When weather conditions such as excessive ice or snow prevented grazing, cows consuming STF were fed rye haylage (yr 1: 59.7% NDF, 36.6% ADF, 12.3% CP; yr 2: 54.4% NDF, 29.6% ADF, 15.1% CP; all DM basis) until conditions improved. Rye haylage had similar nutrient composition to STF, making it a viable substitution for STF. Feeding rye haylage was necessary for 17 d (8 d prior to the beginning of calving) in yr 1 and 0 d in yr 2 while

cows were grazing STF pasture. At 7.0 ± 1 d (yr 1) and 8.5 ± 0.9 d (yr 2) prior to parturition, cows grazing STF were moved in groups to dry lots adjacent to HAY pens and fed rye haylage to ensure calves born to cows from either forage system were treated similarly postnatally.

Summer-baled, endophyte-infected tall fescue-based grass hay was fed ad libitum in round bale rings with cone chains for the HAY forage system. Hay was baled into round bales and stored in a barn prior to use. Cows were confined in 18 x 61 m uncovered dry lots that were well-drained, limestone-based, and contained a 9.1 x 9.1 m concrete pad where hay was fed to prevent excessive mud accumulation around the feeders. When the quantity of hay remaining in a feeder appeared to be limiting within 24 h, a new hay bale was weighed and core sampled for nutrient analysis before feeding. Cows in both forage systems had ad libitum access to water and were allowed a mineral and vitamin supplement (Gold Star® MFA Breeder 12 Mineral: MFA, Columbia, MO) to provide the recommended $2 \text{ oz} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$, with additional salt to limit intake when necessary.

Forage Measurements

Each STF pasture was sampled 3 times in yr 1 (d -7, 62, and 131 of grazing) and 4 times (d 5, 29, 62, and 119 of grazing) during yr 2. Pre-grazing samples collected on d -7 and 62 of yr 1 as well as d 5, 29, and 62 of yr 2 were used to determine pre-grazing forage yield and quality during late gestation. Post-grazing samples collected on d 62 and 131 of yr 1 as well as d 29, 62, and 119 of yr 2 were used to determine post-grazing forage yield and quality. Our goal was to sample STF pastures every 30 d, but snow and ice accumulation prevented timely sampling (especially in yr 1). At sampling, pre- and

post-grazing forage samples were collected before and after each pasture section was offered to cows. Samples were collected using a flail-type harvester pulled by a tractor (Curtis and Kallenbach, 2007). Ten random 0.8 x 4.6 m sample strips were clipped to a height of 2 cm before each new section was offered to determine the pre-grazing nutrient composition and forage yield (Curtis and Kallenbach, 2007). The clipped sections were weighed and subsampled for nutrient analysis. Post-grazing samples of grazed sections were taken in the same manner as pre-grazing samples to estimate forage disappearance and grazing residue nutrient composition. Cow estimated DMI was calculated as the difference in the pre-grazing and post-grazing forage yield using pasture area and grazing days for STF. Estimated DMI of HAY was calculated as total bale weight divided by total number of animals. Waste was estimated to be 18% using results from similar hay feeders (Moore and Sexten, 2015). Pasture utilization was calculated as percentage of forage disappearance $[(\text{pre-grazing DM yield} - \text{post-grazing DM yield})/\text{pre-grazing yield}] \times 100$. In yr 1 estimated DMI was $11.6 \text{ kg} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$ of HAY and $11.4 \text{ kg} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$ of STF. During yr 2 estimated DMI was $13.1 \text{ kg} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$ and $12.0 \text{ kg} \cdot \text{animal}^{-1} \cdot \text{d}^{-1}$ of HAY and STF respectively.

Both hay core samples and clipped STF samples were first dried in a 55°C oven for a minimum of 48 h. Samples were then ground through a 5 mm screen, followed by a 2 mm screen using a Thomas Wiley Mill (Thomas Scientific, Swedensboro, NJ), and finally ground through a 1 mm screen using a Cyclotec sample mill (Model 1093, CyclotecTM TecatorTM, Höganäs, Sweden). Neutral detergent fiber and ADF were sequentially analyzed using an ANKOM Fiber Analyzer (Model 200, ANKOM Technology Corp., Fairport, NY). In vitro true digestibility (**IVTD**) was determined by a

48-h in vitro digestion followed by washing with NDF solution as described by Ankom Technology (Daisy Incubator, ANKOM Technology Corp., Fairport, NY). Nitrogen content of forages was determined by thermoconductivity using an Elementar Nitrogen Analyzer (Vario Macro Cube, Elementar Americas, Mt. Laurel, NJ) and used to calculate CP ($N \times 6.25$). To determine total DM, samples were dried in a 105°C oven for 24 hours, then put into a 500°C oven for 16 h to determine ash content. During yr 2, STF and HAY samples were freeze-dried for analysis of ergovaline concentration (Rottinghaus et al., 1991; Hill et al., 1993). In the STF, ergovaline concentrations ranged from <25 parts per billion to 140 parts per billion in December and from 30 to 120 parts per billion in January. The ergovaline concentration in HAY was 25 parts per billion.

Postnatal Sample and Data Collection

Cows were closely monitored during calving in both years. A trained individual was present throughout the calving season for observation of cows showing signs of labor and to record calf time of birth (yr 1 and 2), first standing time (yr 2), and first suckling time (yr 2). Standing was defined as the newborn calf standing on all 4 legs for at least 5 s consecutively, and suckling was defined as the newborn calf suckling its dam's teat for at least 5 consecutive seconds. These measurements were chosen as objective measurements to quantify calf vigor in AI sired calves during yr 2 (Dwyer, 2003). Within 8 h of birth, calves were weighed, tagged, and sex was determined.

