

EFFECTS OF FEEDING PERENNIAL PEANUT HAY ON GROWTH, DEVELOPMENT,
ATTAINMENT OF PUBERTY, AND FERTILITY IN BEEF REPLACEMENT HEIFERS

By

KALYN MARIE BISCHOFF

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2011

© 2011 Kalyn Marie Bischoff

To my family

ACKNOWLEDGMENTS

Most importantly, I would like to thank my Lord and Savior for giving me the strength, wisdom, and passion that allows me to achieve the desires of my heart. The opportunities He has allowed me to live out are beyond what I could have dreamed. In addition, I would like to thank my family. My parents have been an unwavering source of support, and taught me at a young age that hard work and dedication will take you far in life. They are my biggest fans and I know that I will always have a place to call home. Thank you to my sister, Sammi, who drives me to be better every day and handles life's challenges with grace, courage, and love in every circumstance. In addition I would like to thank my brother-in-law Pat, who is fighting overseas for our nation's freedom, all the while being an amazing husband and father, and Weston my first nephew who brings so much joy to our entire family. I would also like to thank two of my best friends, Tyler and Clayton, my brothers. No matter what, they have always been there for me, and thanks to my grandmother Leone for her love, support, and Sunday chats!

The friends that have supported me, and made my life the joy that it is too numerous to mention, I have been blessed immensely to have these people sharing my life with me and for that I am eternally grateful.

My thanks are not enough for Tera Black and Vitor Mercadante. Tera is one of my dearest friends, the hours, miles, and laughs we shared are some of my best memories of graduate school. Her love of life is intoxicating! Obrigado to Vitor who was always willing to help with the worst job! Be it doing round bales orts at 9 P.M. or feeding heifers on cold early mornings, he is a true friend I can always count on. I would also like to thank their other halves, Paula and Seth, who are truly great friends, as well as Guilherme Marquezini. I would also like to thank everyone at the NFREC. Tina, Gina,

Mary, David, Olivia, Mark, Pete, Harvey, Don Don, Butch, the farm shop guys, and peanut crew; everyone has been a joy to work with. I truly love coming to work every day and you have a big part to do with that.

Dr. Cliff Lamb has become not only a mentor but also a great friend in the past two years. I am thankful that he believed in me and allowed me to have the opportunity to work with him. Not only is he a role model for my career but also in life. In addition, I would like to thank Dr. Nicolas DiLorenzo, whose door is always open; he is always willing to help. I would also like to thank their families for welcoming me into their lives, never once have I felt 2,000 miles away from home. I would also like to thank the United States department of agriculture (USDA) for funding this study through a TSTAR-C grant and ABS Global, Incorporated for the donation of the semen each year. In addition to Dr. Bob Myer and Dr. Gbola Adesogan for being excellent committee members, giving guidance and support throughout my masters.

Lastly, I would like to thank Jason Waters. I never dreamt that I would meet the man of my dreams working bulls in Florida, but God has an amazing plan for each of our lives! He knows and understands me better than anyone, and is my best friend. His willingness to help me achieve my goals and live my dream is something I am truly thankful for.

TABLE OF CONTENTS

	<u>page</u>
ACKNOWLEDGMENTS.....	4
LIST OF TABLES.....	8
LIST OF FIGURES.....	9
LIST OF ABBREVIATIONS.....	10
ABSTRACT.....	12
CHAPTER	
1 INTRODUCTION.....	14
2 LITERATURE REVIEW.....	17
Attainment of Puberty.....	17
Puberty.....	17
Hormonal Change.....	17
Hypothalamic GnRH Neurons.....	19
Follicle Dynamics.....	20
Factors Affecting Puberty.....	21
Genetics.....	21
Weight.....	22
Age.....	23
Body Composition.....	23
Metabolic Indicators.....	24
Time of Gain.....	26
Rate of Gain.....	26
Plane of Nutrition.....	27
Predicting Puberty.....	27
Concepts of Nutrition.....	28
Effect of Nutrition on Reproduction.....	28
Regulation of Intake.....	29
Energy.....	31
Protein.....	33
Nutrient Synchrony.....	34
Associative Effects.....	35
Nitrogen Recycling and Blood Urea-Nitrogen.....	35

3	EFFECTS OF FEEDING PERENNIAL PEANUT HAY ON GROWTH, DEVELOPMENT, ATTAINMENT OF PUBERTY, AND FERTILITY IN BEEF REPLACEMENT HEIFERS	39
	Materials and Methods.....	40
	Animals and Treatments.....	40
	Feed Sample Collection and Analysis	42
	Blood Collection and Analyses	44
	Assessment of Puberty.....	45
	Temperament Characteristics	46
	Reproductive Management	46
	Statistical Analysis	47
	Results and Discussion.....	50
	Feed Intake	50
	Animal Growth and Performance	52
	Fertility.....	57
	Temperament.....	60
	Conclusion	62
	LIST OF REFERENCES	79
	BIOGRAPHICAL SKETCH.....	98

LIST OF TABLES

<u>Table</u>		<u>page</u>
3-1	Nutritional values of feeds offered during the developmental phase.	74
3-2	Chemical composition of the mineral supplements provided to developing heifers during the development phase and breeding phase.	75
3-3	Nutritional values of feed available to heifers during the breeding phase.....	76
3-4	DMI parameters of heifers during the development phase and growth parameters.	77
3-5	Temperament data (Year 2 only) during the development phase and fertility data.	78

LIST OF FIGURES

<u>Figure</u>		<u>page</u>
3-1	Schematic representing data collection for the development and breeding phase for heifers receiving different development diets.....	63
3-2	Schematic of specific breeding events during the breeding phase for heifers receiving different developmental diets.	64
3-3	Mean ADG in kg by period for heifers receiving three different development diets.....	65
3-4	Mean BW by day for heifers receiving three different developmental diets..	66
3-5	Mean BCS (scale of 1 to 9, with 1 = emaciated and 9 = obese) by day for heifers during the receiving three different developmental diets.....	67
3-6	Mean pen score by day for heifers receiving three different development diets.....	68
3-7	Mean chute score (on 5 point scale, with 1 being calm and 5 being aggressive) by day for heifers receiving three different development diets... ..	69
3-8	Mean exit velocity by day for heifers receiving three different development diets.....	70
3-9	Mean temperature by 28 d period during the development and breeding phase for heifers receiving three different development diets.....	71
3-10	Mean relative humidity by 28 d period during the development and breeding phase for heifers receiving three different development diets.....	72
3-11	Mean rainfall by 28 d period during the development and breeding phase for heifers receiving three different development diets	73

LIST OF ABBREVIATIONS

ACTH	Adrenocorticotrophic hormone
ADF	Acid-detergent fiber
ADG	Average daily gain
AGRP	Agouti-related protein
AI	Artificial Insemination
BCS	Body condition score on a 1 to 9 scale
BGH	Bermudagrass hay
BUN	Blood urea nitrogen
BW	Body weight
CL	Corpus luteum
CON	Control treatment: no supplement
CP	Crude protein
CS	Chute score on a 1 to 5 scale
CSBM	Corn and soybean meal supplemented treatment
CT	Condensed tannins
D	Day
DMI	Dry matter intake
EV	Exit velocity
FFA	Free fatty acid
FSH	Follicle-stimulating hormone
GnRH	Gonadotropin-releasing hormone
HOT	Hepatic oxidation theory
Hr	Hour
IGF-I	Insulin-like growth factor I

Im	Intramuscular
LH	Luteinizing hormone
Max	Maximum
Min	Minimum
NDF	Neutral-detergent fiber
NPN	Nonprotein nitrogen
NPY	Neuropeptide Y
NSC	Nonstructural carbohydrate
PDV	Portal drain viscera
PGF ₂ α	Prostaglandin
PPH	Perennial peanut hay supplemented treatment
PS	Pen score on a 1 to 5 scale
RTS	Reproductive tract score
SC	Structural carbohydrate
TDN	Total digestible nutrient
TRT	Treatment
VFA	Volatile fatty acid
Vs.	Versus
Yr1	Year 1: October 2009 to June 2010
Yr2	Year 2: October 2010 to June 2011

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

EFFECTS OF FEEDING PERENNIAL PEANUT HAY ON GROWTH, DEVELOPMENT,
ATTAINMENT OF PUBERTY, AND FERTILITY IN BEEF REPLACEMENT HEIFERS

By

Kalyn Marie Bischoff

August 2011

Chair: G.C. Lamb
Major: Animal Science

The objective of this study was to determine the influence of supplemental feeding of perennial peanut hay (*Arachis glabrata* Benth.) on growth performance and age at puberty in growing beef cattle heifers. Over a two year period, 120 heifers were randomly allocated into pens and assigned to one of three supplement treatments: 80% corn and 20% soybean meal supplement (CSBM), perennial peanut hay supplementation (PPH), and a control which received no supplement (CON). All heifers received ad libitum access to bermudagrass hay (*Cynodon dactylon* (L.) Pers.) during the 140-developmental phase. Following the developmental phase, heifers were comingled for a 77 d breeding season during the breeding phase. Period influenced ADG ($P = 0.002$) and treatment effected ADG, with the CON tending ($P = 0.06$) to be have lesser ADG than the CSBM and PPH heifers. There was a treatment \times day interaction ($P = 0.06$) on mean body weight (BW) with heifers in the CON treatment being lighter at the conclusion of the development phase ($P = 0.02$). Total DMI during the 140-d development phase was greater ($P < 0.01$) for PPH ($5.3 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) than for CON ($3.4 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), and CSBM heifers ($4.3 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), with CSBM being greater than CON. There was no effect of treatment on age ($P = 0.32$),

BW ($P = 0.16$), and body condition score (BCS; $P = 0.27$) at attainment of puberty, nor days on treatment prior to attainment of puberty. In addition, no differences in fetal age ($P = 0.34$) and overall pregnancy rate ($P = 0.50$) were observed. In conclusion, there were no differences among treatments in reproductive performance despite the occurrence of differences in DMI, BW, and ADG, making PPH a viable feed option in the southeastern United States of America for replacement heifer development.

CHAPTER 1 INTRODUCTION

The successful development of replacement heifers, to sustain cow numbers, in the United States beef industry is critical for meeting the world's growing protein requirement. As of January 2011, there were 30.9 million beef cows, with 5.2 million replacement heifers on inventory within the U.S.A. (USDA, 2011). With replacement heifer numbers decreasing by 5% from 2010, the size of the U.S. cow herd will likely continue to decline during the next two years, making it essential for proper development of existing heifers to ensure their successful entrance into the cow herd. In Florida, there are more than 110,000 head of replacement heifers that may be developed to sustain the 926,000 head of beef cows (USDA, 2011). However, producers face regional challenges, making the management of replacement heifer development even more of a challenge.

It is estimated that heifers must reach a target weight of approximately 65% of their mature body weight (BW) to attain puberty (Patterson et al., 1991) and heifers that become pregnant early in the breeding season will continue to do so as cows (Albaugh and Strong, 1972; Lesmeister et al., 1973), with increased lifetime production rates (Byerley et al., 1987). Therefore, ensuring proper nutritional management of heifers, allowing adequate average daily gain (ADG) to support the attainment of puberty, is a focus in heifer development. While these management goals are widely understood, they present a major expense for producers; therefore, management strategies that allow attainment of these goals must be considered in order to meet the needs of the growing female, while minimizing the opportunity cost associated with that heifer becoming pregnant and reaching the production phase of her life (Clark et al., 2005). In

addition, continually rising corn and commodity prices make concentrate-based supplementation economically challenging, resulting in the need for exploration of alternative nutritional methods of heifer development.

While bermudagrass (*Cynodon dactylon* (L.) Pers.) is one of the main forages in the southeastern U.S.A., its' low dry matter (DM) digestibility and crude protein (CP) concentrations make it nutritionally inadequate as a sole source of feed for growing or lactating beef cattle (Duble et al., 1971; Johnson et al., 2001). Thus, a common feeding strategy is to supplement poor quality basal grass diets with legume forage which results in increased DMI and diet digestibility in ruminant livestock (Minson and Milford, 1967; Getachew et al., 1994).

With production of perennial peanut forage (*Arachis glabrata* Benth.) growing in popularity over the past decade in regions known for bermudagrass production (Myer et al., 2009), its use as a supplement in low quality-forage based diets could yield favorable results in ruminant production scenarios. Perennial peanut forage is a warm season, tropical legume, native to South America, which is comparable to alfalfa (*Medicago sativa* L.) in nutritive value and feeding quality (French et al., 2006; Myer et al., 2009). In Florida, it is estimated that 12,140 hectares are planted annually (Newman et al., 2009). In addition, it is estimated that every 404 hectares of coastal bermudagrass that is replaced with perennial peanut production will yield an annual savings of 196,841 liters of diesel fuel energy equivalents. With rising fuel prices and need for quality forages, implementation of perennial peanut production continues to grow in the southeastern states (French et al., 2006). These savings may be realized through the crops' decreased reliance on fertilizer, drought resistance, and pest

tolerance, making it a viable protein and energy supplement for replacement heifer development in the southeastern U.S.A.

CHAPTER 2 LITERATURE REVIEW

Attainment of Puberty

Puberty

Puberty, in beef heifers, may be defined as the first fertile ovulation, resulting in the development of a fully functional corpus luteum (CL), followed by normal estrous cycles. Beef replacement heifers should be managed so that they reach puberty early, conceive early in the first breeding season, calve without need of assistance, and become pregnant early with their second calf (Funston and Deutscher, 2004). Age at puberty is an economically important trait to achieve optimal lifetime productivity of a replacement heifer. Heifers that become pregnant as yearling heifer's, produce their first calf by 24 months of age and conceive earlier in the breeding season, continue to do so during subsequent breeding seasons, allowing for greater lifetime productivity and increased overall kilograms of calf weaned while in production (Albaugh and Strong, 1972; Lesmeister et al., 1973). In addition, prior to the breeding season, heifers that have experienced multiple estrous cycles have an increased probability for early conception (Byerley et al., 1987).

Hormonal Change

Successful coordination of the reproductive hormones of the hypothalamic-pituitary-adrenal axis is critical to allow for the reproductive maturation that leads to puberty. The "gonadostat" theory of puberty was proposed by Ramirez and McCann (1963), who indicated that prepubertal luteinizing hormone (LH) secretions and negative feedback from estrogen in the hypothalamic centers are critical to the onset of puberty (Day et al., 1984; 1987). As puberty approaches, the negative feedback of estrogen on

the secretion of gonadotropins by the pituitary declines. This coincides with an increase in LH pulse frequency (Day et al., 1984) and a decrease in amplitude (Day et al., 1987). While the mechanism for this response is not clearly understood, a reduction in the number of estrogen receptors on which estrogen exerts a negative effect on the hypothalamo-pituitary axis has been documented. A decline in estrogen receptors has been shown in rats near puberty (Kato et al. 1974), corresponding to the age in which negative feedback of estrogen declined and in heifers in the area of the medial basal hypothalamus (Day et al., 1984). Widely accepted theories support that upon estrogen binding to its receptor; it forms a receptor-steroid complex. This complex is then transformed and translocate into the nucleus of the target cell, causing a decline in receptor numbers (Day et al., 1987). However, this change in receptor numbers only occurs in specific tissues indicating that this maybe a result of sexual maturation (Day et al., 1987).

As early as 130 to 60 d prior to the onset of puberty, the number of estrogen receptors in the hypothalamus and pituitary remain high, but at 40 d preceding ovulation, they begin to decline and continue to do so until ovulation. Concurrently, the negative feedback loop of estrogen on LH secretion begins to reduce at 40 d prior to puberty, continues to diminish at 20 d and becomes a positive feedback loop as ovulation nears (Day et al., 1987). Estrogen secretion and uterine weight also increase as puberty nears, and as the negative feedback of estrogen is removed LH pulse frequency begins to increase around 40 d prior to ovulation with the LH surge resulting in ovulation. The increase in LH results from increased responsiveness to gonadotropin-releasing hormone (GnRH), which stimulates LH and follicle-stimulating

hormone (FSH) secretion, which results in increased follicle growth. Follicular development allows estrogen to reach threshold concentrations, stimulating the preovulatory LH surge to induce ovulation (Day et al., 1987).

When puberty approaches, an increase in responsiveness of the pituitary to GnRH occurs (Schams et al., 1981) without alterations in the number of GnRH receptors being observed peripubertally, showing a concentration related response (Day et al., 1987). The secretion of GnRH is fundamental for the induction of puberty, with the appropriate pulse frequency and amplitude being required to stimulate gonadotropin release from the anterior pituitary. The number of neurons that secrete GnRH, their morphology and distribution are well established prior to puberty. However, the degree of functionality of the neurons increases dramatically prior to the onset of puberty (Senger, 2003). It was postulated that a mechanism controlling the onset of puberty is the ability of presynaptic neurons to transmit information to GnRH neurons to elicit secretion (Senger, 2003). Presynaptic neuron function is influenced by nutritional plane, environmental and social cues, and genetics (Senger, 2003).

Hypothalamic GnRH Neurons

Prior to puberty the anterior pituitary lobe is capable of secreting FSH and LH after receiving an exogenous GnRH stimulus, with subsequent response by the ovaries via production of follicles and estrogen. Thus, the onset of puberty is not only limited by gonadal function but also the ability of the hypothalamus to produce sufficient quantities of GnRH (Senger, 2003). The development of the hypothalamus is a gradual process involving the tonic GnRH center and the preovulatory surge center. In order to allow the preovulatory surge of LH stimulated by GnRH, full development of the surge center must occur by increased frequency and amplitude of GnRH secretion. In addition, the

tonic center must develop as it is the regulatory system of the frequency of GnRH pulses. A lack of gonadal estrogen characterizes the prepubertal female's inability to activate the surge center (Senger, 2003).

Follicle Dynamics

In cattle, follicle growth is characterized by follicle wave patterns, with two or three FSH-induced waves commonly occurring in the 21 d estrous cycle (Evans, 2003), with heifers typically having three-wave estrous cycles (Savio et al., 1988; Sirois and Fortune, 1988; Knopf et al., 1989). These waves of antral follicle growth occur in 7 to 10 d intervals (Evans et al., 1994; Sunderland et al., 1994; Ireland et al., 2000). An increase in FSH initiates the recruitment of a cohort of 3 to 4 mm antral follicles, which is followed by the selection and development of a single dominant follicle (12 to 20 mm), while the remaining follicles undergo atresia (Adams et al., 1992; Evans et al., 1994; Fortune, 1994). Growth of the dominant follicle to ovulatory size (> 10 mm) occurs during the latter portion of the follicular wave. The development of a dominant follicle takes place during dioestrus (d 6 to 12) and then again reoccurring during luteolysis (approximately d 18) of the follicular phase in a two-wave cycle, with ovulation occurring on d 1 (Matton et al., 1981). Intrafollicular ratios of estrogen and progesterone are critical in the selection, dominance and atresia, or ovulation of follicular waves (Ireland et al., 1987; Ireland and Roche, 1987), with the number of LH receptors increasing while the number of FSH receptors decrease during growth of estrogen active follicles during estrus and dioestrus (Ireland and Roche, 1983).

Endocrine mechanisms that lead to the emergence, growth, and selection of dominant follicles are similar between prepubertal and pubertal heifers (Evans et al., 1994), with no known predictive indicators to the exact timing of the pubertal ovulation,

or the number of follicular waves in the subsequent estrous cycle of normal duration in beef heifers (Evans et al., 1994). The developmental pattern, growth of follicles, and regression is similar in peripubertal heifers to older, cyclic heifers (Sirois and Fortune, 1988; Ginther et al., 1989).