Jugular blood samples were collected at ≥ 48 h of age to ensure passive transfer (>48 h was used when sampling at 48 h was not possible or exact time of birth was not known). Actual sampling times were 52 ± 0.6 h (yr 1) and 50 ± 0.5 h (yr 2) postnatally. At this time, blood samples were collected into 4 blood collection tubes (2 Vacutainer®

serum collection tubes with no additive [10 mL draw; Becton, Dickinson, and Co., Franklin Lakes, NJ), 1 Monoject™ plasma collection tube containing 0.10 mL of 15% K₃ EDTA liquid [10 mL draw; Covidien, Mansfield, MA], and 1 Vacutainer® plasma collection tube for glucose determination containing 15 mg of sodium fluoride and 12 mg of potassium oxalate [6 mL draw; Becton, Dickinson, and Co., Franklin Lakes, NJ]. Plasma tubes were immediately placed on ice and serum tubes were allowed to clot before being placed on ice. Samples were centrifuged within 4 h of collection at 1500 x g for 30 min at 4°C, and either plasma or serum was pipetted into 2 mL microcentrifuge tubes and stored at -20°C for future analysis. Additionally, at approximately 80 d of age (yr 1, 82.7 ± 1.0 d; yr 2, 85.6 ± 1.1 d) and at weaning (yr 1, 225.8 ± 2.1 d), jugular blood samples were obtained from calves and processed in the same manner. To reduced age variation, calves were split into 2 groups based on conception date (AI or natural service) and calf jugular samples were collected on 2 separate dates when average calf age was approximately 80 d in each group.

Chemistry Profile, Metabolite, and Hormone Analyses

Calf serum collected at 48 h in yr 2 was transported without freezing to the University of Missouri Veterinary Medical Diagnostic Laboratory, where a Beckman Coulter AU 400e Chemistry System (Beckman Coulter Inc., Brea, CA) was used to determine creatinine, sodium, chloride, bicarbonate, anion gap, albumin, total protein, globulin, calcium, phosphorus, magnesium, total bilirubin, direct bilirubin, aspartate aminotransferase, gamma-glutamyl transpeptidase, and creatine kinase concentrations. Samples were analyzed on the day of collection, except on evenings or weekends when samples were refrigerated until analysis.

Serum triiodothyronine (**T₃**) and thyroxine (**T₄**) concentrations were determined in 48-h serum samples using an Immulite 1000 (Siemens, Los Angeles, CA) and commercially available kits (Cat. #LKT31 [**T₃**] and LKT41 [**T₄**]; Siemens, Los Angeles, CA) following the procedures given by the manufacturer. The intraassay and interassay CV were 8.84% and 9.45%, respectively, for **T₃** and 5.80% and 9.73%, respectively, for **T₄**. Serum cortisol concentration was determined in 48-h samples by chemiluminescence immunoassay using an Immulite 1000 (Siemens, Los Angeles, CA) and components of commercial kits (Cat. #LKCO1; Diagnostic Products Corp., Los Angeles, CA). The intraassay CV was 7.21% and the interassay CV was 2.55%. All serum hormone analyses were performed in duplicate.

Circulating AA concentrations were determined in 48-h calf plasma samples by ultra performance liquid chromatography (UPLC) using an Aquity UPLC System and solution kit with methods previously described (Lemley et al., 2013).

Blood urea nitrogen (**BUN**) concentration was determined in 48 h, 80 d, and weaning (yr 1 only) calf serum samples using a commercially available urea nitrogen kit (Stanbio Urea Nitrogen Procedure No. 0580, Stanbio Laboratory, Boerne, TX) based on the diacetylmoxime method. Glucose concentration was determined in 48 h, 80 d, and weaning (yr 1 only) calf plasma utilizing a commercially available glucose kit (InfinityTM Glucose, Fisher Diagnostics, Middletown, VA). Samples were read in 96-well plates on a microplate reader (Biotek SynergyTM HT, Biotek® Instruments inc., Winooski, Vt) at 520 (BUN) or 340 (glucose) nm. The average intraassay and interassay CV were 3.12% and 4.87% respectively for BUN and 3.43% and 3.17% for glucose.

Statistical Analysis

Cows were removed from the study due to failure to calve (yr 1: n = 1; yr 2: n = 1), twin pregnancy (yr 2: n = 1), calving prematurely (yr 2: n = 1), or calving outside of a 60-d calving window (yr 2: n = 3), resulting in 47 cows included in yr 1 and 50 cows in yr 2. Cows with calving difficulties were included in prepartum data analysis, but stillborn calves or those that died soon after birth were excluded after birth weight data analysis (yr 1: n = 1; yr 2; n = 2) resulting in 46 calves in yr 1 and 48 calves in yr 2.

Data were analyzed using the MIXED procedure in SAS (SAS version 9.3, SAS Inst. Inc., Cary, NC, USA) with late gestation pasture or drylot as the experimental unit. Forage system was a fixed effect, and when 2 yr of data were analyzed, forage system, year, and their interaction were considered fixed effects. Calf date of birth and sex were also included in the model as fixed effects if $P < 0.25$. Calf metabolites sampled through weaning were analyzed using sampling day as a repeated measure with compound symmetry covariance structure. Main effects of year were not of interests, so these will not be discussed.

RESULTS AND DISCUSSION

It was previously reported that calf birth weight was impacted by late gestation forage system where calves born to cows consuming STF during late gestation weighed more ($P = 0.03$) at birth than calves born to cows consuming HAY (Table 3.2). Despite this, there were no differences ($P \geq 0.18$) in gestation length or calf date of birth (Table 3.2). Many postnatal measurements were obtained to help explain the impact of late gestation maternal nutrition on calf metabolic status and performance through weaning.

Calf Vigor

Calf vigor after birth is essential, especially in a spring-calving herd where cold temperatures can negatively affect calf survival. Previous research indicates colostrum intake is reduced in calves that are less vigorous (Vasseur et al., 2009), and it is imperative for calves to consume colostrum to achieve passive transfer of immunity and obtain vital nutrients.

During yr 2 calf vigor was assessed, and there were no differences ($P \geq 0.39$) in time to stand, time to suckle, or the interval between standing and suckling for calves born to cows consuming STF or HAY during late gestation (Table 3.2). These data are in opposition to previously reported data in sheep where lambs born to ewes with less mobilized back fat stood and suckled more quickly than lambs born to ewes mobilizing more back fat (Dwyer et al., 2003). Additionally, lambs born to ewes with less mobilized back fat were heavier at birth than their counterparts and heavier lambs were more active after birth (Dwyer et al., 2003). Previous results in sheep combined with our calf birth weight difference between forage systems could indicate that calf vigor at birth is not as sensitive to dam late gestation nutrition as lambs. The lack of differences in recorded times could also be due to changes in cow behavior from close monitoring near calving, despite our efforts to stay at a distance and out of the cow's sight.

Neonatal Calf Serum Chemistry Profile

When assessing calf serum chemical profile at 48 h of age in yr 2, serum creatinine concentrations were greater ($P = 0.05$) for calves born to cows consuming STF during late gestation compared to calves born to cows consuming HAY (Table 3.3). Creatinine is formed in the muscle by the dehydration of muscle creatine (Borsook et al.,

1947), therefore more muscle mass increases the amount of circulating creatinine (Perrone et al., 1992). Muscle cell type and number form from d 60 to d 240 of gestation in cattle (Russell and Otheruelo, 1981), with the majority of muscle cell proliferation occurring during mid-gestation (Du et al., 2010). Maternal nutrient restriction during late gestation has resulted in decreased muscle fiber size but not muscle fiber number (Greenwood et al., 1999). One potential explanation for observed creatinine results is that the calves born to the STF cows had increased muscle fiber number or size at birth compared to calves born to cows consuming HAY during late gestation. This could also be supported by the increased birth weight of calves born to STF cows, as greater muscle mass would lead to increased birth weight. Given the average d of gestation at the start of the study in yr 2 was 188 ± 2 , more of the increased creatinine levels is probably due to overall muscle fiber size rather than cell type or number.

Serum albumin concentrations were greater ($P = 0.04$) for calves born to cows consuming STF during late gestation compared to calves born to HAY cows. Albumin is important in maintaining homeostasis as it is an important buffer and carrier protein; it also binds molecules of many types such as long-chain fatty acids, steroids, calcium, and magnesium and acts in waste removal (Peters et al., 1996). Increased albumin concentrations in calves born to STF cows may improve calf nutrient transfer but more research is necessary to determine normal albumin levels in neonatal calves.

There were no differences ($P \geq 0.44$) in all other calf serum chemistry profile variables tested (Table 3.3). Bull et al. (1991) measured serum constituents during the first 72 h postpartum in calves born to heifers that were either limited in CP or ME during the last 150 d of gestation and reported no differences in circulating creatinine, total

protein, alkaline phosphatase, total bilirubin, and cholesterol in calves born to heifers from either treatment. Other than creatinine, our results are similar to previously reported serum constituents despite differences in maternal plane of nutrition during gestation.

Neonatal Calf Serum Cortisol and Thyroid Hormones

Although there tended ($P = 0.09$) to be a forage system x year interaction for calf T_3 concentrations at 48 h postnatally, there were no differences between forage systems within year (Table 3.3). There were no effects of forage system ($P \geq 0.14$) for T_4 , the ratio of T_3 to T_4 , or cortisol concentrations at 48 h postnatally.

Thyroid hormones play an important role in fetal development as well as energy metabolism (McNabb and King, 1993), and concentrations in the blood can be used as an indicator of available energy (Fowden and Forhead, 2004). It has been previously reported that lambs born to nutrient restricted dams (60% NRC requirements starting on d 40 of gestation) had decreased T_3 at birth but there were no differences in T_4 or cortisol concentrations when compared to lambs born to control ewes (Camacho et al., 2012). Despite this, lambs born to ewes exceeding their nutrient requirements had increased T_4 compared to lambs born to ewes restricted or consuming the control diet and decreased cortisol concentrations compared to lambs born to ewes restricted from d 40 of gestation through parturition (Camacho et al., 2012). Additionally, circulating T_3 , T_4 , and cortisol from d 3 to 19 were not affected by ewe nutrient intake. Although our data indicate no differences in thyroid hormone or cortisol concentrations due to dam late gestation forage system, this may be due to sampling time. We sampled blood from calves at 48 h postnatally, which was after colostrum consumption, and may have negated differences in hormone concentrations prenatally or at the time of birth. Additionally, although our

forage systems reflect increased (STF) and decreased (HAY) nutritional planes, potentially the calves born to HAY cows were not restricted enough to cause an extended decrease in hormone levels.

Neonatal Calf Plasma AA

There were many forage system x year interactions ($P \leq 0.04$) for individual, total, total essential, and branched chain calf plasma AA concentrations at 48 h postnatally (Table 3.5). Calves born to cows consuming STF during late gestation in yr 1 had greater ($P = 0.02$) plasma concentration of total branched chain AA than calves born to cows consuming HAY, but in yr 2 calves born to cows consuming HAY tended ($P = 0.06$) to have greater concentrations of branched chain AA than STF calves. Total essential AA concentrations followed a similar pattern where calves born to cows consuming STF in yr 1 tended ($P = 0.10$) to have greater concentrations of total essential AA than calves born to cows consuming HAY in yr 1. Despite this, in yr 2 calves born to cows consuming HAY had greater ($P < 0.04$) concentrations of total essential AA than calves born to cows consuming STF. Additionally, in yr 2 calves born to cows consuming HAY had greater ($P = 0.02$) concentrations of total AA than calves born to cows consuming STF, but in yr 1 there were no differences ($P = 0.13$) between forage systems.