Factors Affecting Puberty

Genetics

Differences in age and weight at the onset of puberty have been established within and across breeds (Laster et al., 1972; Dow et al., 1982; Cundiff et al., 1986). These differences are attributed to diverse frequencies and additive effects of the genes present (Martin et al., 1992). *Bos indicus* and *Bos indicus*-influenced breeds (those breeds with genetic crosses of *Bos indicus* such as Brangus, Braford, and Santa Gertrudis etc.) tend to be older and heavier, with increased frame size at puberty, compared to *Bos taurus* heifers (Warnick et al., 1956; Temple et al., 1961; Baker et al., 1989). Heifers of Brahman influence were older, taller, and heavier at the onset of puberty compared to *Bos taurus* counterparts (Stewart et al., 1980). Crossbred heifers had increased weight and hip height at puberty, compared to purebred heifers (Stewart et al., 1980). Regardless of *Bos indicus* or *Bos taurus* influence, breed groups with larger frame size and faster rate of gain reach puberty at a later age when compared to breeds with a history of selection for maternal traits (Martin et al., 1992). However, the correlation between age at attainment of puberty and mature size can be offset by associations with milk production, with those breeds that have been selected for increased milk yields being lighter and younger at puberty (i.e., Gelbvieh, Brown Swiss and Simmental have been selected for milk vs. Charolais and Chianina that have been selected for carcass traits, Martin et al., 1992).

The percentage of crossbred heifers reaching puberty by a certain age is greater than purebred counterparts, with heterosis diminishing as age increases (Laster et al., 1976), and crossbred heifers developed in a pasture system reach puberty earlier (15 d; $P < 0.05$) than their purebred constituents (Stewart et al., 1980). Heterosis is not limited to across breed effects because line breeding may reduce age of puberty, accompanied by increased gains (Burgening et al., 1979). A study of 301 heifers resulted in significant differences in age at puberty among different breed types. At 19.5 months of age, 96% of Red Poll, 68% of Herefords, 89% of Angus × Charolais, 81% of Angus × Herefords, 74% of the Brahman × Angus, and 48% of Brahman × Herefords had attained puberty, indicating that those heifers with *Bos indicus* influence were older when they attained puberty than those without *Bos indicus* influence (Dow et al., 1982).

Weight

It is well established that weaning weight and post-weaning growth rate affect age and weight at which puberty is attained. Puberty may be expected to occur at a genetically predetermined weight and size for each individual heifer. There was a positive correlation for weight and hip height at puberty ($r^2 = 0.77$, $P < 0.01$; Nelsen et al., 1982). The general dogma associated with the onset of puberty is that at approximately 60 to 66% of a heifer's mature body weight (BW), independent of frame size, puberty will be attained (Patterson et al., 1992). However, additional reports do not support this critical BW hypothesis (Brooks et al., 1985), or the 60 to 66% theory (Patterson et al., 1992). A three year study ($n = 240$) of *Bos taurus* heifers indicated that there were no differences in reproductive or calf performance in heifers developed to reach 53% of their mature BW in comparison to those heifers that were developed to reach 58% of their mature BW (Funston and Deutscher, 2004). In addition, the

increased costs of development for higher target weight heifers yielded no economic return (Funston and Deutscher, 2004).

Age

In evaluation of genetic lineages selected for use in the beef industry, age at puberty is critical and indicates that there is a minimum age that must be achieved for puberty to occur (Laster et al. 1972). Age at puberty is influenced by level of nutrition (Hansel, 1959; Wiltbank et al., 1969) and prepubertal gains (Reynolds et al., 1963; Short and Bellows, 1971; Laster et al., 1972).

Age at puberty is a moderately heritable trait ($h^2 = 0.43$) with associations to weaning weight and yearling weight (Brinks, 1994). The mean age of first CL formation in 83 *Bos indicus* heifers was 19.4 months, with a range of 14 to 20 months (Plasse et al., 1968). There also was a correlation between weaning weight, age at puberty ($r^2 = -0.21$; $P < 0.01$; Arije and Wiltbank, 1971), and 205-day weights ($r^2 = -0.41$; $P < 0.01$; Plasse et al., 1968). In addition, heterosis was negatively correlated ($P < 0.05$) with age at puberty (Nelsen et al., 1982) and the age at which estrogen's negative feedback system on gonadotropin secretion begins to decline can be influenced by diet, allowing for nutritional induced precocious puberty to occur (Kurz et al., 1990; Gasser et al., 2006).

Body Composition

A critical amount of body fat may be required for attainment of puberty. Peripubertal increases in adipose tissue have been reported in beef heifers, in comparison heifer's prepubertal body composition (McShane et al., 1989; Buckley et al., 1990). However, these changes could have been a result of breed and nutritional status (Brown et al., 1972; Carstens et al., 1991; Keele et al., 1992). In contrast, no

abrupt changes in body composition have been reported 75 d prior to puberty (Hall et al., 1995). In many experimental models dietary energy and interaction of breed modify the rate of change of body composition. Increased rate of gain results in a greater BCS, carcass weight, fat thickness, and total separable fat at puberty (Brooks et al., 1985; Hopper et al., 1993; Yelich et al., 1995). In addition, hormonal and metabolic changes which alter body composition may regulate LH secretion, a key component hormone responsible for the attainment of puberty (Schillo, 1992). The “whole body energy balance” hypothesis proposes that availability of total body energy modulates the activity of GnRH pulse generators, regulating ovulation (Bronson and Manning, 1991). Thus, body composition may not be a sole regulator of attainment of puberty but is directly associated with many hormones and metabolites (Yelich et al., 1995).

Metabolic Indicators

The reproductive axis is more sensitive to nutrient availability than the growth axis (Hileman et al., 1991), therefore attainment of a specific metabolic status by cattle may be critical to the onset of puberty which is characterized by several metabolites and hormones such as glucose, insulin, and insulin-like growth factor I (IGF-I; Steiner et al., 1987). Blood urea nitrogen (BUN) and insulin at puberty indicated that heifers were at differing metabolic states at the onset of puberty (McShane et al., 1989). While insulin and BUN concentrations differed throughout the prepubertal period, only insulin increased as puberty neared (Hall et al., 1995; McShane et al., 1989), indicating that BUN appears to be unrelated to puberty and is more a function of diet (Kennedy, 1980) and rate of protein degradation (McShane et al., 1989). Insulin can be influenced by feed intake and dietary energy density (Bassett et al., 1971; Richards et al., 1989), with

dry matter intake being proportional to BW (NRC, 1984), thus, increases in insulin could also be linked to DMI and diet.

Metabolic factors are highly dependent on diet composition and feed intake and as heifers near puberty, increases in BW may lead to increased intake, resulting in differing concentrations in plasma of glucose. Alterations in rumen fermentation patterns and volatile fatty acid profiles have been reported to alter LH secretions. Increases in propionate, the key component of gluconeogenesis in the ruminant, are reported to increase LH pulse frequency and amplitude (Moseley et al., 1977; Rhodes et al., 1978; McCartor et al., 1979). Decreasing concentrations of insulin are associated with decreased LH concentrations (McCann and Hansel, 1986); however exogenous insulin does not increase LH secretion (Hileman et al., 1993). It has been reported that as puberty nears, glucose concentrations are not altered; however, hypoglycemia has been reported to decrease LH pulsatility in ovariectomized ewes (Clarke et al., 1990) and decreased LH pulse amplitude in intact cows (Rutter and Manns, 1987). In addition, greater postpubertal concentrations of glucose were noted in heifers, compared to prepubertal heifers (Verde and Trenkle, 1987).

When no alteration in glucose concentrations were reported, a decrease in serum concentrations of insulin from 40 to 17 d prior to puberty was observed, indicating possible increases in peripheral tissue sensitivity to insulin at puberty with a link to an increased LH pulse frequency in Angus heifers (Jones et al., 1991). In addition, as insulin concentrations decreased prior to puberty, an increase in free fatty acids (FFA) was reported (Jones et al., 1991). Concurrently, prepubertal increases of IGF-I may reflect increased activity of the hypothalamic-hypophyseal-ovarian axis, with follicular

fluid containing abundant quantities of insulin-like growth factor I (IGF-I; Hammond et al., 1988).

Time of Gain

When gain was delayed until the last half of development there were no negative effects of reproduction in heifers, and while heifers may weigh less throughout the development process, there was no difference in BW or age at the onset of puberty, with similar first service conception and overall pregnancy rates (Clanton et al., 1983). In addition, heifers that gained late in the development phase had significantly reduced feed inputs and DMI compared to heifers with a constant ADG, with no differences in body condition score (BCS) or backfat thickness determined by ultrasound. Pelvic area and frame score at the conclusion of the breeding season also were similar, indicating that no effect on skeletal development was observed (Lynch et al., 1997). However, Yelich et al. (1995) reported that heifers that gained at a high-steady rate of gain had increased BCS and BW at puberty, with decreased age of puberty, which were similar to previous reports (Arije and Wiltbank, 1971; Short and Bellows, 1971). Underfeeding, resulting in low weight gains or weight loss throughout the development phase was reported to delay the onset of puberty (Wiltbank et al., 1966, 1969; Day et al., 1986).

Rate of Gain

Body weight and age at puberty are influenced by nutrient intake (Short and Bellows, 1971). Heifers fed to gain at a higher ADG had a significantly greater number of females cycling prior to the breeding season (85% vs. 74%; $P < 0.01$; Funston and Deutscher, 2004). Similarly heifers on a high weight gain diet reached puberty 43 d younger than those on moderate or slow gain diets (Hall et al., 1995). High-gain heifers also had increased instances of calving difficulty with reduced adjusted 205-d weights of

their calves at second calving (Funston and Deutscher, 2004). Increased ADG resulted in increased lipid depots and total percentage of carcass weight being lipids (Waldman et al., 1971; Kempster et al., 1976), which may be linked to the onset of puberty by the critical body fat hypothesis (McShane et al., 1989). In addition, it is hypothesized that limit feeding, compared to programmed feeding in which an energy equation is used to meet nutrient requirements plus provide for desired gains, may improve cow herd efficiency through the development of replacement heifers on an accelerated rate of gain. This accelerated gain results in heavier mature cow weights, making rate of gain during development a possible tool to manipulate mature cow size and nutrient requirements (Galyean, 1999).

Plane of Nutrition

Increasing planes of nutrition resulted in decreased age of puberty, with lighter weights and smaller body frames (Wiltbank et al., 1969; Stewart et al., 1980). In addition, interactions between breed type and plane of nutrition exist ($P < 0.05$) for age, height, and weight at puberty (Nelsen et al., 1982). Low planes of nutrition or negative energy balance inhibits LH secretion through both estrogen dependent and ovarian independent mechanisms (Kurz et al., 1990).

Predicting Puberty

After analysis of 353 *Bos taurus* heifers, prediction equations were developed for age and weight of puberty, and the regression of age and weight of puberty on birth date, actual weaning weight, and ADG (Arije and Wiltbank, 1975). The accuracy of these equations was then validated using two sets of unrelated, known puberty data. Age at puberty was similar but lower than observed data in one experiment and not different in the subsequent experiment, with the same being true for weight at puberty,

revealing that mathematical and statistical equations may be useful however lack complete accuracy in the prediction of the onset of puberty (Arije and Wiltbank, 1975).

Reproductive tract scoring (RTS) was developed as a means to assess age at puberty indirectly (Anderson et al, 1991) on a five point scale. A RTS of 1 is an immature, prepubertal reproductive tract, with 5 being a reproductively mature heifer that is cycling and has a CL. With adjustments for BW and age, RTS was positively correlated with pregnancy rate ($P < 0.01$), calf weaning weight ($r^2 = 0.22$, $P < 0.01$) and negatively associated with days to calving ($r^2 = 0.28$, $P < 0.01$) in replacement heifers. The RTS of heifers was associated with age, BW, and BCS, with the strongest association being to age (Holm et al., 2009).

Concepts of Nutrition

Effect of Nutrition on Reproduction

Low energy diets are associated with reduced concentrations of pituitary hormone (Rutter and Randel, 1984; Imakawa et al., 1986) and poor reproductive performance (Rakestraw et al., 1986; Perry et al., 1991; Wiley et al., 1991). Heifers with an increase in ruminal propionate concentration ($P < 0.01$) reached puberty at 29.5 d younger ($P = 0.009$) and weighed 17.2 kg less ($P = 0.03$) those heifers with increased acetate to propionate ratios (McCartor et al., 1979). In addition, maternal nutrient restriction has been shown to have an impact on the reproductive performance of female offspring. A 19 d increase in age at puberty was reported in offspring of prepartum energy-restricted dams (Corah et al., 1975) and altered adrenal steroid production in ewes restricted in late gestation (Bloomfield et al., 2003); however, additional research contradicts these studies stating that there was no observed differences in age of puberty of maternally restricted heifers ($P = 0.15$; Martin et al., 2007). Therefore, proper understanding of

intake, supplementation of replacement heifers, and synchrony of nutrients is critical in the success of reproductive performance and development.

Regulation of Intake

The control of feed intake is multifaceted with alternate and redundant mechanisms working through the feeding center of the brain (Allen et al., 2009), and despite decades of research there is still no unified explanation of intake regulation (Forbes, 2007). Clearance of digesta from the rumen has been indicated to be the primary factor limiting intake by ruminants (Ulyatt et al., 1986) as suggested by the physical theory (Forbes, 1996) with total DMI being highly correlated ($r^2 = 0.98$) to rate of passage from the rumen (Guthrie and Wagner, 1988). This is thought to be regulated by the sensitivity of receptors in the rumen wall which respond to stretch and touch, where intake is suppressed when the capacity of the rumen is reached (Allen, 1996). As a result, improvements in forage intake may be noted when rate of digestion, rate of passage, or both are improved (Moseley and Jones, 1979). Rumen retention time is dependent on the extent of cell wall digestion, in conjunction with quantity and quality of fiber, as a function of the rate of passage of digesta (Robertson and Von Soest, 1975; Staples et al., 1984).

The hepatic oxidation theory (HOT) hypothesizes that feed intake is regulated by signals from the liver to the brain that are stimulated by oxidation of various metabolic fuels (Allen et al., 2009). The inhibition of glycolysis and fatty acid oxidation (Friedman and Tordoff, 1986), blocking glycolysis and lipolysis (Friedman et al., 1986), increased feed intake in rats. Physiologically this is supported by association of the liver with afferent and efferent hepatic vagal fibers, allowing for crosstalk with the central nervous system to convey energy status which results in feeding behavior changes through

alterations in firing rate of neurons (Berthoud and Neububer, 2000). Amalgamation of the two theories would imply that when a diet is low in caloric density it is likely that gut fill will elicit the satiety effect; however, in a high energy diet energy balance via H₂O is likely the signal. In addition, hormones have been noted to influence feed intake in cattle, with the two of primary hormones being ghrelin and leptin.

Ghrelin, a peptide hormone synthesized by the abomasal and ruminal tissues of cattle, has been shown to stimulate feed intake through neuropeptide Y (NPY) and agouti-related protein (AGRP; Inui, 2001; Nakazato et al., 2001; Shintani et al., 2001). In fasted steers, the average plasma ghrelin concentration was elevated ($P < 0.05$) compared to steers on feed, with no differences in glucose concentrations (Wertz-Lutz et al., 2006). In contrast, leptin has been shown to reduce food intake (Morrison et al., 2001). As a hormone that works to control body homeostasis and regulate appetite, leptin is implicated in metabolic regulation through its action on the hypothalamic-pituitary-adrenal axis activity and on reproductive activity (Keisler et al., 1999). Concentrations of leptin are positively correlated to adipose tissue leptin mRNA, (Amstalden et al., 2000) such that administration of leptin will reduce feed intake in ruminants (Morrison et al., 2001). Variations in leptin concentrations in ruminants of 17 and 35% were explained by adiposity and nutritional status (Delavaud et al., 2000), with 37% being accounted for by BCS in lactating cows (Ehrhardt et al., 2000).

Insulin has also been shown to have an effect on feed intake, with infusion of low levels of insulin exogenously resulting in an increase in feed intake most likely as an effect of the increased rate of fat deposition and growth, however it is likely that insulin

is not a primary regulator of intake (Forbes, 2000) but an integrated system of several control mechanisms.

Energy

Energy in feed is derived from the denaturation and manipulation of protein, carbohydrates, and lipids, each of which have a relative caloric density of 5.6 kcal/g, 4.2 kcal/g, and 9.4 kcal/g, respectively. Energy supplies are used first to meet the maintenance requirements of the animal, followed by partitioning for production (NRC, 2000), with maintenance being influenced by level of feeding, previous plane of nutrition and breed (Graham and Searle, 1972; Gray and McCracken, 1979; Ferrell et al., 1986). A truncated list of reasons for differences in maintenance requirements that are seen includes: physiological status (Ferrell and Oltjen, 2008), season (Senft et al., 1987), confinement (Osuji, 1974), breed (Laurenz et al., 1991), digestive and metabolic efficiencies (Grovmum, 1986), and environment (NRC, 2000).. In ruminants energy is supplied primarily by the fermentation of ingested organic matter to volatile fatty acids (VFA) followed by ruminal-absorption, and some post ruminal absorption. The fermentation of glucose results in pyruvate molecules which are converted into VFA as an energy source. In the reduction of pyruvate to the primary VFA (propionate, acetate, and butyrate) differences in efficiency exist (Stewart et al., 1997).

For energy supplementation, carbohydrates are the primary energy substrate fed to cattle. Carbohydrates are classified into two groups: 1) non-structural carbohydrates (NSC), such as starches, that are highly soluble, leading to rapid rates of digestion and increased rate of passage; and 2) structural carbohydrates (SC) which are contained within the cell wall of plants. These cell walls are composed of hemicellulose, cellulose, lignin, and pectin, which have slow rates of digestion and passage. The NSC are often

fed to increase the energy density of a diet (Huntington, 1997), consisting primarily of grains and concentrates. The NSC are highly fermentable substrates that typically cause a shift in the acetate to propionate ratio, with a greater proportion of propionate being produced, resulting in a decline in ruminal pH. Feeding NCS, such as corn, alters the microbial population of the rumen, shifting ruminal conditions to favor amylolytic bacteria and decreasing functionality of cellulolytic populations typically as a result of decreased ruminal pH resulting in a reduction of fiber digestion. The reduction of intake that accompanies this effect is likely due to subacute acidosis (Mould and Orskov, 1983). When pH ranges from 6.7 (Mertens, 1977) to 6.2 (Mould et al., 1983) or lower, SC digestion may decline. Ruminants that consume high concentrate diets (NSC \geq 70% concentrate) typically has a ruminal pH that ranges from 5.8 to 6.6, whereas those on a forage-based diet range from 6.2 to 6.8 (Church, 1979).

When heifers receiving a 75% concentrate diet were compared with those received a 75% alfalfa (*Medicago sativa* L.) diet, those consuming the concentrate diet ingested less dry matter, energy, and nitrogen, while producing less heat and retaining more tissue energy in addition to decreased portal drain viscera blood flow and O₂ uptake by the liver (Blaxter, 1980; Reynolds et al., 1991). This concurs with reports indicating that high NSC diets were utilized more efficiently by ruminants (Blaxter and Wainman, 1964; Garrett, 1979). In addition, the increased propionate levels that are associated with NCS feeding (Reed et al., 1997) have been shown to be beneficial for reproductive hormone secretion such as LH (Bushmich et al., 1980; Randel and Rhodes, 1980; Randel et al., 1982) and reproductive performance (McCartor et al., 1979; Hardin and Randel, 1983; Lalman et al., 1993). The readily available energy from

starch fermentation also increases ruminal outflow of microbial protein in cattle (Spicer et al., 1986; Streeter et al., 1989; Poore et al., 1993).

Protein

Supplementation of protein to cattle consuming lower quality forages comprises a substantial portion of annual feeding costs in the cow-calf sector of beef production (Wickersham et al., 2008). In an effort to decrease cost and labor, alteration in protein supplementation frequency has been explored under the hypothesis that nitrogen recycling will support ruminal fermentation needs between supplementation events (Currier et al., 2004a). Decreased supplementation frequency maintained desired growth performance (Bohnert et al., 2002) with minimal impact on nutrient intake and digestibility (Beaty et al., 1994; Köster et al., 1997). Reductions in BCS and BW have been reported when supplements were fed less frequently but offered similar total protein (Beaty et al., 1994; Currier et al., 2004b; Farmer et al., 2004). However, with decreases in frequency of supplementation, decreases in forage intake were observed (Bohnert et al., 2002; Farmer et al., 2004). These decreases were reported particularly on the day of supplementation ($P < 0.01$; Cooke et al., 2007), and accompanied by significant alterations in microbial populations and differing lag times of fermentation, or the time from which the ingested feedstuff enters the rumen until attachment of microorganisms and penetration to initiate digestion (Farmer et al., 2004).

A positive effect of protein or nitrogen supplementation on intake or utilization with forages has been recognized (Church and Santos, 1981; Coleman and Wyatt, 1982; Hennessy et al., 1983). When steers received protein supplement (soybean meal) with a low quality prairie hay (4% CP) diet increased ($P < 0.01$) digestibility of dry matter, organic matter, crude protein, cellulose, and increased concentrations of ruminal NH_3

were noted compared with those not receiving the protein supplement (Guthrie and Wagner, 1988).

Nutrient Synchrony

Developing an integrated system between protein and energy (carbohydrates) digestion to maximize nutrient utilization and microbial yields substantially improves performance of ruminants (Nocek and Russell, 1988). With nutrient availability being determined by the extent and rate of digestion in the rumen, microbial populations, and yields are critical. Microbial yields are a function of energy (Bauchop and Elsdon, 1960) and nitrogen availability in the rumen. When ATP is available (primarily from carbohydrate fermentation) amino acids are incorporated into microbial protein; however, when there are insufficient carbohydrates to match protein in the rumen, protein nitrogen is deaminated, increasing ruminal NH_3 , which may enter the urea cycle rather than being incorporated into microbial biosynthesis (Hogan, 1975). Therefore, the rate of digestion of energy carbohydrates and nitrogen must be synchronized to optimize microbial biosynthesis. The feeding of structural and non-structural carbohydrates, which differs in rate of digestion, must be matched with the rate of digestion of the protein source provided to maximize the performance and microbial protein yield (Nocek and Russell, 1988). The synchronization of starch and protein degradation reduced NH_3 absorption and increased nitrogen retention in steers (Taniguchi et al., 1995) and lambs (Matras et al., 1991). In addition, microbial protein flow into the duodenum increased in a linear fashion as the level of protein supplementation increased (Wickersham et al., 2008).

Associative Effects

When a diet is formulated, it is assumed that each ingredient will have a positive contribution to the nutritional value of the diet; however, this is not always the case. Associative effects describe the non-linear response in the utilization of two nutrients when combined together (Moe, 1979), compared to when the same feedstuffs are fed individually. Typically diets are calculated with linear equations, and do not account for the associative effects that are present. True associative effects on digestibility are difficult to determine due to their strong link to intake which is confounded by digestibility data (Church, 1988).

Negative associative effects often occur in forage-concentrate diets (Lamb and Eadie, 1979; Vadiveloo and Holms, 1979). Depressions or reductions in digestibility of starch, protein, and NDF accounted for 57, 12, and 32% of the total depression of digestibility, respectively, in high intake scenarios with associative effects (Church, 1979). An 8.9% deviation in the predicted net energy of gain in corn silage diets containing 30 to 70% added corn has been documented (Woody et al., 1983). In addition, a positive associative effect with high quality alfalfa and soybean stover was reported (Soofi et al., 1982). An associative effect of increased forage digestibility was reported when protein was supplemented (Gallup and Briggs, 1948), and conversely, carbohydrate supplementation decreased cellulose digestion of corncobs and timothy hay (Burroughs et al., 1949).

Nitrogen Recycling and Blood Urea-Nitrogen

The tissues of the digestive tract account for 25 to 40% of whole body protein synthesis, accounting for a small portion of exchanges and transactions involving nitrogen metabolites (Lobley, 1993). Urea recycling has a considerable role in nitrogen

supply to the rumen and the animal, especially when supplementation of high protein feedstuffs occurs infrequently (Wickersham et al., 2008). Ruminant bacteria require ATP and a nitrogen source for microbial synthesis and most bacteria species are able to use $\text{NH}_3\text{-N}$ as a source of nitrogen for growth, however, specific N sources are required and can be limiting factors for specific microbial populations.

In general, most microorganisms can use ammonia and a carbon source to synthesize the amino acids required for growth (Bryant and Robinson, 1962). With all the essential amino acids being synthesized by the rumen microbial populations (Loosli et al., 1949), indicating that protein in a ruminant diet could be replaced with non-protein nitrogen (NPN) without affecting the animal's protein supply. However, lambs whose N-sources was limited to only urea, had growth and efficiency that was reduced 70% (Clifford and Tillman, 1968), when compared to lambs fed isolated soy protein. Increases in production have been seen when percentages of a dietary protein were replaced with NPN (Flatt et al., 1967). Thus, complete replacement of dietary protein with NPN reduces animal performance, but replacing protein nitrogen with NPN at certain levels may improve ruminal efficiency. This is likely due to the fact that some species of bacteria can use ammonia as their sole N-source while others have substantial improvement in bacterial protein yields when supplemented with preformed amino-acids, showing that some bacteria have a requirement for amino acids and or peptides (Bryant and Robinson, 1962; Hume and Brid, 1970; Maeng et al., 1976).

Selenomonas ruminantium, *Bacteroides ruminicola*, *Megasphaera elsdenii*, *Streptococcus bovis*, and *Butyrivibrio fibrisolvens* are found in the rumen in large quantities under various feeding conditions, and differ in response to NPN and amino

acid levels in the rumen. *Bacteroides ruminicola* and *Megasphaera elsdenii* yields were not affected by a reduction to amino acid supply in the rumen, while removal of amino acids from the diet greatly suppressed *Selenomonas ruminantium* and *Streptococcus bovis* (Cotta and Russell, 1982).

Microbial protein synthesis provides for 50 to 80% of the protein that is supplied to the small intestine of the ruminant (Storm and Ørskov, 1983). Blood urea nitrogen (BUN) is a useful indicator of the protein utilization and status of an animal. There is a strong linear relationship between BUN and nitrogen excretion in several species, therefore, BUN may be used as an indicator of nitrogen utilization, fecal nitrogen, and intake nitrogen with estimates of intake, retention and digestibility of diets (Kohn et al., 2005).

Transfer of endogenous BUN into the rumen supplies substantial quantities of nitrogen to ruminal microorganisms (Egan, 1980). Approximately 40 to 80% of the urea-nitrogen synthesized in the liver is returned to the gut to support microbial protein synthesis (Harmeyer and Martens, 1980). The total proportion of BUN incorporation into the microbial population of the rumen is inversely linked to the level of protein intake (Bunting et al., 1989), and nitrogen intake in growing cattle is correlated with hepatic ureagenesis ($r^2 = 0.58$) with synthesis ranging from 49 to 178% (mean of 93%) of digested nitrogen (Lapierre and Lobley, 2001). The magnitude of reuptake by the rumen of urea as a nitrogen source for the synthesis of the microbial population has been suggested to be driven by BUN concentration (Harmeyer and Martens, 1980); however, contrasting data indicates that concentration dependent transfer across portal

drain viscera is only applicable at a 4 mM plasma urea concentration for cattle (Lapierre and Lobley, 2001; Lobley et al., 1998).

As supplementation of ruminal degradable protein increased there was a linear increase ($P < 0.006$) in production and gut entry of urea, microbial flow of nitrogen ($P < 0.001$), and incorporation of recycled urea-nitrogen was greater when protein was supplemented less frequently in higher quantities (Farmer et al., 2004; Wickersham et al., 2008).

CHAPTER 3

EFFECTS OF FEEDING PERENNIAL PEANUT HAY ON GROWTH, DEVELOPMENT, ATTAINMENT OF PUBERTY, AND FERTILITY IN BEEF REPLACEMENT HEIFERS

In the beef cattle industry two thirds of the annual cost of production is associated with the cost of feed (Arthur et al., 2001) emphasizing the importance of successful replacement development to minimize the time a heifer enters a herd until she becomes a productive cow. For this to occur, replacement heifers must be well managed to optimize their lifetime productivity and future profitability of all females.

Critical analyses of nutritional and reproductive factors that influence the growth and reproductive maturation of replacement heifers have revealed benchmarks that serve as guidelines for beef heifer development that most producers adhere to. Decades of research have led to the conclusion that BW (Nelsen et al., 1982), body composition (Buckley et al., 1990), age (Laster et al. 1972), and genetics (Baker et al., 1989) are critical components to the attainment of puberty. Selection by producers can control age at which a replacement heifer enters the development program, in addition to genetics, allowing the remaining factors that affect puberty to be managed nutritionally.

In the southeastern United States, typical rations that are used for heifer development scenarios are not available due to limitations of commodities and lack of availability of high quality legume forage. Thus, alternative feeds are being explored as an option for replacement heifer diets. A forage source that is gaining popularity and availability is perennial peanut forage (*Arachis glabrata* Benth.). As a warm season legume, it is grown in the southeastern United States for use as hay, silage, and improved pasture land. Similar to alfalfa (*Medicago sativa* L.) in nutritive value and appearance (Myer et al., 2009), perennial peanut forage has typical yields of 1,145 to

1,908 kg per hectare, with approximately 12,140 hectares being planted in North Florida and South Georgia (Hill, 2002; Newman et al., 2009). Thus, perennial peanut hay has potential for incorporation into replacement heifer feeding strategies due to its increasing availability in the southeastern United States and high nutritive values (TDN = 60%; CP = 14%; Myer et al., 2009).

The objective of this study was to determine the influence of supplemental feeding of perennial peanut hay on growth performance and age at puberty in growing beef cattle heifers. It was hypothesized that heifers receiving perennial peanut hay as their supplementation would have similar or improved growth performance and attain puberty at a similar age compared to contemporaries supplemented with a grain-based concentrate supplement.

Materials and Methods

Animals and Treatments

All animal handling and care was approved and performed according to Institutional Animal Care and Use Committee guidelines under protocol 200902813 and funded by the USDA TSTAR-C grant (project number FLA-NFC-0049934). During two heifer development and breeding seasons 120 *Bos indicus* × *Bos taurus* crossbred, spring-born heifer calves at the North Florida Research and Education Center in Marianna, Florida (30.8406191 Lat. and -85.1659651 Long.) were used for this study. The climate at this location is subtropical/ temperate, with hot humid summers and cool winters. Breeds origin of crossbred heifers were Angus, Brahman, Charolais, Beefmaster, and Romosinuano. The mean age of the heifers at the initiation of year 1 (Yr1) was 270 ± 21.7 d (mean \pm SD) of age (DOA) and mean body weight (BW) was 244 ± 23.7 kg (mean \pm SD), in year 2 (Yr2) the mean DOA was 255 ± 23.9 d (mean \pm

SD) with a mean body weight (BW) 226 ± 29.7 kg (mean \pm SD). Heifers were weaned on August 28, 2009 for Yr1 and on July 29, 2010 for Yr2. All heifers were managed as a single herd from weaning until the initiation of the experiment (d 0) on October 20, 2009 (Yr1) and October 19, 2010 (Yr2). The experiment consisted of two separate phases: the development phase (d 0 to 140; phase in which treatments were applied) and the breeding phase (d 141 to 224; phase in which heifers were comingled for breeding).

A generalized randomized complete block arrangement was used with pen serving as the experimental unit, with 5 heifers per pen for 12 pens, resulting in 4 replicates per year per treatment. Within year, heifers were blocked by weight and pen (1.3 Ha paddock with limited to no forage availability for grazing and no shelter), and then randomly assigned to one of three treatments: perennial peanut hay (*Arachis glabrata* Benth.) supplementation (PPH), 80% Corn and 20% soybean meal (44%) supplement (CSBM), or no supplement control (CON). The CSBM was fed to average $1.23 \text{ kg} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$ and the PPH was fed at $2.74 \text{ kg} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$ (DM basis) of each respective supplement (Table 3-1). All heifers received ad libitum access to water via automatic troughs and bermudagrass (*Cynodon dactylon* (L.) Pers.) hay (BGH) fed round bales in ring feeders.

A complete mineral supplement was provided for ad libitum consumption but formulated for $0.11 \text{ kg} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$ daily intakes. Mineral supplement for PPH differed from that for CON and CSBM to account for differences in mineral levels supplied by the diets (Table 3-2).

Each year, every 28 d during the developmental phase, heifers were fasted for at least 16 hr prior to measurement of BW, body condition scoring (BCS), and collection of

blood samples (Figure 3-1). The BCS was assigned by the same trained individual for both years of the experiment, and was based on a 1 to 9 point scale (1 = emaciated to 9 = obese; Wagner et al., 1988). All heifers received dietary supplement treatments for a 140-d developmental phase, prior to the initiation of the breeding phase.

In Yr2, on d 28 a heifer from the control treatment was removed from the study because of an injury. She was replaced with a heifer of similar BW and age. Data from the replacement heifer was not included in statistical analyses. In addition, in Yr2 a second heifer from the control treatment died during the breeding season phase; therefore, data associated with the development phase was included for statistical analyses, in addition to puberty data, as she reached puberty before death. All other fertility data was excluded from the analyses. All weather data was reported as means of the 28 d periods as indicated by the Florida automated weather network for the Marianna, Florida location.

Feed Sample Collection and Analysis

Near infrared reflectance spectroscopy (NIR) was used for analyses of dry matter (DM), crude protein (CP), total digestible nutrient (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF), calcium (Ca), and phosphorous (P) on all representative samples of supplements and BGH prior to the initiation of the experiment each year (Dairy One Forage Laboratory, Ithaca, NY). Rations were formulated to be offered on an isocaloric basis assuming constant daily DMI and assuming that differences in BGH intake, accounting for differences in supplement TDN intake to meet the requirements of a 230 kg beef heifer growing at 0.5 to 0.7 kg per day (NRC, 2000). Heifers in the CSBM and PPH treatments received supplements in each pen 3 x per week (Monday, Wednesday, and Friday). Ad libitum access to BGH was allowed for all treatments

throughout the development phase. After completion of the development phase all heifers received $1.81 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$ of 50% corn gluten and 50% soybean meal supplement (Table 3-3), with ad libitum access to BGH and water for 13 d (Yr1) or 21 d (Yr2) until annual ryegrass (*Lolium perenne* L.) pastures had sufficient growth to support all heifers grazing together until completion of the breeding season.

Weekly samples of the PPH were taken from each pen to determine average weekly DM of the PPH supplement and a monthly composite sample of the CSBM was taken to determine monthly DM percentage of CSBM delivered. All samples were bagged and frozen immediately after collection until drying.

Bermudagrass hay round bales were individually weighed, with four core samples taken on the same day the weight was recorded and composited. Samples were stored for future analysis following grinding and composition. Orts were collected for each individual round bale and subsampled for DM analysis to determine DM disappearance in each pen.

All feed samples analyzed for nutritive values were dried at 55°C for 48 hr in a forced air oven. Orts were dried at 100°C for 72 hr because of their higher moisture content. At the conclusion of the drying period all samples were ground in a Wiley mill (Arthur H. Thomas Company, Philadelphia, PA, USA) using a 1.0 mm screen.

After grinding, samples were composited for analysis on an equal weight basis. Core samples from bermudagrass bales fed within a 28-d period were composited within each pen and then composited among pens within each 28-d period. These samples were combined into a yearly sample of round bale cores to be analyzed for the

developmental phase. In Yr1 116 round bales were fed with a mean DM weight of 344 ± 41.6 kg and in Yr2 79 round bales with DM weight of 421 ± 65.2 kg were delivered.

Similarly, DM was analyzed for the weekly PPH samples that were taken from each pen. Samples were ground and composited into a weekly sample which was composited by 28-d period, with each 28-d period sample combined into a single PPH sample to determine the nutritive value of PPH supplement for each year.

Representative samples of CSBM were taken every 28-d of the feeding phase of each year and were analyzed for DM and composited to generate a single CSBM supplement sample for nutritive analysis across all experimental units for this treatment. All nutritive value samples (round bale cores, CSBM, PPH, and ryegrass) were analyzed for DM, CP, TDN, ADF, NDF, Ca, and P in duplicate by a commercial laboratory using NIR procedures (Dairy One Forage Laboratory, Ithaca, NY).

Blood Collection and Analyses

Blood samples were collected weekly for analysis of progesterone concentrations. In addition, blood samples were collected every 28-d for analysis of blood urea nitrogen (BUN) concentrations. Blood was collected via jugular or coccygeal venipuncture using 10 mL glass vials containing 143 IU units of Na heparin (BD Diagnostics, Franklin Lakes, NJ). All blood samples were placed on ice following collection, and then centrifuged for 18 min at $4,000 \times g$ at 4°C . After centrifugation a pipette was used to siphon plasma into polypropylene vials (12mm x 75mm; Fisherbrand; Thermo Fisher Scientific Inc., Waltham, MA) which were stored at -20°C until analyses.

Concentrations of plasma progesterone were determined by competitive binding enzyme-linked immunosorbant assay (ELISA) to determine pubertal status. The ELISA procedure was adopted from that previously described by Rasmussen et al. (1996).

Quality controls were established using 100 µl plasma with a known progesterone concentration of 2.5 ng/mL. Standards were determined with 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, and 20.0 ng/mL concentrations with a duplicate of each respective standard. Assay sensitivity for a 100 µL sample was 0.1 ng/mL. Pooled samples revealed that the intra- and inter-assay coefficient of variation were 7.0% and 19.0% for 29 assays, respectively.

Analysis of BUN was determined via a QuantiChrom™ Urea Assay Kit (DIUR-500; BioAssay Systems, Hayward, CA). No dilution was used during the analysis and samples were not deemed to be low value samples. Standard samples revealed that the intra- and inter-assay coefficient of variation was 2.0% and 5.4% for 22 assays, respectively for BUN analysis.

Assessment of Puberty

To determine puberty, the first increase in progesterone (evidence of first pubertal ovulation) that exceeded 0.5 ng/mL followed by a progesterone pattern consistent with normal estrous cycles was the criteria used for assessing age at attainment of puberty (Perry et al., 1991). Age of puberty (AOP) was defined as the age of the heifer at the first rise in progesterone. Weight at puberty was the BW associated with the onset of puberty and was calculated using average daily gain (ADG) during the 28-d period associated with the onset of puberty. The equation for weight at puberty was: last 28-d weight before onset of puberty + (average daily gain during the 28-d period associated with onset of puberty × days from last 28-d weight to onset of puberty). For both Yr1 and Yr2, weight data collection ceased on d 224 after initiation of heifer development and coincided with the last week of the breeding phase. Blood collection ceased 21 d following. All heifers that had not attained puberty were assigned an onset of puberty

age to coincide with the last day of the data collection period (d 245). In Yr1 4 heifers had not attained puberty and in Yr2 7 heifers had not attained puberty prior to the conclusion of the study.

Temperament Characteristics

In Yr2, chute score (CS), exit velocity (EV), and pen score (PS) were temperament traits that were evaluated using procedures previously described by Arthington et al. (2008). Chute score and EV were assessed every 28 d and PS was assessed on d 84 and 140 of the development phase. The subjective measurement of the behavioral response to restraint within the squeeze chute (CS) was assigned on a 1 to 5 scale (1 = calm, docile, and quiet; 2 = restless; 3 = nervous; 4 = excited and flighty; 5 = aggressive) by a trained evaluator. Exit velocity was the speed (m/s) at which each heifer exited the squeeze chute and passed by LED optical sensors placed at a distance of 1.83 m apart. Pen Score was a subjective measurement of the animal's behavioral response to isolation in the pen with a handler present. Three trained evaluators assigned scores on a 1 to 5 scale (1 = calm, docile, and quiet; 5 = aggressive) that were used to compute a mean score for each animal.