When evaluating individual AA concentrations, calves born to cows consuming STF in yr 1 had greater ($P = 0.01$) plasma concentrations of glutamic acid and tended ($P = 0.07$) to have greater concentrations of isoleucine than HAY calves. Glutamic acid and isoleucine concentrations were not different ($P \geq 0.15$) between forage systems in yr 2. Calves born to cows consuming STF in yr 1 had greater ($P \leq 0.04$) concentrations of valine and leucine compared to calves born to cows consuming HAY, but in yr 2, valine

and leucine tended to be greater ($P \leq 0.07$) for calves born to cows consuming HAY than STF. In year 2, calf plasma concentrations of threonine, methionine, arginine, asparagine, and tyrosine were greater ($P \leq 0.03$) in calves born to cows consuming HAY than STF, but there were no differences ($P \geq 0.18$) in plasma concentrations of these AA between calves born from cows in either forage system in yr 1. Additionally, proline concentrations tended ($P = 0.06$) to be greater for calves born to cows consuming HAY in yr 2 compared to STF, with no differences ($P = 0.18$) in proline concentrations during yr 1. Plasma concentrations of glutamine tended ($P = 0.07$) to follow a similar pattern where calves born to HAY cows in yr 2 had greater ($P = 0.02$) glutamine concentrations than calves born to cows consuming STF in yr 2, but there were no differences ($P = 0.96$) in calves born to cows from either forage system during yr 1. The only main effect of forage system was a tendency ($P = 0.09$) for calf plasma concentration of lysine to be greater for calves born to cows consuming HAY than calves born to cows consuming STF. There were not any forage system ($P \geq 0.13$) effects for calf plasma concentrations of phenylalanine, tryptophan, histidine, serine, glycine, aspartic acid, or alanine at 48 h postnatally.

When expressed as a percentage of total AA (Table 3.6), there tended ($P = 0.08$) to be a forage system x year interaction for valine where calves born to cows consuming STF during yr 1 had greater ($P = 0.02$) valine than calves born to cows consuming HAY in yr 1, but there were no differences ($P = 0.93$) between forage systems in yr 2. Asparagine (% total AA) tended ($P = 0.07$) to have forage system by year interaction, where calves born to cows consuming HAY during yr 2 tended to have greater ($P = 0.08$) asparagine (% total AA) than calves born to cows consuming STF in yr 2, but there was

no effect ($P = 0.36$) of forage system in yr 1. When glycine was expressed as a percentage of total AA, there tended ($P = 0.08$) to be a forage system x year interaction, but when comparing calves within a year, there were no differences ($P \geq 0.11$) between forage systems. Branched chain AA (% total AA) tended ($P = 0.08$) to be greater for calves born to cows consuming STF than calves born to cows consuming HAY. Additionally, calves born to cows consuming STF had a greater ($P = 0.03$) percentage of glutamic acid when expressed as a percentage of total AA. Conversely, threonine tended ($P \leq 0.09$) to be greater and methionine was greater ($P = 0.005$) for calves born to cows consuming HAY than STF. There were no forage system effects ($P \geq 0.15$) for calf total essential AA or other individual AA when expressed as percentage of total AA.

When expressed as a percentage of total essential AA (Table 3.7), there tended ($P \leq 0.08$) to be a forage system x year interaction for total branched chain AA and valine, where in yr 1 calves born to cows consuming STF had a greater ($P = 0.01$) branched chain AA compared to HAY, but there was no effect ($P = 0.58$) of forage system in yr 2. Valine expressed as a percentage of total essential AA also had a forage system x year interaction ($P = 0.05$), where calves born to cows consuming STF had a greater ($P = 0.01$) percentage of valine than calves born to cows consuming HAY in yr 1, but there was no difference ($P = 0.80$) during yr 2. Leucine (% total essential AA) tended ($P = 0.09$) to be greater for calves born to cows consuming STF than HAY. In contrast, calves born to cows consuming HAY had greater ($P = 0.01$) threonine and tended to have greater ($P = 0.09$) methionine when expressed as a percentage of total essential AA. When phenylalanine, tryptophan, isoleucine, arginine, histidine, or lysine were expressed as a percentage of total essential AA, there was no effect ($P \geq 0.12$) of forage system.

Maternal AA are the primary source of nitrogen for a growing fetus and can be impacted by maternal nutrition during gestation (Regnault and Fredererick, 2003). They are an essential substrate for protein and regulate fetal and placental protein synthesis (Regnault et al., 2005). Amino acid delivery to the fetus for fetal growth is only possible through placental transfer from maternal to fetal blood (Battaglia and Regnault, 2001) and, in cattle, placental development starts early in gestation and growth increases progressively throughout gestation (Vonnahme et al., 2013). Therefore, in our study where nutritional differences were in late gestation, nutrients available to the dam could be impacting fetal circulating AA by altering AA concentration of blood flowing to the uteroplacenta.

Cows consuming STF during late gestation should have had increased circulating AA from increased nutrient intake due to increased CP and decreased NDF in STF compared to HAY, providing increased nutrients available to the fetus during this time. Branched chain AA are mainly used to build skeletal muscle, but also in the brain, kidneys, liver and heart and serve as an important energy substrate during physical activity and precursor for other important proteins and AA synthesis (Platell et al., 2000). Increased concentrations of branched chain AA and total essential AA in STF calves in yr 1 compared to HAY calves would be beneficial to offspring growth and development perinatally. The fact that the opposite happened in yr 2 is interesting. These results were not expected given cows grazing STF had access to forage with greater CP and reduced NDF in both yr. Additionally, many other AA, whether expressed as a concentration or percentage of total or total essential, are conflicting and do not give clear insight into how late gestation maternal nutrition impacted circulating AA perinatally in the current study.

By 48 h postnatally, circulating calf AA concentrations were no longer reflecting only AA available to the fetus because of colostrum consumption by the calf prior to the time of blood sampling. Previous research evaluating the impact of a maternal nutrient restriction to 50% of NRC recommendations from either d 28 to 78 or d 28 to 135 in sheep revealed nutritional restriction reduced plasma AA concentrations in the maternal and fetal plasma as well as in the fetal amniotic fluid at both mid and late gestation (Kwon et al., 2004). Despite this, there are little data researching how maternal nutrition during gestation influences offspring AA supply, especially postnatally. More research is necessary to determine average expected calf AA concentrations after birth and how maternal nutrition during late gestation affects AA during the perinatal period.