Reproductive Management

During Yr1 and Yr2, on d 140 (the conclusion of the development phase) the breeding phase was initiated (Figure 3-2) by comingling all heifers and managing them as a single herd. On that day, each heifer received a 25 mg intramuscular (i.m.) injection of prostaglandin (PGF_{2α}) and an Estroject™ heat detection aid (Rockway Inc, Spring Valley, WI) was placed on the tailhead of each heifer to assist with detection of estrus. Estrus detection was performed 2x per day at 0700 and 1600 hr for 45 min during each session. Each heifer detected in estrus was inseminated artificially by an

experienced technician using the AM/PM rule (Larson et al., 2009). Heifers that were not detected in estrus within 11 d of the initial injection of PGF_{2α} received a second 25 mg injection of PGF_{2α} i.m. followed by detection of estrus for a further 6 d. Natural service sires were introduced into the herd 17 d after initiation of the breeding phase, and remained in the herd for 60 d. In Yr1 two mature sires were used and in Yr2 three yearling sires were used, all sires passed a breeding soundness exam before introduction into the herd.

Pregnancy was diagnosed using transrectal ultrasonography (5.0-MHz linear array transducer, Aloka 500V, Corometrics Medical Systems, Inc., Wallingford, CT) on d 47 of the breeding phase to confirm pregnancy to AI. Final pregnancy rates were reported based on a 77-d breeding phase for Yr1 and Yr2 (17d of AI and 60d of natural service), with final pregnancy diagnosis being performed on d 107, 30 d following the conclusion of breeding season.

Statistical Analysis

Average daily gain was calculated using two ADG calculation methods: 1) as the mean of the ADG of each period (or total ADG from d 0 to 140) divided by d on feed (OADG); and 2) by regressing the BW against period and calculating the slope of the regression line (RADG). The resulting ADG values were compared using the PROC CORR procedure of SAS (SAS Inst. Inc., Cary, NC.) to determine the correlation coefficients between the two calculations.

Developmental phase data including: ADG, BW, BCS, and BUN, in addition to temperament data were analyzed by analysis of variance for repeated measures using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC.). The final statistical model was:

$$Y_{ijkm} = \mu + \alpha_i + T_m + \beta_k + (\alpha\beta)_{ik} + (\alpha\tau)_{mi} + (\alpha\beta\tau)_{ikm} + e_{ijkm}$$

where:

Y_{ijkm} = Animal performance characteristic (ADG, BW, BCS, or BUN) from i^{th} treatment, of the j^{th} pen, on the k^{th} day (or period), from the m^{th} year

μ = overall mean

α_i = fixed effect of i^{th} treatment

β_k = fixed effect of k^{th} day (or period)

T_m = random effect of year

$(\alpha\beta)_{ik}$ = treatment \times day (or period) interaction

$(\alpha\tau)_{mi}$ = treatment \times year interaction

$(\alpha\beta\tau)_{ikm}$ = treatment \times day (or period) \times year interaction

e_{ijkm} = random error associated with measurement of the k^{th} day (or period), on the j^{th} pen, assigned to the i^{th} treatment of the m^{th} year

The repeated measures statement included pen within year as the subject and were analyzed for d 0, 28, 56, 84, 112, and 140. Year was considered a random effect.

All total DMI (total, supplement, and BGH) and nutrient intake (TDN and CP), percent of DMI of total BW, and cost of gain, were analyzed using the PROC MIXED procedures of SAS (SAS Inst. Inc., Cary, NC.). In addition, initial and final BW and BCS, and fertility data including age at puberty, weight at puberty, BCS at puberty, and days on treatment to puberty. Fetal age and pregnancy rates within pen were analyzed using the same model. Year and pen were considered random effects, with treatment and day being the main effect. The statistical model was:

$$Y_{ij} = \mu + \alpha_i + \beta_k + e_{ij}$$

where:

Y_{ij} = Performance characteristic (intake, BW, BCS, fertility, or temperament) from i^{th} pen, assigned to the j^{th} treatment

μ = overall mean

α_i = fixed effect of j^{th} treatment

β_k = random effect of year

e_{ij} = random error associated with measurement of the i^{th} pen, assigned to the j^{th} treatment

In all cases in which covariance analyses were utilized, autoregressive, toeplitz, unstructured, and compound symmetry covariance structures were assessed for best fit. The autoregressive structure was revealed to be the best fit.

The procedure LIFETEST was used for survival analyses on the age at puberty, days on treatment to puberty, and fetal age with the resulting statistical model:

$$S(t) = \Pr(T_{ij} > t)$$

Where:

S = the survival function

T = random response variable of the i^{th} heifer from the j^{th} pen

t = Time (d) until T is achieved

\Pr = probability that time of T is later than time t

For all analysis, statistical differences were reported at $P < 0.05$, tendencies were identified at $P = 0.06$ to $P = 0.1$, and interactions were reported to be statistically different at $P < 0.1$ with means being reported as LS means \pm SE.

Results and Discussion

Feed Intake

Intake of BGH differed ($P < 0.01$) among treatments with heifers in the CON treatment ($3.5 \pm 0.37 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) consuming greater ($P < 0.05$) quantities of BGH than CSBM ($3.0 \pm 0.37 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) and PPH ($2.6 \pm 0.37 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) treatments. Similarly total TDN and CP intake from BGH differed ($P < 0.05$) by treatment; intake of TDN and CP for heifers in the CON treatment ($0.40 \pm 0.038 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; $0.09 \pm 0.016 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; for TDN and CP, respectively) was greater ($P < 0.05$) than CSBM ($0.35 \pm 0.038 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; $0.08 \pm 0.016 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), and PPH ($0.30 \pm 0.038 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; $0.07 \pm 0.016 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) treatments. The TDN and CP intake were also greater ($P < 0.05$) for CSBM than PPH (Table 3-4).

Within the two treatments receiving supplementation (CSBM and PPH), DMI of supplement during the development phase was greater ($P < 0.001$) for heifers in the PPH treatment ($2.8 \pm 0.18 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) than the CSBM treatment ($1.2 \pm 0.18 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$). Similarly, TDN ($0.33 \pm 0.021 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$ and $0.21 \pm 0.021 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$ for PPH and CSBM, respectively) and CP ($0.08 \pm 0.008 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$ and $0.05 \pm 0.008 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$ for PPH and CSBM, respectively) intake was greater ($P < 0.01$) for heifers fed PPH than those fed CSBM.

Average total DMI during the development phase, including DMI from supplement and BGH, was affected by treatment ($P < 0.0001$; Table 3-4). Heifers in the CON treatment, consuming only BGH, had the least total DMI ($3.4 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), and consequently the least total TDN ($P < 0.0001$; $0.39 \pm 0.024 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) and CP ($P < 0.0001$; $0.09 \pm 0.017 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) intake. This reduced DMI was likely associated with physical fill effect (Forbes, 1996), because diets exceeding an NDF content of 25%,

such as the BGH, have been shown to decrease DMI (Allen, 2000) due to physical fill effect. Since BGH was the sole source of nutrient intake for CON pens, its high NDF concentration possibly limited the rate of passage of feed from the rumen, causing a lengthened satiety signal and thereby limiting intake, a factor likely affecting not only the CON heifers, but all heifers because of their ad libitum access to BGH.

The NDF, ADF, TDN, and CP concentrations of the PPH used as supplement for the PPH treatment (Table 3-2) were similar to previously reported values (Foster et al., 2009; Myer et al., 2009). Heifers in the PPH treatment pens consumed a total forage diet of BGH and PPH resulting in the greatest total DMI ($5.3 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), total TDN ($P < 0.01$; $0.63 \pm 0.024 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), and CP ($P < 0.0001$; $0.14 \pm 0.017 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) intake. In addition, PPH heifers consumed the greatest daily DMI as a percentage of their BW ($P = 0.001$; $2.0 \pm 0.07\%$) compared to CON ($1.4 \pm 0.07\%$), and CSBM ($1.6 \pm 0.07\%$) heifers. Dry matter digestibility has an influence on ruminal physical fill by the physical presences of feedstuffs within the rumen, and thus can regulate DMI. Previous research showed a significant interaction between forage type and DMI, such that DMI was greater in legumes than grasses due to fragility of plant matter reducing retention time in the rumen (Waghorn et al., 1989; Oba and Allen, 1999). This decreased retention time is due to relative differences in digestibility, with the legumes hay-supplement having the structural fiber concentrations and morphological characteristic that that result in decreased NDF and ADF, consequently being more digestible (Foster et al., 2009). The greater DMI of heifers supplemented with a legume (PPH) is supported by reports indicating increased DMI and organic matter digestibility when poor quality forages were supplemented with legumes in feeding scenarios (Minson and

Milford, 1967; Getachew et al., 1994; Foster et al., 2009) creating a synergistic associative effect. This associative effect of feeding a 100% forage diet possibly modified the metabolic processes in the digestive tract, and created positive digestive interactions (Niderkorn and Baumont, 2009; Niderkorn et al., 2011), such that the response of the heifer to a combination of forages differed from the response to the individual forages.

Heifers receiving the CSBM treatment had intermediate total DMI intake ($P < 0.01$; $4.3 \pm 0.25 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), resulting in intermediate total TDN ($0.56 \pm 0.024 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) and CP intake ($0.13 \pm 0.017 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$). This could be explained through the hepatic oxidation theory, in which total body energetics work as an intake regulator. Volatile fatty acid profiles are strongly correlated to the type of feed being consumed (Allen, 2000), such that animals consuming a diet which will shift the acetate to propionate ratio in favor of propionate, typically a diet including non-structural carbohydrates, tend to have reduced DMI (Illius and Jessop, 1996; Allen, 2000). Thus, with propionate being the primary precursor to gluconeogenesis in the liver, increased propionate absorption in the rumen likely increases insulin secretion (Grovmum, 1995), triggering satiety. Another proposed explanation of HOT suggests receptors in the liver exist that are sensitive to propionate and have afferent fibers in the hepatic plexus (Anil and Forbes, 1980).

Animal Growth and Performance

For the two methods used to calculate ADG, Pearson correlation coefficient analyses revealed that both methods of ADG were highly correlated ($r^2=0.99$; $P < 0.0001$). For all subsequent analyses the OADG calculation for ADG was used as the

preferred method. No treatment \times period interactions were detected for ADG, but treatment (Table 3-4) and period influenced ADG (Figure 3-3).

There was a tendency ($P = 0.06$) for the CON-treated heifers ($0.18 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) to have lesser ADG than the PPH and CSBM, which was likely a direct result of the reduced total DMI, TDN, and CP intake during the developmental phase. While the PPH-treated heifers ($0.46 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) had significantly greater total DMI, TDN, and CP intake, their ADG did not differ from the CSBM-treated heifers ($0.48 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), suggesting improved efficiency of nutrient utilization the CSBM heifers. Typically the passage rate from the rumen increases in conjunction with increasing DMI, resulting in a decrease in ruminal propionate proportions (Harrison et al., 1975, 1976). Therefore, the greater DMI of the PPH pens, without resulting in greater ADG differing energy density of feeds. In addition, this may be resulted in decreased ruminal propionate proportions and increased acetate:propionate ratios. This decrease in propionate could result in a decrease in availability of gluconeogenic precursors within the liver (Allen, 2000). Ruminal fermentations are less efficient in most legume-supplemented diets, compared to concentrate-supplemented diets, because greater dilution rates reduce total metabolic hydrogen recovery into VFA. Thus, having the greater rate of passage from the rumen of forage diets can reduce the amount of ruminal digestion taking place and nutrient capture (Chalupa, 1977).

The effect of period was noted when ADG declined from d 0 to 84 (d 0 to 28 = $0.43 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; d 28 to 56 = $0.20 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; d 56 to 84 = $0.17 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$), peaking from d 84 to 112 ($0.67 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$) and being intermediate from d 112 to 140 ($0.38 \pm 0.11 \text{ kg}\cdot\text{hd}^{-1}\cdot\text{d}^{-1}$; Figure 3-3). The decline noted in the first 84

d of the development phase could be attributed to decreased temperatures, causing increased maintenance requirements of the heifers due to cooler weather (Baile and Della-Fera, 1981; Young, 1983; Birkelo et al., 1991; Figure 3-9). In addition, supplementation amounts were not adjusted during the developmental phase. Thus, as heifers increased in BW, a greater proportion of their nutrient requirements were being met through the intake of BGH in the supplemented heifers. Diets that are low in nutrient density and with reduced rate of digestion may result in decreased DMI, which could account for the decrease in ADG for the final 28-d period in all treatments.

There was no difference in initial BW (d 0; $P = 0.98$) among treatments. Mean BW throughout the development phase was not affected by treatment, however there was a treatment \times day interaction ($P = 0.06$) for BW. The rate of increase of BW for the CON was at a lesser rate than the supplemented heifers. The BW of CON from d 0 was 234 ± 16.9 kg and on d 140 was 260 ± 16.9 kg, and when compared to the PPH (d 0 = 236 ± 16.9 kg; d 140 = 300 ± 16.9 kg), and the CSBM heifers (d 0 = 237 ± 16.9 kg; d 140 = 303 ± 16.9 kg; Figure 3-4) the CON heifers gained at a slower rate. Final BW on d 140 was affected by treatment ($P = 0.05$), with CON being lightest on d 140 (260 ± 24.2 kg), and no differences observed between CSBM (303 ± 24.2 kg) and PPH heifers (300 ± 24.2 kg; Table 3-4).

Initial BCS (d 0) did not differ across treatments ($P = 0.85$). Throughout the development phase there was no effect of treatment, day, or treatment \times day interaction on mean BCS. However, mean BCS on d 0 (5.2 ± 0.13) tended ($P = 0.64$) to be greater than BCS on d 56 (4.9 ± 0.13), d 84 (5.0 ± 0.13), d 112 (4.9 ± 0.13), and d 140 (4.9 ± 0.13 ; Figure 3-5). Final BCS (d 140) differed ($P = 0.003$) with CON having the lesser

BCS (4.6 ± 0.15) than the supplement treatments, which did not differ (CSBM = 5.1 ± 0.15 ; PPH = 5.2 ± 0.15). The decrease in BCS in the CON heifers is attributable to the differences in caloric intake and treatment \times day interaction in BW.

Concentrations of BUN were similar to those reported by Cooke et al. (2008) for animals of a similar physiological status, and were within the normal physiological range (Kaneko, 1989). The mean concentrations of BUN for CON, CSBM, and PPH were 21.02 mg/dL, 21.68 mg/dL, and 22.08 mg/dL, respectively, with no treatment \times day ($P = 0.966$), treatment ($P = 0.669$), or day ($P = 0.231$) differences detected (Table 3-4). Optimal concentrations of BUN have been reported to be 11 to 15 mg/dL in growing heifers (Byers and Moxon, 1980), indicating that these heifers consumed a diet exceeding CP requirements.

Strong linear relationships between BUN concentrations and rate of nitrogen excretion were reported in animals of several species (Kohn et al., 2005). The concentration of BUN was positively correlated between rumen degradable protein, level of ruminal ammonia and ruminal protein:energy ratio (Hammond, 1997). Typically, feeding of forages, such as BGH, decreases the digestibility of the protein, with reduced protein degradation in the rumen resulting in the absorption of nitrogen across the ruminal wall and into the blood stream (Kohn et al., 2005). However, with CSBM and PPH pens having increased CP intake and no difference in BUN concentrations, the effect of nutrient synchrony may have resulted in similar concentrations of BUN, with N being incorporated into microbial protein, in contrast to being absorbed into the blood stream.

Typically legume-supplemented cattle have increased ruminal $\text{NH}_3\text{-N}$ concentrations because with most of the protein in legumes is in the form of soluble protein or rumendegradable protein (Broderick, 1995). However, because treatment and total CP intake did not alter concentrations of BUN, all diets may have supplied adequate energy and $\text{NH}_3\text{-N}$, resulting in improved microbial efficiency and protein synthesis (Clark et al., 1992; Macrae et al., 2006). In addition, increased N intake and improved digestion and retention were observed when perennial peanut hay was supplemented to lambs (Foster et al., 2009). This is in contrast to when grass hay diets that were supplemented with legumes, and did not meet the ruminant energy and N needs to optimize microbial synthesis (Mosi and Butterworth, 1985; Matizha et al., 1997).

While the PPH heifers had the greatest total CP intake, with similar concentrations of BUN in this study could possibly be explained by the presence of condensed tannins (CT) in the PPH supplemented heifers. Condensed tannins have the ability to react with supplemented plant proteins to form stable complexes and reduce their degradation in the rumen. Condensed tannins have been shown to eliminate $\text{NH}_3\text{-N}$ production at 3.5 hr of incubation during an in vitro study when legumes were fermented with grasses (Niderkorn et al., 2011). Thus, with a 3.82% concentration of CT on a DM basis previously reported in perennial peanut hay (Foster et al., 2009). While current samples of PPH were not analyzed for CT concentrations, their presences could have resulted in an increase in the N flowing from the rumen (a result of decreased ruminal digestion; Aufrere et al., 2008) due to the associative effect of CT concentrations in the PPH treatment may have reduced the $\text{NH}_3\text{-N}$ production in the rumen. In addition, with the

BUN concentration of the CSBM not differing from the CON heifers could be a result of a decrease in ruminal digestions in the CSBM heifers, due to increased rate of passage (Chalupa, 1977).

Total cost of feed for the entire trial was \$2,653.38 for CON, \$4,648.30 for CSBM, and \$6,605.75 for the PPH heifers. To calculate cost of gain, the mean of the actual purchase price of feed and supplements for each year was used for each pen every year. Purchase prices were as follows (all on an as fed basis): PPH hay was valued at \$242.61/tonne for Yr1 and Yr2, CSBM supplement was valued at \$299.83/tonne for Yr1 and \$390.21/tonne for Yr2, and BGH was valued at \$99.02/tonne for Yr1 and Yr2, all on an as-fed basis. The cost of feed per head per day was different ($P < 0.001$) for treatments with CON being the least ($\$0.48 \pm 0.021$), CSBM being intermediate ($\$0.83 \pm 0.021$), and PPH being greatest ($\$1.17 \pm 0.021$). Cost of weight gain was \$2.67 per kg gain for CON, \$2.54 per kg gain for PPH, and \$1.73 per kg gain for CSBM (Table 3-4). It can be noted that high quality square bales which had been housed under a barn were used for the perennial peanut hay. In a practical beef cattle production scenario feeding of large round bales would reduce costs. The reduced cost of weight gain for the CSBM heifers, with similar labor in this feeding scenario make it the most economically sound choice for beef cattle producers.

Fertility

The mean age at puberty for CON (446 ± 11.1 d), CSBM (423 ± 11.1 d), and PPH (439 ± 11.1 d; Table 3-5) was not affected by treatment ($P = 0.322$). This agreed with survival analysis which indicated no differences in age of puberty ($P = 0.167$).

Nutritional management has an impact on the attainment of puberty, with heifers on a low plane of nutrition having delayed puberty (Day et al., 1986), particularly in breeds

known to be later maturing (Berg and Walters, 1983) such as *Bos indicus* crosses of cattle. However, in this experiment, with no delay in puberty in the CON treatment compared to the supplemented treatments (PPH and CSBM), the plane of nutrition provided to the heifers may have been sufficient to prevent delaying the attainment of puberty. In addition, feed efficiency may influence the attainment of puberty since heifers that had greater (less efficient) RFI values had decreased age at puberty (Shaffer et al., 2010). However, in the current study no differences between CSBM and PPH heifer ADG was detected, whereas heifers in the CSBM had lower total DMI, indicating that they may have been more efficient without altering age at puberty.

The days on treatment, or days from the initiation of the development phase, when supplementation began, until heifers reached puberty, was no effect of treatment ($P = 0.424$) on the mean age at attainment of puberty. In addition, analysis of the distribution through survival analysis reported no difference ($P = 0.140$) among treatments. The average interval to attainment of puberty was similar for CON (183 ± 8.5 d), CSBM (163 ± 8.5 d), and PPH (175 ± 8.5 d) heifers. It appears that heifers in the CON treatment were receiving adequate energy to support the energy triggers on LH release required for the attainment of puberty at a similar age as CSBM and PPH heifers (Rhodes et al., 1978; McCartor et al., 1979; Day et al., 1986).

Weight is a primary factor affecting age of puberty (Joubert, 1963). The CON (292 ± 12.2 kg), PPH (324 ± 12.2 kg), and CSBM (316 ± 12.2 kg) heifers did not differ in weight at puberty ($P = 0.164$), despite the occurrence of differences in their ADG and DMI. Mean BW of lactating, non-pregnant cows from within the herd is 585 kg (not including cows over 10 years of age or first calf heifers). It was suggested that heifers

will reach puberty at 60% to 66% of their mature BW (Patterson et al., 1992). However, CON heifers reached puberty at 50% of their mature BW, CSBM at 54% and PPH at 55%, a possible result of time and rate of gain (Lynch et al., 1997).

When heifers were fed to gain most of their weight in the final 90 d of the development phase, compared to heifers gaining at a steady rate, there was no effect of delayed ADG on age and weight at attainment of puberty (Clanton et al., 1983). This allows for heifers to be managed such that minimum feed inputs are used through the development phase, taking advantage of compensatory gains (Lalman et al., 1993). Therefore, with the tendency for differences in ADG that were noted during the development phase not existing during the breeding phase (Table 3-4), compensatory gain may have influenced CON heifers during the breeding phase. In addition, it has been reported that the preweaning growth phase exerts a larger effect on puberty in beef heifers than does the postweaning or developmental phase (Little et al., 1981; Clanton et al., 1983). This supports our current findings as all heifers, regardless of treatment, were managed together prior to weaning, with similar weaning weights while differences in post-weaning gains existed.

In this study, there were no differences in BCS at puberty (Table 3-5), but previous reports indicate that there was a degree of fatness, or a body composition that must be achieved before puberty may be attained in replacement heifers (Grass et al., 1982; Nelson et al., 1982), however conflicting results exist as well (Brooks et al., 1985). Thus, BCS may be correlated with puberty but may not be a primary factor causing the onset of puberty. Yelich et al. (1995) reported that the percentage of BW that was lipids at puberty was independent of ADG. Thus, with heifers in the CON having lesser

ADG, they may have reached puberty at a different percentage of body fat than CSBM and PPH heifers.

Overall pregnancy rate was derived from the pregnancy diagnosis 30 d following conclusion of the breeding phase. Overall pregnancy rates were no different ($P = 0.50$) among treatments with $65 \pm 12.4\%$ for CON, $77.5 \pm 12.4\%$ for CSBM, and $87.5 \pm 12.4\%$ for the PPH. Fetal ages was determined by ultrasonography and which were similar ($P = 0.434$) for CON (38 ± 10.2 d), CSBM (51.1 ± 10.2 d), and PPH (58 ± 10.2 d) treatments (Table 3-5). In addition, survival analysis indicated no differences in fetal age ($P = 0.378$) among treatments. Thus, since heifers that become pregnant earlier in the breeding season calve earlier, and tend to continue doing so throughout their production life, having increased kilograms of calves weaned throughout their lives (Lesmeister et al., 1973), treatment should not affect lifetime productivity of the heifers. Results indicated no differences in production after first calf with no differences among treatments from Yr1 for BW of cow ($P = 0.30$), BCS of cow ($P = 0.49$), and BW of calves ($P = 0.66$) 95 d after initiation of their first calving season. Combined production data from first calf heifers and fertility data from the study, suggests that there was no effect of treatment on the current reproductive performance of the heifers.

Temperament

In Yr2 when PS was assessed on d 84 and 140 with day tending ($P = 0.06$) to influence PS (Figure 3-6). From mid-point (d 84; 2.9 ± 0.09) to the end of the development phase (d 140; 2.7 ± 0.09), PS tended ($P = 0.06$) to decline, indicating an improvement in temperament and reduced stress caused by cattle handling. Treatment influenced PS ($P < 0.05$). Heifers in the CSBM treatment (3.1 ± 0.13) were more aggressive than CON (2.8 ± 0.13) and PPH (2.5 ± 0.13) heifers (Table 3-5). This can

likely be attributed to the random assignment of aggressive animals to the same pen within CSBM treatment, causing a high mean PS throughout the development phase. Decreased growth rates (Burrow and Dillon, 1997) and reduced feed conversion efficiency (Petherick et al., 2002) has previously established to be associated with more temperamental animals. However, the CSBM heifers had the greatest PS, but their ADG did not differ from the PPH heifers, which had more docile PS.

In assessment of EV and CS on d 0, 28, 56, 84, 112, and 140 there was no treatment \times day interaction or treatment effect for either variable; however EV ($P < 0.05$; Figure 3-8) and CS ($P < 0.001$; Figure 3-7) was influenced by day. Heifers were handled in the same manor each time they were processed through the cattle working facility. Strong correlations to EV for feedlot behavior, barometric pressure, and ambient air temperatures changes from moderate to either high or low have been reported (Rittenhouse and Senft 1982; Hahn 1995), thus weather patterns could be an explanation for the effects of day on EV (Figure 3-9; 3-10; 3-11).

From d 0 to d 140, CS decreased significantly (Figure 3-7) indicating acclimation to human handling and improved temperament over time. Results reported in Brahm-crossbred cows indicated that exposure to human handling over time did not improve temperament (Cooke et al., 2009); however, this is likely because the acclimation was less intense in the latter study, with only twice weekly visits to cows on pasture. This is in contrast to the current study when heifers were exposed to human interaction three mornings per week, and processed weekly through the cattle working facility. Similarly, the acclimation of cattle to human interaction and handling reduced PS and CS, indicating improvements in temperament (Krohn et al., 2001). It is possible that age

and physiological status affect the animal's adaptations to human interaction. However, improvement in temperament could improve the reproductive performance of replacement heifers, as ill-tempered animals have heightened secretion and circulating concentrations of ACTH and cortisol (Curley et al., 2008).

Conclusion

Successful development of replacement heifers is critical in the beef industry; however the opportunity cost of developing a heifer calf into a bred heifer can be substantial. Thus, continuous research on new replacement heifer development strategies is essential. This study revealed that temperament of heifers improved with handling and human interaction. Body weight (BW), age, and body composition have all been identified as benchmarks in the attainment of puberty. However in this study there was no difference in the age, BW, and BCS at puberty existed despite differences in ADG, DMI, nutritional intakes, and mean BW despite differing. In addition, reproductive performance of the heifers was not affected by treatment.

The supplementation of PPH provided gains similar to CSBM supplemented heifers, with no difference in reproductive performance, BW, ADG, and BCS indicating that PPH is an adequate feed option for replacement heifer development in the southeastern U.S.A. However, CSBM supplementation appeared to be the most economically efficient supplement, with lesser DMI, TDN, and CP intakes resulting in apparent lesser cost of weight gain with similar BW, ADG, and BCS, and no effect on fertility. While these cost analyses may change over time with rising corn prices and in differing supplementation scenarios; this experiment reveals that PPH-supplemented heifers had similar growth and reproductive performance when compared to CSBM-supplemented heifers.

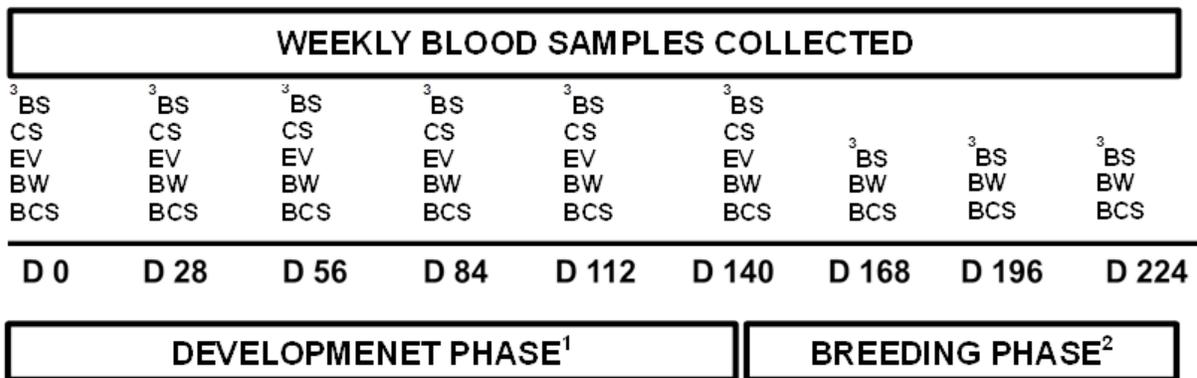


Figure 3-1. Schematic representing data collection for the development and breeding phase for heifers receiving different development diets.

¹ Development phase - development phase was initiated 140-d prior to initiation of the breeding season (supplemental treatments were being applied).

² Breeding phase - 77 d breeding season following development phase (heifers were comingles with no treatments being applied).

³ Samples collected each d; BS - blood sample, CS- chute score, EV - exit velocity, WT - fasted body weight, BCS - body condition score, and PS - pen score; CS, PS, EV were only collect during Yr2 (Year 2).

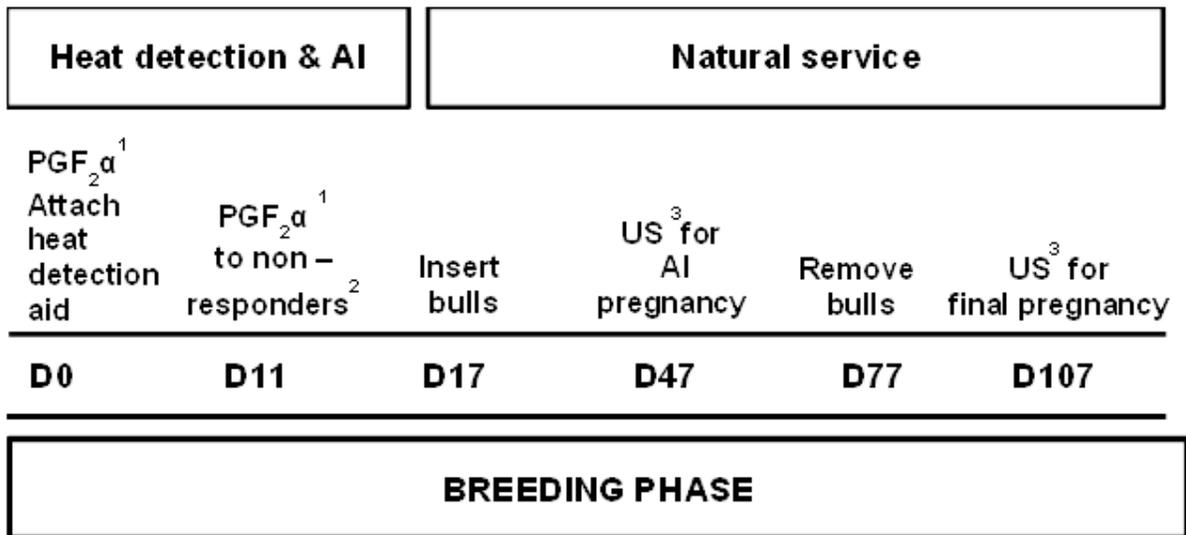


Figure 3-2. Schematic of specific breeding events during the breeding phase for heifers receiving different developmental diets.

¹ PGF₂α - Injection of 25 mg of Prostaglandin

² Non-responders - heifers that were not detected in estrus between d 0 to d 11

³ US - transrectal ultrasonography

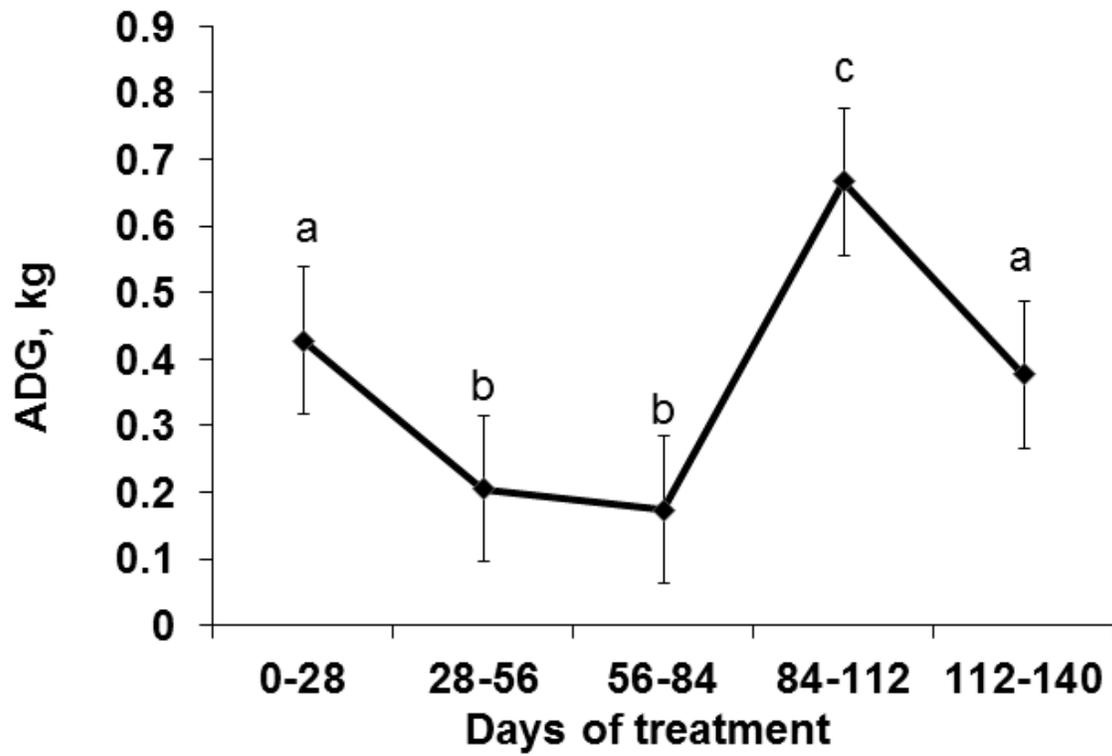


Figure 3-3. Mean ADG in kg by period for heifers receiving three different development diets. ^{a,b,c} Means differ ($P < 0.05$).

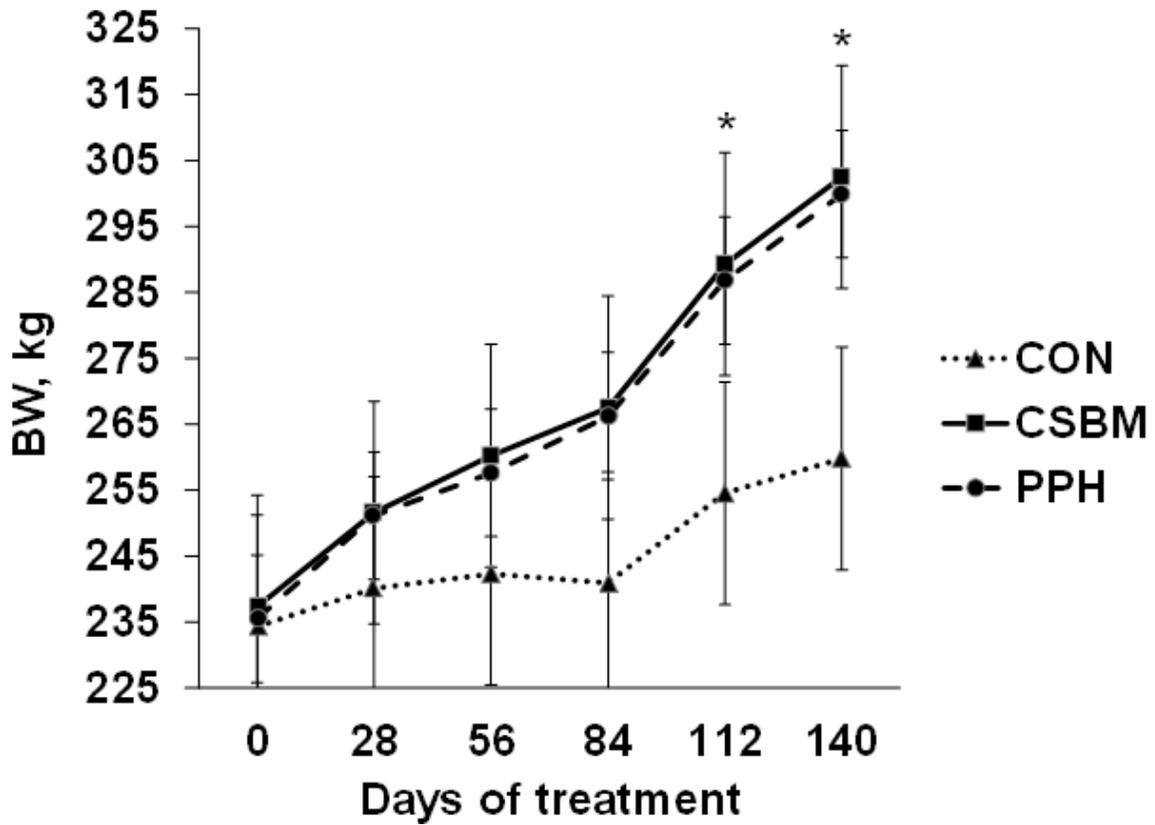


Figure 3-4. Mean BW by day for heifers receiving three different developmental diets. CON – Control, CSBM – 80% corn – 20% soybean meal supplement treatment, PPH – perennial peanut hay supplement * CSBM and PPH differ from CON on d 112 ($P < 0.05$).

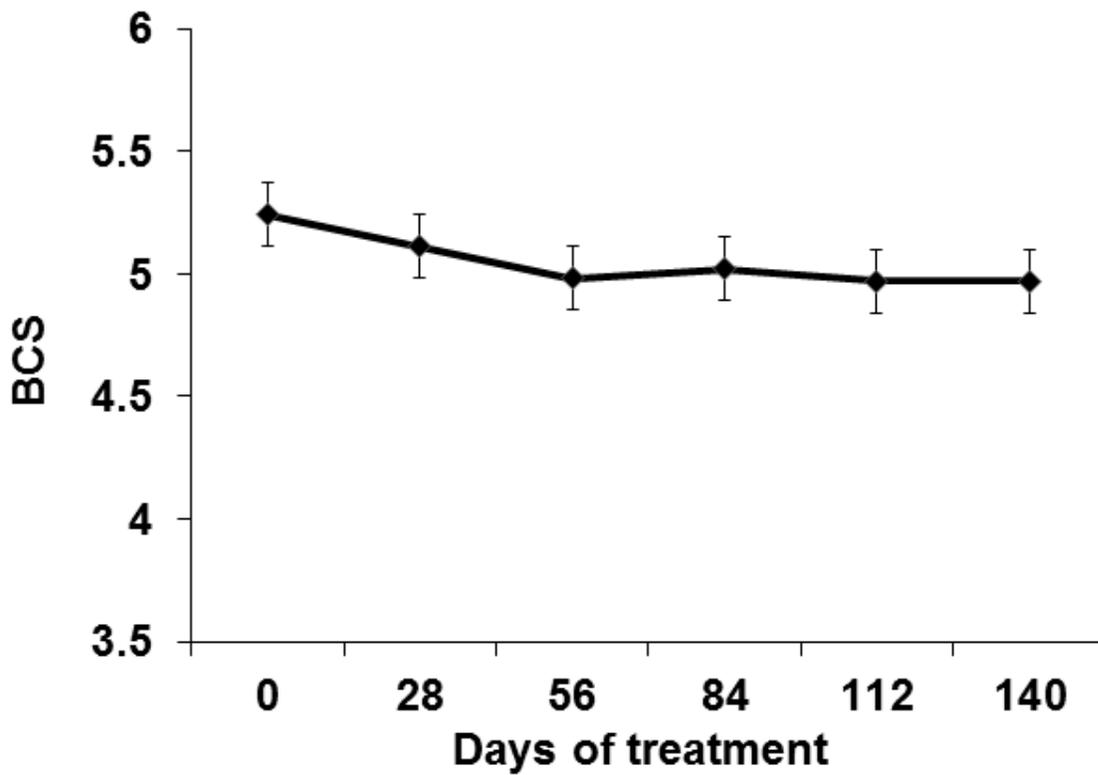


Figure 3-5. Mean BCS (scale of 1 to 9, with 1 = emaciated and 9 = obese) by day for heifers during the receiving three different developmental diets.