Prewaning Calf Circulating BUN and Glucose

There was a forage system x day interaction ($P = 0.06$) in yr 1 for BUN concentrations in calves (Figure 3.1). Calves born to cows consuming STF during late gestation had increased ($P = 0.007$) serum BUN concentrations at 48 h when compared to calves born to cows consuming HAY during late gestation. This data is in agreement with previously reported data where calves born to heifers restricted in CP or ME during the last 150 d of gestation had decreased BUN concentrations compared to calves born to cows offered adequate amounts of CP or ME (Bull et al., 1991). These data indicate that late gestation dam nutrition impacts perinatal nutrient supply. At 80 d of age and weaning (225 d of age) there were no differences ($P \geq 0.86$) in BUN concentrations between calves born to cows from either forage system, however. These data potentially indicate a lack of differences in milk nutrient composition or yield due to late gestation dam nutrition. Additionally, calves also had access to forage as a source of nutrients during

this time, which may have negated any late gestation effects. These data give a better indication of how BUN concentrations change over time in calves through weaning.

There was not ($P = 0.31$) a forage system x day interaction for plasma glucose, so only main effects will be discussed (Figure 3.2). Calves born to cows consuming STF during late gestation tended ($P = 0.08$; STF: 104.6 ± 2.0 ; HAY: 98.9 ± 1) to have increased plasma glucose concentrations compared to calves born to cows consuming HAY. There are little data published investigating plasma glucose concentrations in calves preweaning as result of maternal nutrition during late gestation. The tendency for increased plasma glucose levels in calves born to cows consuming STF could indicate that late gestation dam nutrition has lasting effects on calf metabolic status. Potentially the calves born to HAY cows had less glucose transport in the placenta or small intestine than calves born to cows consuming STF. Additionally calf plasma glucose concentrations decreased with age from 48 h to 225 d ($P < 0.001$; 48 h: 122.2 ± 2.2 ; 80 d: 98.2 ± 2.2 ; 225 d: 84.7 ± 2.2). Because lactose concentrations in milk decrease as lactation progresses (Barry and Rowland, 1953; Caffin et al., 1985), it is expected that calf glucose concentrations in blood over time follow the same pattern as lactose concentrations in milk. Additionally, calves have a functioning rumen and had access to forage, reducing absorbed glucose from the small intestine due to ruminal fermentation. More research is necessary to provide additional insight on the expected metabolic status of calves preweaning as well as the impact late gestation maternal nutrition has on plasma glucose in calves.

CONCLUSION

In conclusion, results of this study indicate that grazing STF during late gestation

impacts calf birth BW and may alter perinatal nutrient supply. Despite this, calf vigor was not affected by late gestation forage system and there were varying effects on calf plasma AA concentrations. More research is necessary to determine the expected calf metabolic status preweaning and the impact of late gestation maternal nutrition during the perinatal period.

Table 3.1. Nutrient composition, digestibility, and yield of stockpiled tall fescue and tall fescue hay offered to beef cows during late gestation in both years

Variable	STF ¹ ,yr 1	HAY ² ,yr 1	STF ¹ ,yr 2	HAY ² ,yr 2
DM, %	45.5	91.5	44.7	85.7
DM basis				
CP, %	12.1	6.2	12.4	7.6
NDF, %	61.4	64.9	66.4	68.3
ADF, %	33.4	36.6	37.8	38.3
Ash, %	8.5	9.7	13.7	9.0
IVTD ³ , %	61.4	59.4	64.1	57.7
Yield, kg/ha	4,668	--	5,622	--
Forage utilization, %	80.4	--	70.8	--

¹Average STF includes pre-grazing forage samples from all 4 pastures throughout the study in each year.

²Average HAY includes core samples collected from each hay bale prior to feeding.

³In vitro true digestibility.

Table 3.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf weight and vigor measures at birth during yr 2

Variable	Forage System ¹		SEM	P-value
	STF	HAY		
Birth BW, kg	38.2	34.6	0.9	0.03
Length of gestation ² , d	283	281	0.9	0.18
Day of birth, d of study	98.2	95.2	2.5	0.86
Time to stand ³ , min	29.2	30.2	5.5	0.90
Time to suckle ⁴ , min	46.3	45.5	8.8	0.95
Time from standing to suckling, min	12.3	16.1	4.2	0.39

¹Cows strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at d 188 ± 2 of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.6 ± 0.4 d postpartum for management together through weaning.

²Fixed-time AI bred cows in both yr.

³Standing was defined as a calf standing up on all 4 legs for at least 5 s consecutively.

⁴Suckling was defined as a calf suckling from a teat for at least 5 s consecutively.

Table 3.3. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation in yr 2 on calf serum chemistry profile at 48 h postnatally

Variable	Forage system ¹		SEM	P-value
	STF	HAY		
Creatinine, mg/dL	1.16	1.05	0.03	0.05
Sodium, mEq/L	138	138	0.5	0.81
Potassium, mEq/L	5.25	5.27	0.09	0.91
Calcium g/dL	11.5	11.4	0.1	0.52
Phosphorus, g/dL	7.56	7.69	0.14	0.50
Magnesium, mg/dL	2.15	2.20	0.08	0.62
Chloride, mEq/L	96.4	96.6	0.8	0.81
Bicarbonate, mEq/L	30.8	31.3	0.6	0.53
Anion Gap, mEq/L	16.6	15.7	0.8	0.44
Albumin, g/dL	2.35	2.24	0.03	0.04
Total protein, g/dL	6.74	6.77	0.24	0.94
Globulin, g/dL	4.42	4.53	0.25	0.75
Total bilirubin, mg/dL	0.434	0.422	0.063	0.89
Direct bilirubin, mg/dL	0.170	0.163	0.028	0.86
Aspartate aminotransferase, U/L	43.8	46.4	4.2	0.67
Gamma-glutamyl transpeptidase, U/L	507	491	69	0.87
Creatine kinase, U/L	93.9	100	20.6	0.84

¹Cows strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at d 188 ± 2 of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.6 ± 0.4 d postpartum for management together through weaning. Average age of calf at blood collection was 50 ± 0.5 h.