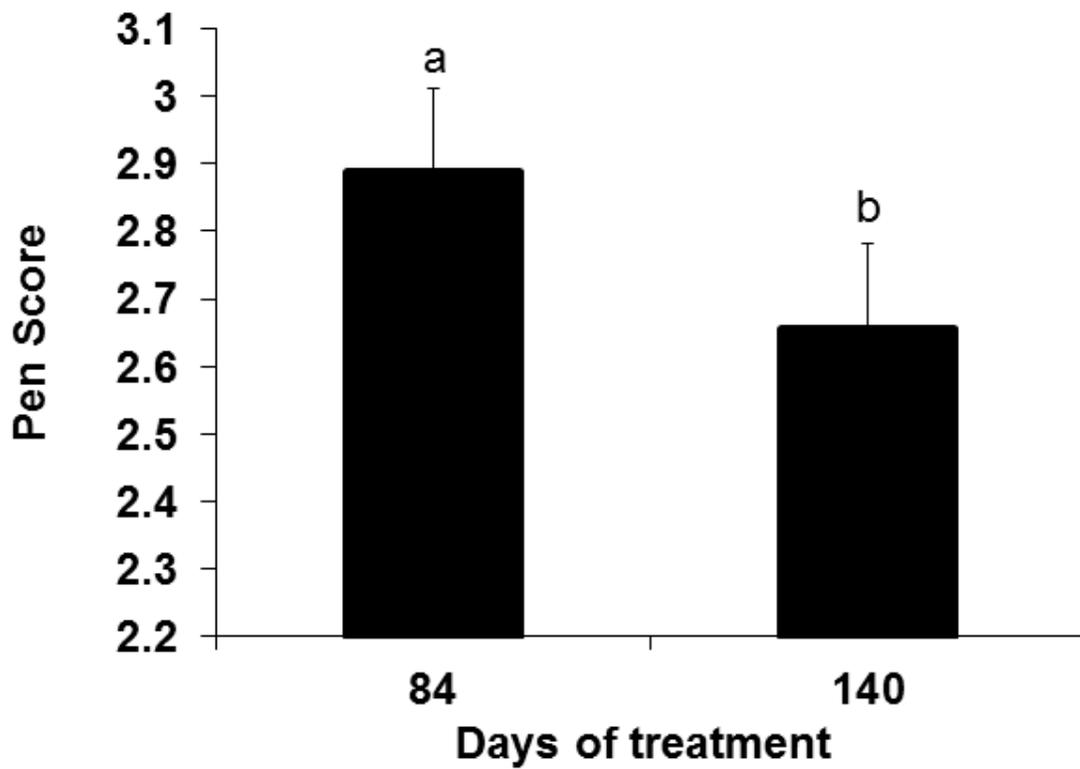


Figure 3-6. Mean pen score (average of 3 pen scores on a given date, on a 5 points scale with 1 being calm and 5 being aggressive) by day for heifers receiving three different development diets. ^{a,b} Means tend to differ ($P = 0.06$). Data collected in Year 2 only.

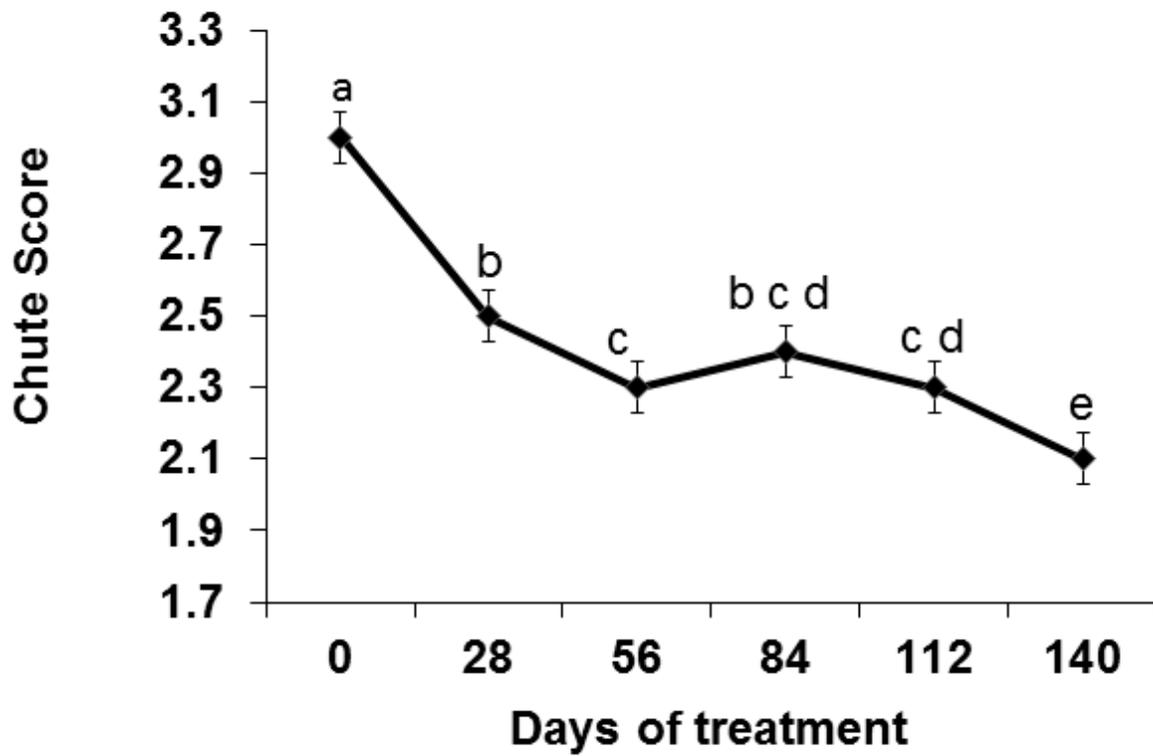


Figure 3-7. Mean chute score (on 5 point scale, with 1 being calm and 5 being aggressive) by day for heifers receiving three different development diets. . Data collected in Year 2 only. ^{a,b,c,d,e} Means differ ($P < 0.05$).

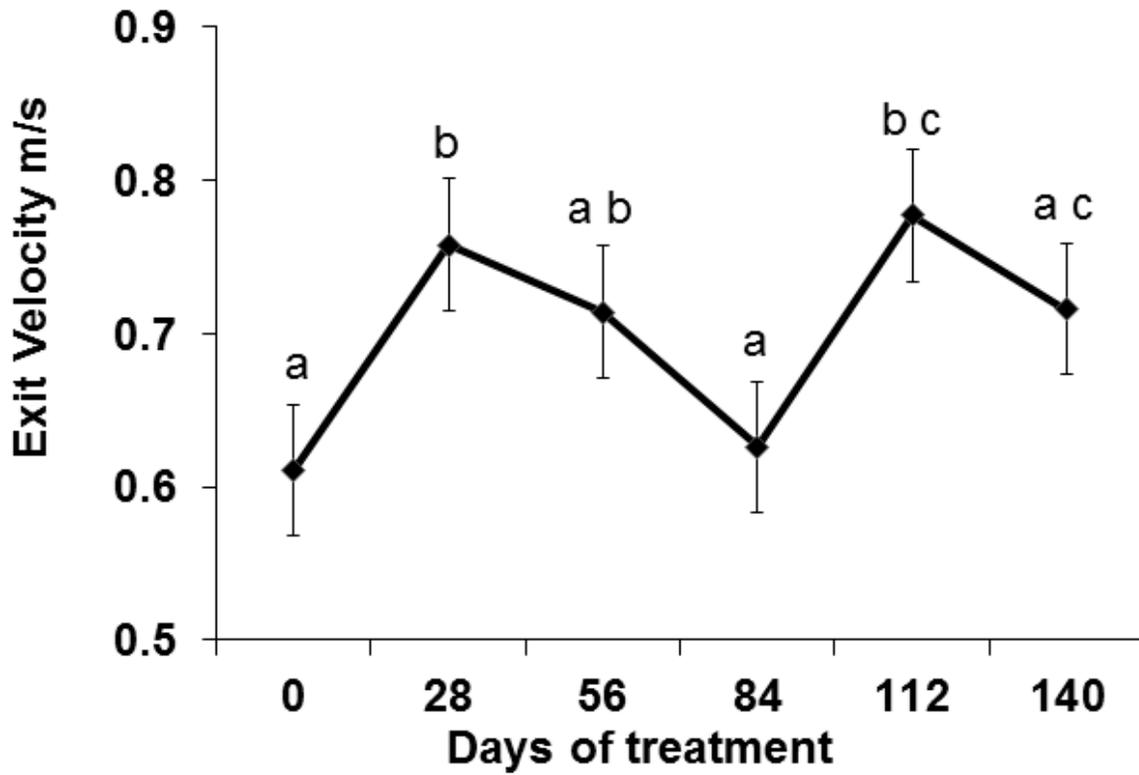


Figure 3-8. Mean exit velocity (seconds for a heifer to travel 1.83 m after being released from a squeeze chute) by day for heifers receiving three different development diets. Data collected in Year 2 only. ^{a,b,c} Means differ ($P < 0.05$).

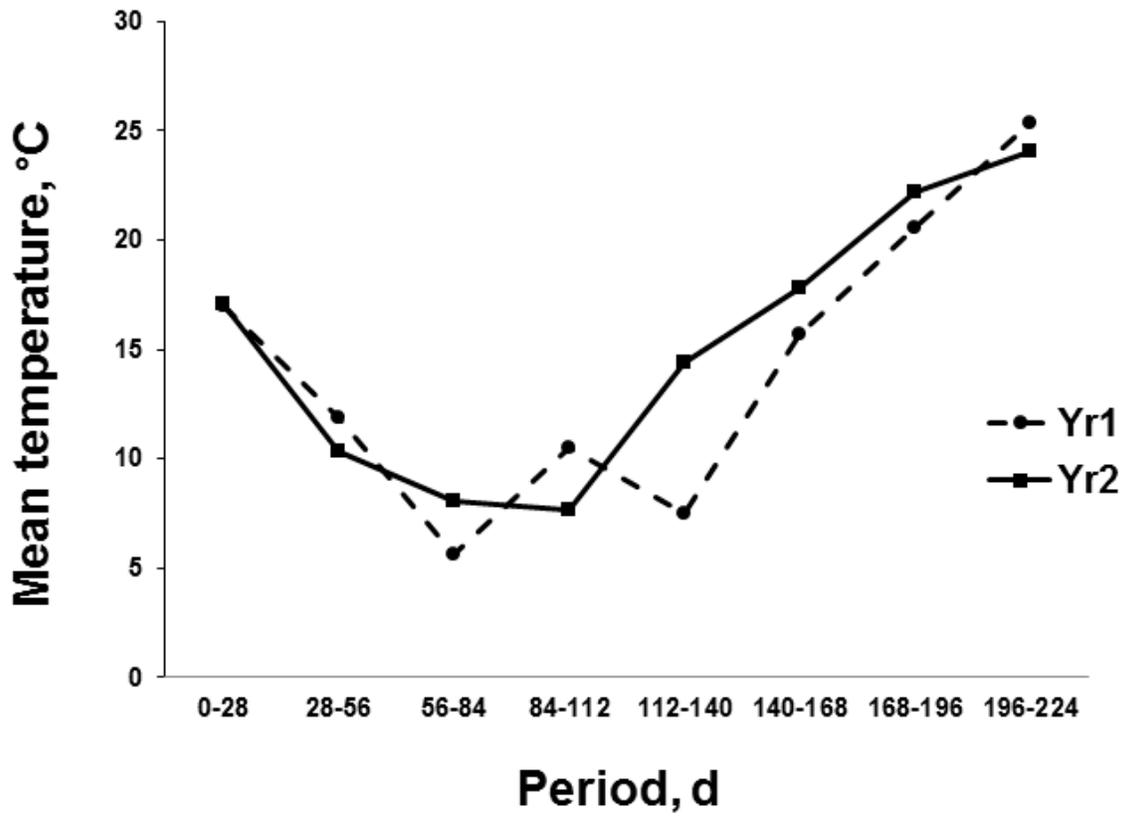


Figure 3-9. Mean temperature from year 1 (Yr1) and year 2 (Yr2) by 28 d period during the development and breeding phase for heifers receiving three different development diets.

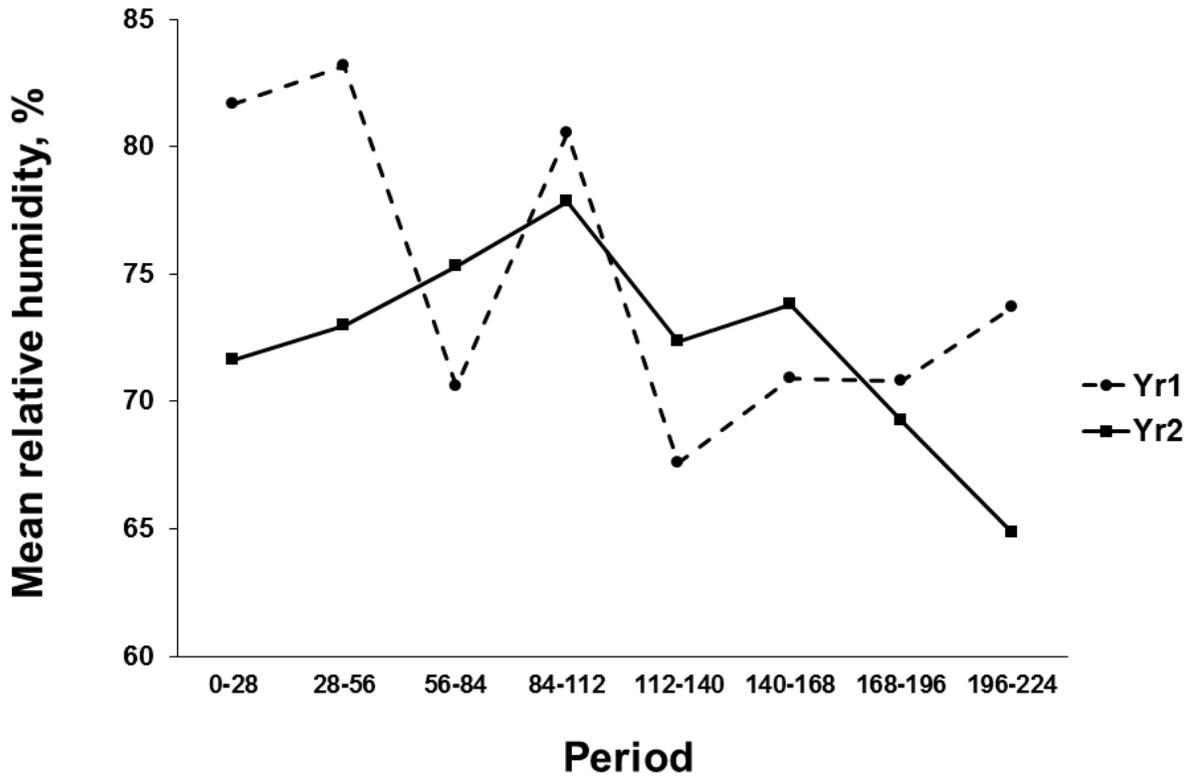


Figure 3-10. Mean relative humidity from year 1 (Yr1) and year 2 (Yr2) by 28 d period during the development and breeding phase for heifers receiving three different development diets.

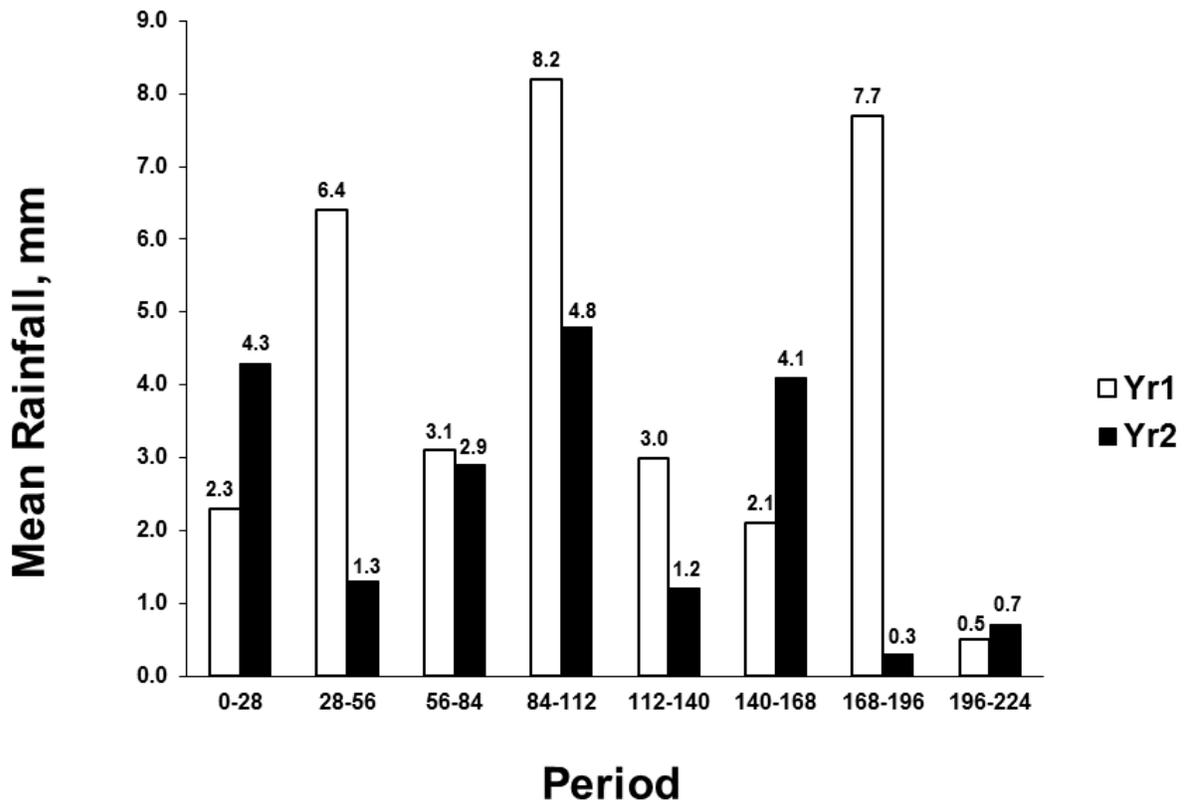


Figure 3-11. Mean rainfall from year 1 (Yr1) and year 2 (Yr2) by 28 d period during the development and breeding phase for heifers receiving three different development diets

Table 3-1. Nutritional values¹ of feeds offered during the developmental phase².

Ingredient, DM Basis	Treatments ³				BGH ⁴	
	CSBM ³		PPH ³		Yr1	Yr2
	Yr1 ⁵	Yr2 ⁶	Yr1	Yr2	Yr1	Yr2
DM, %	92.7	93.6	90.7	91.3	91.1	92.1
TDN, %	83.5	84.0	61.0	60.0	56.5	58.0
CP, %	20.1	20.4	13.2	15.3	14.5	10.0
ADF, %	5.7	5.2	35.1	33.7	38.6	40.9
NDF, %	10.8	9.8	40.4	38.9	73.7	74.8
NEm (Mcal/kg)	1.52	1.53	1.28	1.27	1.06	1.09
NEg (Mcal/kg)	1.04	1.05	0.71	0.7	0.50	0.54

¹ Mean of two samples analyzed via Near Infrared Reflectance Analysis (NIR).

² Development phase was initiated 140 d prior to initiation of the breeding season.

³ Heifers were assigned to one of three supplementation treatments: 1) heifers received no supplementation with ad libitum access to bermudagrass hay (CON); 2) heifers received a corn/soybean supplement at 1.23 kg.hd⁻¹.d⁻¹ with ad libitum access to bermudagrass hay (CSBM); and 3) heifers received perennial peanut hay supplement at 2.74 kg.hd⁻¹.d⁻¹ with with ad libitum access to bermudagrass hay (PPH).

⁴ BGH - bermudagrass hay nutritive values offered to all treatments during the development phase.

⁵ Yr1 - Year 1 from Oct. 2009 to March 2010

⁶ Yr2 - Year 2 from Oct. 2010 to March 2011

Table 3-2. Chemical composition of the mineral supplements provided to developing heifers during the development phase¹ and breeding phase².

Component	CON & CSBM		PPH		Breeding Phase	
	Min	Max	Min	Max	Min	Max
Calcium,%	14.00	16.80	12.00	14.40	16.0	19.0
Phosphorus, %	7.00	-	12.00	-	3.0	-
Salt, %	17.00	20.00	3.00	4.00	15.0	18.0
Magnesium, %	3.50	-	1.00	-	10.0	-
Potassium, %	1.00	-	1.00	-	-	-
Sulfur, %	1.50	-	-	-	-	-
Zinc, PPM	2,500	-	6,600	-	2,800	-
Manganese, %	-	-	3,500	-	-	-
Copper, %	-	-	2,200	-	1,200	-
Cobalt, %	-	-	19.0	-	-	-
Iodine, PPM ⁴	60.0	-	90.0	-	68.0	-
Selenium, PPM	52.0	-	54.0	-	30.0	-
Vitamin A, IU ⁵	225,000	-	150,000	-	140,000	-
Vitamin D3, IU	25,000	-	15,500	-	45,000	-
Vitamin E, IU	200	-	150	-	-	-

¹ Development phase was initiated 140 d prior to initiation of the breeding season.

² Breeding phase - all heifers were comingled, on grazing, receiving no dietary treatment.

³ Heifers were assigned to one of three supplementation treatments: 1) heifers received no supplementation with ad libitum access to bermudagrass hay (CON); 2) heifers received a corn/soybean supplement with ad libitum access to bermudagrass hay (CSBM); and 3) heifers received perennial peanut hay supplement with ad libitum access to bermudagrass hay (PPH).

Table 3-3. Nutritional values of feed available to heifers during the breeding phase¹.

Ingredient, DM Basis	Ryegrass ²		50/50 ³
	Yr1 ⁴	Yr2 ⁵	-
DM, %	89.6	92.1	90.5
TDN, %	67.0	65.5	80.0
NEm, Mcal/kg of DM	1.48	1.44	1.3
NEg, Mcal/kg of DM	0.89	0.86	1.94
Crude protein, %	20.2	24.8	18.0
ADF, %	30.4	27.7	25.35
NDF, %	50.7	44.7	51.45

¹ Breeding phase was initiated after a 140 d development phase for 77 d.

² Ryegrass pasture (*Lolium perenne* L.) grazing

³ Mixture of 50% corn gluten feed and 50% soybean hulls, values based on of NRC (2000) fed at 1.81 kg.hd⁻¹.d⁻¹.

⁴ Yr1 - Year 1 from Oct. 2009 to March 2010

⁵ Yr2 - Year 2 from Oct. 2010 to March 2011

Table 3-4. DMI parameters of heifers during the development phase¹ and growth parameters.

Item	Treatments ²			SE	P-value
	CON	CSBM	PPH		
Intake					
Total DMI, % BW	1.4 ^a	1.6 ^b	2.0 ^c	0.07	0.0003
Total DMI, kg.hd ⁻¹ .d ⁻¹	3.4	4.3 ^b	5.3 ^c	0.25	<0.0001
Total TDN intake ³ , kg.hd ⁻¹ .d ⁻¹	0.39 ^a	0.56 ^b	0.63 ^c	0.024	<0.0001
Total CP intake, kg.hd ⁻¹ .d ⁻¹	0.09 ^a	0.13 ^b	0.14 ^c	0.017	<0.0001
Total supplementation DM intake, kg.hd ⁻¹ .d ⁻¹	-	1.2 ^a	2.8 ^b	0.183	0.0001
Total supplementation TDN intake, kg.hd ⁻¹ .d ⁻¹	-	0.21 ^a	0.33 ^b	0.021	0.0004
Total supplementation CP intake, kg.hd ⁻¹ .d ⁻¹	-	0.05 ^a	0.08 ^b	0.008	0.0023
Total bermuda grass hay DMI, kg.hd ⁻¹ .d ⁻¹	3.5 ^c	3.0 ^b	2.6 ^a	0.372	0.0014
Total bermuda grass hay TDN intake, kg.hd ⁻¹ .d ⁻¹	0.40 ^c	0.35 ^b	0.30 ^a	0.038	0.0014
Total bermuda grass hay CP intake, kg.hd ⁻¹ .d ⁻¹	0.09 ^c	0.08 ^b	0.07 ^a	0.016	0.0025
Animal performance					
ADG during development phase, kg	0.18 ^a	0.48 ^b	0.46 ^b	0.109	0.069
ADG during breeding phase ⁴ , kg	0.72	0.64	0.85	0.084	0.209
Initial BW ⁵ , kg	234	237	236	11.4	0.975
Final BW ⁵ , kg	260 ^a	303 ^b	300 ^b	24.21	0.024
Mean BW ⁶	245	268	266	16.34	0.370
Initial BCS ⁷	5.2	5.3	5.3	0.285	0.850
Final BCS ⁷	4.6 ^a	5.1 ^b	5.2 ^b	0.145	0.003
Mean BCS ⁸	4.8	5.2	5.2	0.13	0.126
BUN ⁹ , mg/dL	21.0	21.7	22.1	0.89	0.669
Feed cost of weight gain ¹⁰ , \$/kg gain	2.67	1.73	2.54	-	-

¹ Development phase - 140 d supplementation period

² Heifers were assigned to one of three supplementation treatments: 1) heifers received no supplementation with ad libitum access to bermudagrass hay (CON); 2) heifers received a corn/soybean supplement at 1.23 kg.hd⁻¹.d⁻¹ with ad libitum access to bermudagrass hay (CSBM); and 3) heifers received perennial peanut hay supplement at 2.74 kg.hd⁻¹.d⁻¹ with ad libitum access to bermudagrass hay (PPH).

³ Intake is defined as the total disappearance of feed (offered feed-orts)

⁴ ADG during breeding season - ADG of the 84 d breeding phase following the development phase.

⁵ Initial and Final BW - Mean body weight of heifers on d 0 and d 140 of development phase.

⁶ Mean BW - Mean body weight as determined by repeated measures.

⁷ Initial and Final BCS - body condition score on d 0 and d 140 of development phase.

⁸ Mean BCS - Mean body condition score as determined by repeated measures.

⁹ BUN- Blood Urea Nitrogen as an average of all 28 d values.

¹⁰ Feed cost of weight gain – calculated based off feed cost of individual treatment on a hd/d basis as a function of ADG.

^{a,b,c} Means differ ($P < 0.05$)

Table 3-5. Temperament data (Year 2 only) during the development phase¹ and fertility data.

	Treatments ²			SE	P - value
	CON	CSBM	PPH		
Temperament					
Pen Score ³	2.8 ^{ab}	3.1 ^b	2.5 ^a	0.13	0.026
Chute Score ⁴	2.4	2.4	2.4	0.06	0.982
Exit Velocity ⁵	0.67	0.67	0.77	0.038	0.117
Fertility					
Age at attainment of puberty, d ⁶	446	423	439	11.1	0.322
WT at attainment of puberty, kg ⁷	291	316	324	12.2	0.164
BCS at attainment of puberty ⁸	5.0	5.2	5.2	0.15	0.265
D on treatment to until attainment of puberty, d ⁹	183	163	175	8.5	0.424
Fetal age, d ¹⁰	38	51	58	10.2	0.434
Overall pregnancy rate, % ¹¹	65	78	88	12.4	0.500

¹ Development phase - 140 d supplementation period for both year 1 and year 2

² Heifers were assigned to one of three supplementation treatments: 1) heifers received no supplementation with ad libitum access to bermudagrass hay (CON); 2) heifers received a corn/soybean supplement at 1.23 kg.hd⁻¹.d⁻¹ with ad libitum access to bermudagrass hay (CSBM); and 3) heifers received perennial peanut hay supplement at 2.74 kg.hd⁻¹.d⁻¹ with ad libitum access to bermudagrass hay (PPH).

³ Pen Score - based on a 1 to 5 scale, with 1 being docile and 5 being aggressive (only year 2).

⁴ Chute Score - based on a 1 to 5 scale, with 1 being docile and 5 being aggressive (only year 2).

⁵ Exit velocity - measure of seconds taken for animal to travel 1.83 m from squeeze chute (only year 2).

⁶ Age at attainment of puberty- the age of the week in which the first rise of P4 was detected.

⁷ BW at attainment of puberty- BW prior to P4 Rise + [ADG of Period of Rise * (Date of P4 Rise - Date of Prior 28 d BW day)].

⁸ BCS at attainment of puberty- body condition score from the period the rise of P4 was detected.

⁹ Days on treatment until attainment of puberty- days from the start of the 140 d development phase until puberty.

¹⁰ Fetal age - estimated age of fetus at pregnancy diagnosis 30 following sire removal.

¹¹ Overall pregnancy rate - total heifers pregnant 30d following bull removal.

^{a,b,c} Means differ ($P < 0.05$).

LIST OF REFERENCES

- Adams, G. P., R. L. Matteri, J. P. Kastelic, J. C. Ko, and O. J. Ginther. 1992. Association between surges of follicle stimulating hormone and the emergence of follicular waves in heifers. *J. Reprod. Fertil.* 94:177–188.
- Albaugh, R. and H. T. Strong. 1972. Breeding yearling beef heifers. *California Agr. Exp. Sta. Circ.* 433.
- Allen, M. 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. *J. Dairy Sci.* 83(Suppl. 7):1598–624.
- Allen, M. S. 1996. Physical constraints on voluntary intake of forages by ruminants. *J. Anim. Sci.* 74:3063–3075.
- Allen, M. S., and B. J. Bradford, and M. Oba. 2009. BOARD-INVITED REVIEW: The hepatic oxidation theory of the control of feed intake and its application to ruminants. *J. Anim. Sci.* 87:3317–3334.
- Amstalden, M., M. R. Garcia, S. W. Williams, R. L. Stanko, S. E. Nizielski, C. D. Morrison, D. H. Keisler, and G. L. Williams. 2000. Leptin gene expression, circulating leptin, and luteinizing hormone pulsatility are acutely responsive to short-term fasting in prepubertal heifers: Relationships to circulating insulin and insulin-like growth factor I. *Biol. Reprod.* 63:127–133.
- Anderson, K. J., D. G. LeFever, J. S. Brinks, and K. G. Odde. 1991. The use of reproductive tract scoring in beef heifers. *Agri-Practice* 12:19–26.
- Anil, M. H., and J. M. Forbes. 1980. Feeding in sheep during intraportal infusions of short-chain fatty acids and the effect of liver denervation. *J. Physiol.* 298:407–414.
- Arije, G. F., and J. N. Wiltbank. 1971. Age and weight at puberty in Hereford heifers. *J. Anim. Sci.* 33:401–406.
- Arije, G. F., and J. N. Wiltbank. 1975. Prediction of Age and Weight at Puberty in Beef Heifers. *J. Anim. Sci.* 38:803–810.
- Arthington, J. D., X. Qiu, R. F. Cooke, J. M. B. Vendramini, D. B. Araujo, C. C. Chase Jr., and S. W. Coleman. 2008. Effects of preshipping management on measures of stress and performance of beef steers during feedlot receiving. *J. Anim. Sci.* 86:2016–2023.
- Arthur, P. F., J. A. Archer, R. M. Herd, and G. J. Melville. 2001. Response to selection for net feed intake in beef cattle. *Proc. Of Assoc. Advmt. Anim. Breed. Genet.* 14:135–138.

- Aufrere, J., M. Dudilieu, and C. Poncet. 2008. In vivo and in situ measurements of the digestive characteristics of sainfoin in comparison with lucerne fed to sheep as fresh forages at two growth stages and as hay. *Animal* 2:1331–1339.
- Baile, C. A., and M. A. Della-Fera. 1981. Nature of hunger and satiety control system in ruminants. *J. Dairy Sci.* 64:1140–1152.
- Baker, J. F., C. R. Long, G. A. Posada, W. H. McElhenney, and T. C. Cartwright. 1989. Comparison of cattle of a five-breed diallel: Size, growth, condition and pubertal characters of second generation heifers. *J. Anim. Sci.* 67:1218–1229.
- Bassett, J. M., R. H. Weston, and J. P. Hogan. 1971. Dietary regulation of plasma insulin and growth hormone concentration in sheep. *Aust. J. Biol. Sci.* 24:321–330.
- Bauchop, T., and S. R. Elsdon. 1960. The growth of microorganisms in relation to their energy supply. *J. Gen. Microbiol.* 23:457–469.
- Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt Jr, and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. *J. Anim. Sci.* 72:2475–2486.
- Berg, R. T., and L. E. Walters. 1983. The meat animal: Changes and challenges. *J. Anim. Sci.* 57(Suppl. 21):133–146.
- Berthoud, H. R., and W. L. Neuhuber. 2000. Functional and chemical anatomy of the afferent vagal system. *Auton. Neurosci.* 85:1–17.
- Birkelo, C. P., D. E. Johnson, and H. P. Phetteplace. 1991. Maintenance requirements of beef cattle as affected by season on different planes of nutrition. *J. Anim. Sci.* 69:1214–1222.
- Blaxter, K. 1980. Discussion paper: use of energy for maintenance and growth. In: *Energy Metabolism, Proceedings of the 8th Symposium on Energy Metabolism.* Mount, L. E. Pages 183–188. Butterworths, London, UK.
- Blaxter, K. L., and F. W. Wainman. 1964. Utilization of energy of different rations by sheep and cattle for maintenance and for fattening. *J. Agric. Sci.* 63:113–128.
- Bloomfield, F. H., M. H. Oliver, C. D. Giannoulas, P. D. Gluckman, J. E. Harding, and J. R. Challis. 2003. Brief undernutrition in late-gestation sheep programs the hypothalamic- pituitary adrenal axis in adult offspring. *Endocrinology* 144:2933–2940.

- Bohnert, D. W., C. S. Schauer, and T. DelCurto. 2002. Influence of rumen protein degradability and supplementation frequency on performance and nitrogen use in ruminants consuming low-quality forage: Cow performance and efficiency of nitrogen use in wethers. *J. Anim. Sci.* 80:1629–1637.
- Bohnert, D. W., C. S. Schauer, M. L. Bauer, and T. DelCurto. 2002. Influence of rumen protein degradability and supplementation frequency on steers consuming low quality forage: Site of digestion and microbial efficiency. *J. Anim. Sci.* 80:2967–2977.
- Brinks, J. S. 1994. Genetic influences on reproductive performance of two-year-old beef females. *Factors Affecting Calf Crop*. Pages 45–53. M. J. Fields and R. J. Sand, ed. CRC Press, Boca Raton, FL.
- Broderick, G. A. 1995. Desirable characteristics of forage legumes for improving protein utilization in ruminants. *J. Anim. Sci.* 73:2760–2773.
- Bronson, F. H., and J. M. Manning. 1991. The energetic regulation of ovulation: A realistic role for body fat. *Biol. of Reprod.* 44:945–950.
- Brooks, A. L., R. E. Morrow, and R. S. Youngquist. 1985. Body composition of beef heifers at puberty. *Theriogenology* 24:235–250.
- Brown, J. E., C. J. Brown, and W. T. Butts. 1972. Relationships among weights, gains and earliness of maturing in Hereford and Angus females. *J. Anim. Sci.* 35:507–517.
- Bryant, M. P., and L. M. Robinson. 1962. Some nutritional characteristics of predominant culturable ruminal bacteria. *J. Bact.* 84:605–614.
- Buckley, B. A., J. F. Baker, G. E. Dickerson, and T. G. Jenkins. 1990. Body composition and tissue distribution from birth to 14 months for three biological types of beef heifers. *J. Anim. Sci.* 68:3109–3123.
- Bunting, L.D., J.A. Boling, and C. T MacKown. 1989. Effect of dietary protein level on nitrogen metabolism in the growing bovine: Nitrogen recycling and intestinal protein supply in calves. *J. Anim. Sci.* 67:810–819.
- Burroughs, W., P. Gerlaugh, B. H. Edgington, and R. M. Bethke. 1949. The influence of corn starch upon roughage digestion in cattle. *J. Anim. Sci.* 8:271–278.
- Burrow, H. M., and R. D. Dillon. 1997. Relationships between temperament and growth in a feedlot and commercial carcass traits of *Bos indicus* crossbreds. *Aust. J. Exp. Agric.* 37:407–411.
- Bushmich, S. L., R. D. Randel, M. M. McCartor, and L. H. Carroll. 1980. Effect of dietary monensin on ovarian response following gonadotropin treatment in prepuberal heifers. *J. Anim. Sci.* 51:692–697.

- Byerley, D. J., J. G. Berardinelli, R. B. Staigmiller, and R. E. Short. 1987. Progesterone concentrations in beef heifers bred at puberty or third estrus. *J. Anim. Sci.* 65:1571–1575.
- Byers, F. M., and A. L. Moxon. 1980. Protein and selenium levels for growing and finishing beef cattle. *J. Anim. Sci.* 50:1136–1144.
- Carstens, G. E., D. E. Johnson, M. A. Ellenberger, and J. D. Tatum. 1991. Physical and chemical components of the empty body during compensatory growth in beef steers. *J. Anim. Sci.* 69:3251–3264.
- Caton, J. S., and D. V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. *J. Anim. Sci.* 75:533–542.
- Chalupa, W. 1977. Manipulating rumen fermentation. *J. Anim. Sci.* 45:585–599.
- Church, D. C. 1979. Digestive physiology and nutrition of ruminants. Vol. 1. Digestive Physiology. 2nd Ed. O&B Books, Corvallis, OR.
- Church, D. C. 1988. The Ruminant Animal: Digestive Physiology and Nutrition. Pages 77–85. 1st Ed. D. C. Church, ed. Prentice Hall, Englewood Cliffs, NJ.
- Church, D. C., and A. Santo, 1981. Effect of graded levels of soybean meal and of nonprotein nitrogen-molasses supplement on consumption and digestibility of wheat straw. *J. Anita. Sci.* 53:1609–1615.
- Clanton, D. C., L. E. Jones, and M. E. England. 1983. Effect of rate and time of gain after weaning on the development of replacement beef heifers. *J. Anim. Sci.* 56:280–285.
- Clark, J. H., T. H. Klusmeyer, and M. R. Cameron. 1992. Microbial protein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. *J. Dairy Sci.* 75:2304–2323.
- Clark, R. T., K. W. Creighton, H. H. Patterson, and T. N. Barrett. 2005. Economic and tax implications for managing beef replacement heifers. *Prf. Anim. Sci.* 21:164–173.
- Clarke, I. J., R. J. E. Horton, and B. W. Doughton. 1990. Investigation of the mechanism by which insulin-induced hypoglycemia decreases luteinizing hormone secretion in ovariectomized ewes. *Endocrinology* 127:1470–1476.
- Clifford, A. J., and A. D. Tillman. 1968. Urea and isolated soy protein in sheep purified diets. *J. Anim. Sci.* 27:485–489.
- Coleman, S. W., and R. D. Wyatt. 1982. Cottonseed meal or small grains forage as protein supplements fed at different intervals. *J. Anita. Sci.* 55:11–17.