Table 3.4. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf serum cortisol, triiodothyronine (T₃), and thyroxine (T₄) concentrations at 48 h postnatally

Variable	Forage system ¹			P-value		
	STF	HAY	SEM	Forage system	Year	Forage system x year
T ₃ , ng/dL	732	730	27	0.96	0.09	0.09
yr 1	811 ^a	729 ^{ab}	39	--	--	--
yr 2	654 ^b	732 ^{ab}	40	--	--	--
T ₄ , µg/dL	12.1	12.0	0.5	0.83	0.33	0.17
T ₃ :T ₄	61.9	62.9	2.5	0.79	0.59	0.96
Cortisol µg/dL	2.77	2.19	0.24	0.14	0.85	0.32

^{a,b}Interactive means within rows or columns lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at $d 188 \pm 2$ of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum for management together through weaning. Average calf age at blood collection was 52 ± 0.6 h (yr 1) and 50 ± 0.5 h (yr 2).

Table 3.5. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma AA concentrations 48 h postnatally

AA, $\mu\text{mol/L}$	Forage system ¹			P-value		
	STF	HAY	SEM	Forage system	Year	Forage system x year
Phenylalanine	62.0	64.3	2.4	0.52	0.002	0.84
Valine	452	435	20	0.56	0.54	0.01
yr 1	510 ^a	394 ^b	29	--	--	--
yr 2	393 ^b	475 ^a	28	--	--	--
Threonine	137	169	9	0.01	0.09	0.04
yr 1	134 ^b	142 ^b	13	--	--	--
yr 2	140 ^b	196 ^a	12	--	--	--
Tryptophan	46.1	44.8	2.0	0.65	0.05	0.17
Isoleucine	139	135	6	0.67	0.04	0.03
yr 1	161 ^a	138 ^b	9	--	--	--
yr 2	117 ^b	133 ^b	9	--	--	--
Methionine	46.9	55.4	3.3	0.04	0.13	0.04
yr 1	46.4 ^b	46.2 ^b	4.7	--	--	--
yr 2	47.3 ^b	64.6 ^a	4.7	--	--	--
Histidine	250	266	11	0.34	0.42	0.18
Arginine	228	244	14	0.41	0.13	0.02
yr 1	237 ^{ab}	197 ^b	21	--	--	--
yr 2	219 ^b	292 ^a	21	--	--	--
Lysine	156	174	9	0.09	0.99	0.14
Leucine	205	202	9	0.78	0.70	0.01
yr 1	222 ^a	180 ^b	13	--	--	--
yr 2	189 ^b	224 ^a	13	--	--	--
Asparagine	100	117	12	0.19	0.02	0.02
yr 1	87.5 ^{bc}	65.9 ^c	16.7	--	--	--
yr 2	113 ^b	169 ^a	16	--	--	--
Serine	139	141	9	0.83	0.35	0.11
					<	
Glutamine	580	688	36	0.07	0.001	0.07
yr 1	264 ^c	261 ^c	53	--	--	--
yr 2	896 ^b	1,116 ^a	52	--	--	--
Glycine	309	326	18	0.52	0.41	0.89
Aspartic acid	13.6	11.5	0.9	0.13	<0.001	0.17
Glutamic acid	245	201	14	0.05	0.00	0.03
yr 1	356 ^a	258 ^b	21	--	--	--
yr 2	135 ^c	144 ^c	20	--	--	--
Alanine	260	272	10	0.36	0.13	0.11
Proline	339	357	25	0.61	0.72	0.03
yr 1	379 ^{ab}	303 ^b	37	--	--	--

yr 2	298 ^b	412 ^a	36	--	--	--
Tyrosine	87.0	96.8	6.7	0.16	0.02	0.01
yr 1	78.4 ^{bc}	66.4 ^c	9.7	--	--	--
yr 2	95.6 ^b	127.3 ^a	9.6	--	--	--
Total branched						
chain AA	797	774	33	0.60	0.47	0.01
yr 1	897 ^a	713 ^{bc}	47	--	--	--
yr 2	698 ^c	835 ^{ab}	48	--	--	--
Total essential AA	1,723	1,788	68	0.44	0.50	0.01
yr 1	1,826 ^{ab}	1,605 ^c	99	--	--	--
yr 2	1,620 ^{bc}	1,971 ^a	98	--	--	--
Total ² AA	3,800	3,996	152	0.32	0.02	0.01
yr 1	3,735 ^{bc}	3,276 ^c	220	--	--	--
yr 2	3,865 ^b	4,715 ^a	218	--	--	--

^{a,b,c}Interactive means within item lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at $d 188 \pm 2$ of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum for management together through weaning. Average calf age at blood collection was 52 ± 0.6 h (yr 1) and 50 ± 0.5 h (yr 2).

²Does not include cysteine.

Table 3.6. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma AA expressed as a percentage of total AA at 48 h postnatally

AA, % of total AA ²	Forage system ¹			P-value		
	STF	HAY	SEM	Forage system	Year	Forage system x year
Phenylalanine	1.65	1.67	0.10	0.90	0.26	0.15
Valine	11.8	11.0	0.3	0.06	< 0.001	0.08
yr 1	13.6 ^a	12.0 ^b	2.5	--	--	--
yr 2	10.1 ^c	10.0 ^c	2.3	--	--	--
Threonine	3.57	4.26	0.12	0.005	0.49	0.46
Tryptophan	1.22	1.15	0.05	0.34	0.59	0.32
Isoleucine	3.67	3.49	0.09	0.20	< 0.001	1.00
Methionine	1.24	1.38	0.05	0.09	0.96	1.00
Histidine	3.67	3.90	0.15	0.30	< 0.001	0.16
Arginine	5.97	6.07	0.26	0.80	0.51	0.25
Lysine	4.15	4.43	0.18	0.21	0.02	0.13
Leucine	5.37	5.12	0.12	0.19	0.00	0.33
Asparagine	2.61	2.81	0.21	0.47	0.02	0.07
yr 1	2.35 ^{bc}	1.97 ^c	0.31	--	--	--
yr 2	2.87 ^b	3.65 ^a	0.31	--	--	--
Serine	3.64	3.57	0.11	0.67	0.04	0.58
Glutamine	15.2	15.9	0.8	0.51	< 0.001	0.90
Glycine	8.22	8.58	0.49	0.60	0.02	0.08
yr 1	8.63 ^{ab}	10.45 ^a	0.71	--	--	--
yr 2	7.80 ^b	6.71 ^b	0.70	--	--	--
Aspartic acid	0.37	0.32	0.02	0.16	< 0.001	0.71
Glutamic acid	6.53	5.40	0.28	0.03	< 0.001	0.15
Alanine	6.99	6.91	0.21	0.79	0.08	0.12
Proline	8.88	8.80	0.37	0.89	0.02	0.16
Tyrosine	2.28	2.36	0.13	0.57	0.05	0.39
Branched chain AA	20.8	19.6	0.4	0.08	< 0.001	0.16
Total essential AA	45.3	45.4	0.6	0.97	< 0.001	0.85

^{a,b,c} Interactive means within rows or columns lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at $d 188 \pm 2$ of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum for management together through weaning. Average calf age at blood collection was 52 ± 0.6 h (yr 1) and 50 ± 0.5 h (yr 2).

²Does not include cysteine.

Table 3.7. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma essential AA expressed as a percentage of total essential AA at 48 h postnatally

Amino acid, % of total essential AA	Forage system ¹			P-value		
	STF	HAY	SEM	Forage system	Year	Forage system x year
Phenylalanine	3.74	3.71	0.24	0.95	0.02	0.16
Valine	25.9	24.2	0.4	0.03	0.01	0.05
yr 1	27.8 ^a	24.6 ^b	0.6	--	--	--
yr 2	24.0 ^b	23.8 ^b	0.6	--	--	--
Threonine	7.95	9.47	0.27	0.01	0.03	0.57
Tryptophan	2.71	2.56	0.11	0.34	0.08	0.24
Isoleucine	8.02	7.64	0.16	0.12	< 0.001	0.74
Methionine	2.76	3.07	0.11	0.09	0.04	0.92
Histidine	14.8	15.1	0.5	0.70	0.63	0.13
Arginine	13.1	13.3	0.5	0.73	0.08	0.18
Lysine	9.19	9.69	0.35	0.29	0.38	0.11
Leucine	11.8	11.3	0.2	0.09	0.64	0.23
Total branched chain AA	45.7	43.1	0.6	0.03	0.003	0.08
yr 1	48.6 ^a	44.3 ^b	0.9	--	--	--
yr 2	42.7 ^b	42.0 ^b	0.9	--	--	--

^{a,b}Interactive means within item lacking a common superscript differ ($P \leq 0.10$).

¹Cows either strip-grazed stockpiled tall fescue pastures (STF) or consumed summer-baled tall fescue hay (HAY) in dry lots. Forage systems started at d 188 ± 2 of gestation and all cows remained in respective forage systems until cow-calf pairs were moved to a common pasture at 6.8 ± 0.5 d (yr 1) and 6.6 ± 0.4 d (yr 2) postpartum for management together through weaning. Average calf age at blood collection was 52 ± 0.6 h (yr 1) and 50 ± 0.5 h (yr 2).

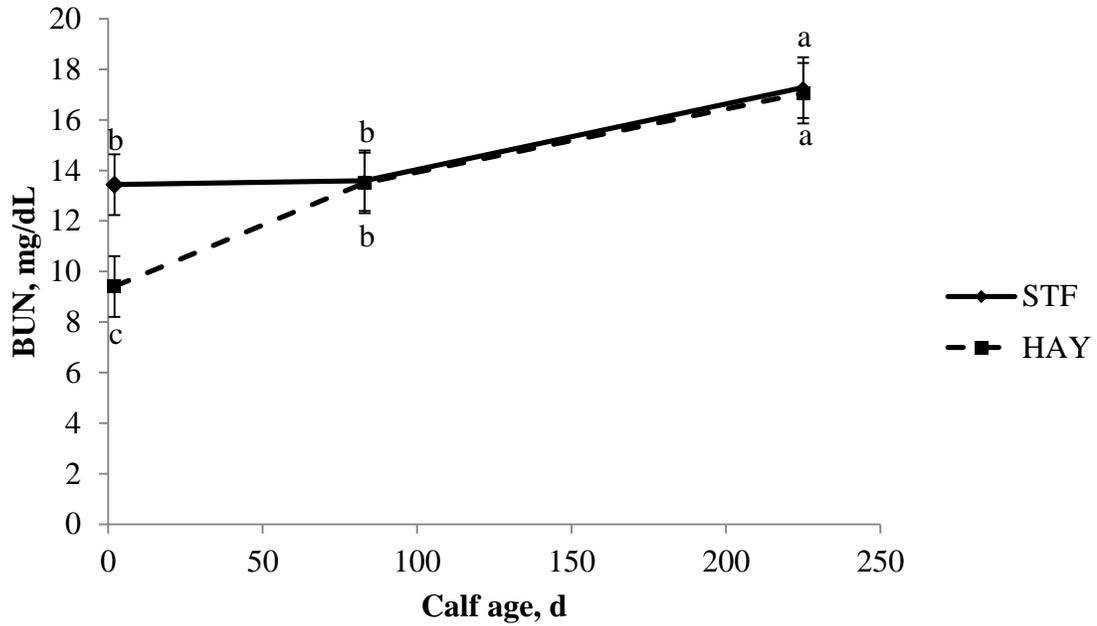


Figure 3.1. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf serum urea nitrogen concentrations through weaning in yr 1.

Forage systems started at $d 188 \pm 2$ of gestation and were terminated on 6.8 ± 0.5 d postpartum; cow-calf pairs were then managed together through weaning. Calf ages at sampling were 52 ± 0.6 (SEM) h, 82.7 ± 1.0 d, and 225.8 ± 2.1 d (weaning). There tended to be a forage system x day interaction (forage system, $P = 0.10$; day $P < 0.001$; forage system x day, $P = 0.06$). ^{a,b,c} items lacking a common superscript differ by $P < 0.05$.

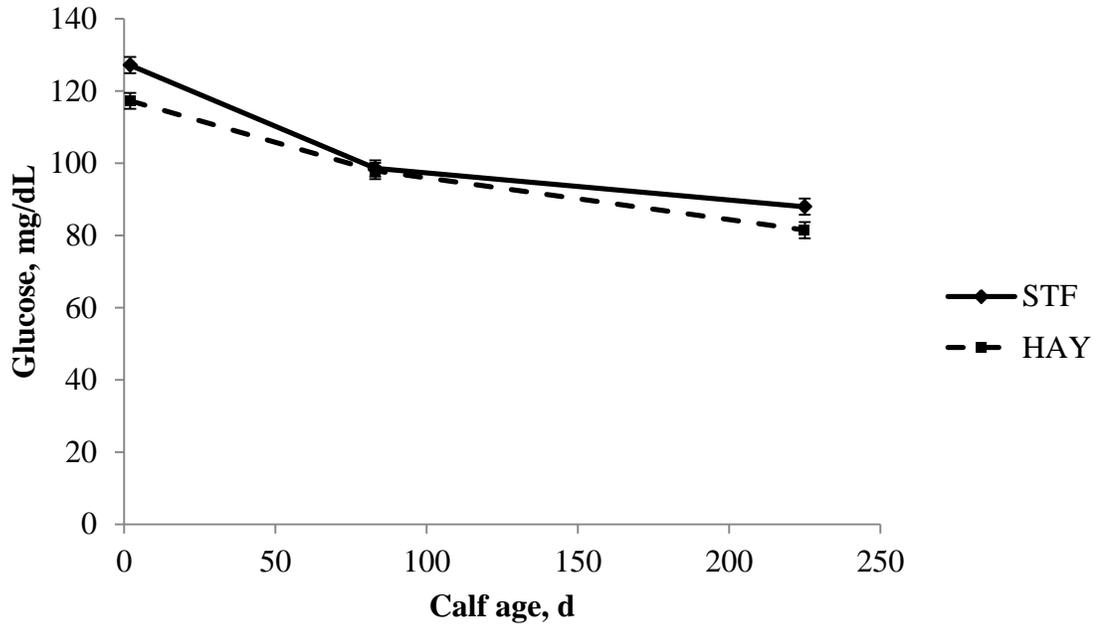


Figure 3.2. Effects of feeding stockpiled tall fescue versus tall fescue hay during late gestation on calf plasma glucose concentrations through weaning in yr 1.

Forage systems started at $d 188 \pm 2$ of gestation and were terminated on 6.8 ± 0.5 d postpartum; cow-calf pairs were then managed together through weaning. Calf ages on sampling d were 52 ± 0.6 (SEM) h, 82.7 ± 1.0 d, and 225.8 ± 2.1 d (weaning). There was not a forage system x day interaction (forage system x day, $P = 0.31$). Calves born to STF cows tended (forage system, $P = 0.08$) to have greater glucose concentrations. Additionally, plasma glucose concentrations decreased (day $P < 0.001$) through weaning.

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APPENDIX

Appendix Table 1. Pre-grazing stockpiled tall fescue forage yield and quality versus hay quality during yr 1

Variable	Stockpiled Tall Fescue Sampling Date ¹		Avg STF ²	Avg HAY ³
	d -6	d 62		
Yield, kg DM/ha	4,949	3,806	4,377	--
DM basis				
CP, %	12.5	11.1	11.8	6.2
NDF, %	59.7	68.4	64.1	64.9
ADF, %	32.2	36.4	34.3	36.6
Ash, %	9.1	5.9	7.5	9.7

¹d -6 = November 8, 2013, d 62 = January 15, 2014. Each sampling was the average of 10 strips from different areas of each paddock prior to grazing. All 4 pastures were averaged for these values.

²Average stockpiled tall fescue (STF) includes both pre-grazing samples from all 4 pastures during the trial.

³Average summer-baled hay (HAY) includes core samples collected from bales from each pen prior to offering.

Appendix Table 2. Post-grazing stockpiled tall fescue forage yield, quality, and utilization rates during yr 1

Variable	Stockpiled Tall Fescue Sampling Dates ¹	
	d 62	d 103
Yield, kg DM/ha	872	816
DM basis		
CP, %	9.5	8.7
NDF, %	70.8	66.6
ADF, %	40.3	40.3
Ash, %	11.8	13.8
Utilization, %	82.3	78.5

¹ d 62 = January 15, 2014 and d 103 = February 25, 2014. Each sampling was the average of 10 strips from different areas of the paddock post grazing. All 4 pastures were averaged for these values.

Appendix Table 3. Pre-grazing stockpiled tall fescue forage yield and quality versus hay quality during yr 2

Variable	Stockpiled Tall Fescue Sampling Dates ¹			Avg STF ²	HAY ³
	d 5	d 29	d 62		
Yield, kg DM/ha	5,799	6,713	5,159	5,890	--
DM basis					
CP, %	14.5	11.6	11.7	12.4	7.6
NDF, %	62.2	69.8	67.6	66.4	68.3
ADF, %	33.0	42.2	38.6	37.8	38.3
Ash, %	11.9	15.7	13.2	13.6	9.0

¹d 5 = November 18, 2014, d 29 = December 12, 2014, d 62 = January 14, 2015, and d 119 = March 12, 2015. Each sampling was the average of 10 strips from different areas of the paddock pre-grazing. All 4 pastures were averaged for these values.

²Average stockpiled tall fescue (STF) includes pre-grazing samples on d 5, 29, and 62 from all 4 pastures during the trial.

³Average summer-baled hay (HAY) includes core samples collected from bales from each pen prior to offering.

Appendix Table 4. Post-grazing stockpiled tall fescue forage yield, quality, and utilization rates during yr 2

Variable	Stockpiled Tall Fescue Sampling Dates ¹		
	d 29	d 62	d 119 ²
Yield, kg DM/ha	1,800	1,485	1,056
DM basis			
CP, %	12.3	12.7	11.3
NDF, %	67.0	70.5	76.2
ADF, %	42.0	41.5	46.6
Ash, %	18.8	11.9	18.0
Utilization, %	69.1	71.5	76.0

¹d 5 = November 18, 2014, d 29 = December 12, 2014, d 62 = January 14, 2015, and d 119 = March 12, 2015. Each sampling was the average of 10 strips from different areas of the paddock post grazing. All 4 pastures were averaged for these values.

²Remaining cows were combined into 2 pastures. Due to weather conditions, only 1 of 2 pastures were sampled.