- Cooke R. F., J. D. Arthington, D. B. Araujo, G. C. Lamb, and A. D. Ealy. 2008. Effects of supplementation frequency on performance, reproductive, and metabolic responses of Brahman-crossbred females. *J. Anim. Sci.* 86:2296–2307.
- Cooke, R. F., J. D. Arthington, C. R. Staples, and X. Qiu. 2007. Effects of supplement type and feeding frequency on performance and physiological responses of yearling Brahman-crossbred steers. *Prof. Anim. Sci.* 23:476–481.
- Cooke, R. F., J. D. Arthington, D. B. Araujo, and G. C. Lamb. 2009. Effects of acclimation to human interaction on performance, temperament, physiological responses, and pregnancy rates of Brahman-crossbred cows. *J. Anim. Sci.* 87:4125–4132.
- Corah, L. R., T. G. Dunn, and C. C. Kalthenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. *J. Anim. Sci.* 41:819–824.
- Cotta, M. A., and J. B. Russell. 1982. Effect of peptides and amino acids on efficiency of rumen bacterial protein synthesis in continuous culture. *J. Dairy Sci.* 65:226–234.
- Cundiff, L. V., K. E. Gregory, R. M. Koch, and G. E. Dickerson. 1986. Genetic diversity among cattle breeds and use to increase beef production efficiency in a temperate environment. *Proc. 3rd World Congr. on Genet. Appl. to Livest. Prod.* IX. Pages 271–282. Lincoln, NE.
- Curley, K. O. Jr., D. A. Neuendorff, A. W. Lewis, J. J. Cleere, T. H. Welsh Jr., and R. D. Randel. 2008. Functional characteristics of the bovine hypothalamic–pituitary–adrenal axis vary with temperament. *Horm. Behav.* 53:20–27.
- Currier, T. A., D. W. Bohnert, S. J. Falck, and S. J. Bartle. 2004a. Daily and alternate day supplementation of urea or biuret to ruminants consuming low-quality forage: I. Effects on cow performance and the efficiency of nitrogen use in wethers. *J. Anim. Sci.* 82:1508–1517.
- Currier, T. A., D. W. Bohnert, S. J. Falck, C. S. Schauer, and S. J. Bartle. 2004b. Daily and alternate-day supplementation of urea or biuret to ruminants consuming low-quality forage: III. Effects on ruminal fermentation characteristics in steers. *J. Anim. Sci.* 82:1528–1535.
- Day, M. L., K. Imakawa, D. D. Zalesky, R. J. Kittok, and J. E. Kinder. 1986. Effects of restriction of dietary energy intake during the prepubertal period on secretion of luteinizing hormone and responsiveness of the pituitary to luteinizing hormone-releasing hormone in heifers. *J. Anim. Sci.* 62:1641–1648.
- Day, M. L., K. Imakawa, M. Garcia-Winder, D. D. Zalesky, B. D. Schanbacher, R. J. Kittok, and J. E. Kinder. 1984. Endocrine mechanisms of puberty in heifers: estradiol negative feedback regulation of luteinizing hormone secretion. *Biol. of Reprod.* 31(Suppl. 2):332–341.

- Day, M. L., K. Imakawa, P. L. Wolfe, R. J. Kittok, and J. E. Kinder. 1987. Endocrine mechanisms of puberty in heifers. Role of hypothalamo-pituitary estradiol receptors in the negative feedback of estradiol on luteinizing hormone secretion. *Biol. of Reprod.* 37(Suppl. 5):1054–1065.
- Delavaud, C., F. Bocquier, Y. Chilliard, D. H. Keisler, A. Gertler, and G. Kann. 2000. Plasma leptin determination in ruminants: Effect of nutritional status and body fatness on plasma leptin concentration assessed by a specific RIA in sheep. *J. Endocrinol.* 165:519–526.
- Dow, J. S., J. D. Moore Jr, C.M. Bailey, and W.D. Foote. 1982. Onset of puberty in heifers of diverse beef breeds and crosses. *J. Anim. Sci.* 55:1041–1047.
- Duble, R. L., J. A. Lancaster, and E. C. Holt. 1971. Forage characteristics limiting animal performance on warm-season perennial grasses. *Agron. J.* 63:795–798.
- Egan, A. R. 1980. Host animal-rumen relationships. *Proc. Nutr. Soc.* 39:79–87.
- Ehrhardt, R. A., R. M. Slepatis, J. Siegal-Willott, M. E. Van Amburgh, A. W. Bell, and Y. R. Boisclair. 2000. Development of a specific radioimmunoassay to measure physiological changes of circulating leptin in cattle and sheep. *J. Endo.* 166:519–528.
- Evans A. C. O., G. P. Adams, and N. C. Rawlings. 1994. Endocrine and ovarian follicular changes leading up to the first ovulation in prepubertal heifers. *J. Reprod. Fertil.* 100:187–194.
- Evans, A. C. O. 2003. Characteristics of ovarian follicle development in domestic animals. *Reprod. Domest. Anim.* 38:1–7.
- Farmer, C. G., R. C. Cochran, T. G. Nagaraja, E. C. Titgemeyer, D. E. Johnson, and T. A. Wickersham. 2004. Ruminant and host adaptations to changes in frequency of protein supplementation. *J. Anim. Sci.* 82:895–903.
- Ferrell, C. L., and J. W. Oltjen. 2008. ASAS CENTENNIAL PAPER: Net energy systems for beef cattle-Concepts, application, and future models. *J. Anim. Sci.* 86: 2779–2794.
- Ferrell, C. L., J. L. Koong, and J. A. Nienaber. 1986. Effect of previous nutrition on body composition and maintenance energy cost of growing lambs. *Br. J. Nutr.* 56:595–605.
- Flatt, W. P., P. W. Moe, R. R. Oltjen, P. A. Putnam and N. W. Hooven. 1967. Fourth Symposium on Energy Metabolism. Jablonna, Poland.
- Forbes, J. M. 1996. Integration of regulatory signals controlling forage intake in ruminants. *J. Anim. Sci.* 74: 3029–3035.

- Forbes, J. M. 2000. Physiological and metabolic aspects of feed intake control. *Farm Animal Metabolism and Nutrition*. Pages 319–332 J. P. F. D'Mello, ed. CAB Intl. Publ., Wallingford, UK.
- Forbes, J. M. 2007. A personal view of how ruminant animals control their intake and choice of food: minimal total discomfort. *Nutrition Research Reviews*. 20:132–146.
- Fortune, J. E. 1994. Ovarian follicular growth and development in mammals. *Biol. Reprod.* 50:225–232.
- Foster, J. L., A. T. Adesogan, J. N. Carter, A. R. Blount, R. O. Myer, and S. C. Phatak. Intake, digestibility, and nitrogen retention by sheep supplemented with warm-season legume hays or soybean meal. *J. Anim. Sci.* 87:2891–2898.
- French, E. C., G. M. Prine and A. R. Blount. 2006. *Perennial Peanut: An Alternative Forage of Growing Importance*. University of Florida, Gainesville, FL. IFAS Extension SS-AGR-39.
- Friedman, M. I., and M. G. Tordoff. 1986. Fatty acid oxidation and glucose utilization interact to control food intake in rats. *Am. J. Physiol.* 51:R840–R845.
- Friedman, M. I., M. G. Tordoff, and I. Ramirez. 1986. Integrated metabolic control of food intake. *Brain Res. Bull.* 17:855–859.
- Funston, R. N. and G. H. Deutscher. 2004. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance. *J. Anim. Sci.* 82:3094–3099.
- Gallup, W. D., and H. M. Briggs. 1948. The apparent digestibility of prairie hay of variable protein content with some observation of fecal nitrogen excretion by steers in relation to their dry matter intake. *J. Anim. Sci.* 7:110–116.
- Galyean, M. L. 1999. Review: Restricted and programmed feeding of beef cattle—Definitions, application, and research results. *Prof. Anim. Sci.* 15:1–6.
- Garrett, W. N. 1979. Relationships among diet, metabolizable energy utilization and net energy values of feedstuffs. *J. Anim. Sci.* 49:1402–1409.
- Gasser, C. L., D. E. Grum, M. L. Mussard, F.L. Fluharty, J. E. Kinder, and M. L. Day. 2006. Induction of precocious puberty in heifers I: Enhanced secretion of luteinizing hormone. *J. Anim. Sci.* 84:2035–2041.
- Getachew, G., A. N. Said, and F. Sundstol. 1994. The effect of forage legume supplementation on digestibility and body weight gain by sheep fed a basal diet of maize stover. *Anim. Feed Sci. Technol.* 46:97–108.

- Ginther, O. J., J. P. Kastelic, and L. Knopf . 1989. Composition and characteristics of follicular waves during the bovine estrous cycle. *Anim. Reprod. Sci.* 20:187–200.
- Graham, N., and T. W. Searle. 1972. Balances of energy and matter in growing sheep at several ages, body weights, and planes of nutrition. *Aust. J. Agric. Res.* 23:97–108.
- Grass, J. A., P. J. Hansen, J. J. Rutledge, and E. R. Hauser. 1982. Genotype x environmental interactions on reproductive traits of bovine females. I. Age at puberty as influenced by breed, breed of sire, dietary regimen and season. *J. Anim. Sci.* 55:1441–1457.
- Gray, R., and K. J. McCracken. 1979. Plane of nutrition and the maintenance requirement. Pages 163–165. *Energy Metabolism of Farm Animals*. EAAP Publ. No. 26, Cambridge, England.
- Grovum, W. L. 1986. A new look at what's controlling food intake. In: F. N. Owens (Ed.) *Feed Intake by Beef Cattle*. Pages 1–121. Okla. Agric. Exp. Sta. MP. Stillwater, OK.
- Grovum, W. L. 1995. Mechanisms explaining the effects of short chain fatty acids on feed intake in ruminants-osmotic pressure, insulin and glucagon. *Ruminant Physiology: Digestion, Metabolism, Growth and Reproduction*. Pages 173–197. W. V. Englehardt, S. Leonhard-Marek, G. Breves, D. Geisecke, ed. Ferdinand Enke Verlag, Stuttgart, Germany.
- Guthrie, M. J., and D. G. Wagner. 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. *J. Anim. Sci.* 66:1529–1537.
- Hahn, G. L. 1995. Environmental influences on feed intake and performance of feedlot cattle. Pages 207–225. *Intake by feedlot cattle: Proceedings of the Symposium*. Oklahoma State University, Stillwater, OK.
- Hall, J. B., R. B. Staigmiller, R. A. Bellows, R. E. Short, W. M. Moseley, and S. E. Bellows. 1995. Body composition and metabolic profiles associated with puberty in beef heifers. *J. Anim. Sci.* 73:3409–3420.
- Hammond, A. C. 1997. Update on BUN and MUN as a guide for protein supplementation in cattle. Pages 43–52. *Proc. Florida Ruminant Nutr. Symp.*, University of Florida, Gainesville, FL.
- Hammond, J. M., C. J. Hsu, I. S. Mondeschein, and S. F. Caurung. 1988. Paracrine and autocrine functions of growth factors in the ovarian follicle. *J. Anim. Sci.* 66(Suppl. 2):21–31.
- Hansel, W. 1959. The estrous cycle of the cow. H. H. Cole and P. T. Cupps (Ed.) *Reproduction*. Vol. I. Acad. Press, New York and London.

- Hardin, D. R., and R. D. Randel. 1983. Effect of monensin on postpartum interval to first estrus and serum LH response to 0, 1, 2, or 4 mg estradiol-17b at 21 days postpartum. *Theriogenology* 19:343–354.
- Harmeyer, J., and H. Martens. 1980. Aspects of urea metabolism in ruminants with reference to the goat. *J. Dairy Sci.* 63:1707–1728.
- Harrison, D. G., D. E. Beever, D. J. Thomson, and D. F. Osbourn. 1975. Manipulation of rumen fermentation in sheep by increasing the rate of flow of water from the rumen. *J. Agric. Sci. Camb.* 85:93–101.
- Harrison, D. G., D. E. Beever, D. J. Thomson, and D. F. Osbourn. 1976. Manipulation of fermentation in the rumen. *J. Sci. Food Agric.* 27:617–620.
- Hennessy, D. W., P. J. Williamson, J. V. Nolan, T. J. Kempton, and R. A. Leng. 1983. The roles of energy- or protein-rich supplements in the subtropics of young cattle consuming basal diets that are low in digestible energy and protein. *J. Agric. Sci. Camb.* 100:657–666.
- Hileman, S. M., K. K. Schillo, and J. B. Hall. 1993. Effects of acute, intra cerebroventricular administration of insulin on serum concentrations of luteinizing hormone, insulin and glucose in ovariectomized lambs during restricted and ad libitum feed intake. *Biol. Reprod.* 48:117–124.
- Hileman, S. M., K. K. Schillo, J. M. Kearnan, J. B. Hall, and S. Mohapatra. 1991. Effects of metabolic fuel restriction on patterns of LH and GH in ovariectomized lambs. *Annu. Mtg. of the Society for the Study of Reproduction.* (Abstr.)138.
- Hill, G. M. 2002. Peanut by-products fed to cattle. *Vet. Clin. Food Anim.* 18:1355–1360.
- Hogan, J. P. 1975. Symposium: Protein and amino acid nutrition in the high producing cow. Quantitative aspects of nitrogen utilization in ruminants. *J. Dairy Sci.* 58:1164–1177.
- Holm, D. E., P. N Thompson, and P. C. Irons. 2009. The value of reproductive tract scoring as a predictor of fertility and production outcomes in beef heifers. *J. Anim. Sci.* 87:1934–1940.
- Hopper, H. W., S. E. Williams, D. J. Byerley, M. M. Rolloson, P. O. Ahmed, and T. E. Kiser. 1993. Effect of prepubertal body weight gain and breed on carcass composition at puberty in beef heifers. *J. Anim. Sci.* 71:1104–1111.
- Hume, I. D., and P. R. Bird. 1970. Synthesis of microbial protein in the rumen. IV. The influence of the level and form of dietary sulphur. *Australian J. Agr. Res.* 21:315–322.
- Huntington, G. B. 1997. Starch utilization by ruminants: From basics to the bunk. *J. Anim. Sci.* 75:852–867.

- Illius, A. W., and N. S. Jessop. 1996. Metabolic constraints on voluntary intake in ruminants. *J. Anim. Sci.* 74:3052–3062.
- Imakawa, K. M., M. L. Day, M. Garcia-Winder, D. D. Zalesky, R. J. Kittok, B. D. Schanbacher, and J. E. Kinder. 1986. Endocrine changes during restoration of estrous cycles following induction of anestrus by restricted nutrient intake in beef heifers. *J. Anim. Sci.* 63:565–571.
- Inui, A. 2001. Ghrelin: An orexigenic and somatotrophic signal from the stomach. *Nature Rev. Neurosci.* 2:551–560.
- Ireland, J. J. 1987. Control of follicular growth and development. *J. of Repro. and Fertility Suppl.* 34:39–54.
- Ireland, J. J., and J. F. Roche. 1983. Growth and differentiation of large antral follicles after spontaneous luteolysis in heifers: changes in concentration of hormones in follicular fluid and specific binding of gonadotropins to follicles *J. of Anim. Sci.* 57:157–167.
- Ireland, J. J., and J. F. Roche. 1987. Hypotheses regarding development of dominant follicles during a bovine estrous cycle. In *Follicular Growth and Ovulation Rate in Farm Animals*. Pages 1–18. Eds JF Roche and D O'Callaghan. Martinus Nijhoff Publishers, Dordrecht, Netherlands.
- Ireland, J. J., M. Mihm, E. Austin, M. G. Diskin, and J. F. Roche. 2000. Historical perspective of turnover of dominant follicles during the bovine estrous cycle: key concepts, studies, advancements, and terms. *J. Dairy Sci.* 83:1648–1658.
- Johnson, C. R., B. A. Reiling, P. Mislevy, and M. B. Hall. 2001. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. *J. Anim. Sci.* 79:2439–2448.
- Jones, E. J., J. D. Armstrong, and R. W. Harvey. 1991. Changes in metabolites, metabolic hormones, and luteinizing hormone before puberty in Angus, Braford, Charolais, and Simmental heifers. *J. Anim. Sci.* 69:1607–1615.
- Joubert, D. M. 1963. Puberty in female farm animals. *Anim. Breed.* 31:295 (Abstr.).
- Kaneko, J. J. 1989. *Clinical Biochemistry of Domestic Animals* (4th Ed.). Pages 886–891. Academic Press, San Diego, CA.
- Kato J., Y. Atsumi, M. Inaba, 1974. Estradiol receptors in female rat hypothalamus in the developmental stages and during pubescence. *Endocrinology* 94:309–317.
- Keele, J. W., C. B. Williams, and G. L. Bennett. 1992. A computer model to predict the effects of level of nutrition on composition of empty body gain in beef cattle: I. Theory and development. *J. Anim. Sci.* 70:841–857.

- Keisler, D. H., J. A. Daniel, and C. D. Morrison. 1999. The role of leptin in nutritional status and reproductive function. *J. Reprod. Fertil. Suppl.* 54:425–435.
- Kempster, A. J., A. Cuthbertson, and G. Harrington. 1976. Fat distribution in steer carcasses of different breeds and crosses distribution between depots. *Anim. Prod.* 23:223–232.
- Kennedy, P. M. 1980. The effects of dietary sucrose and the concentration of plasma urea and rumen ammonia on the degradation of urea in the gastrointestinal tract of cattle. *Br. J. Nutr.* 43:125–140.
- Knopf, L., J. P. Kastelic, E. Schallenberger and O. J. Ginther. 1989. Ovarian follicular dynamics in heifers: test of two-wave hypothesis by ultrasonically monitoring individual follicles. *Domestic Anim. Endo.* 6:111–119.
- Kohn, R. A, M. M. Dinneen, and E. Russek-Cohen. 2005. Ruminant Nutrition: Using blood urea nitrogen to predict nitrogen excretion and efficiency of nitrogen utilization in cattle, sheep, goats, horses, pigs, and rats. *J. Anim. Sci.* 83:879–889.
- Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, T. G. Nagaraja, K. K. Kreikemeier, and G. St-Jean. 1997. Effect of increasing proportion of supplemental nitrogen from urea on intake and utilization of low-quality, tallgrass-prairie forage by beef steers. *J. Anim. Sci.* 75:1393–1399.
- Krohn, C. C., J. G. Jago, and X. Boivin. 2001. The effect of early handling on the socialisation of young calves to humans. *Appl. Anim. Behav. Sci.* 74:121–133.
- Kurz, S. G., R. M. Dyer, Y. Hu, M. D. Wright, and M. L. Day. 1990. Regulation of luteinizing hormone secretion in prepubertal heifers fed an energy-deficient diet. *Biol. Reprod.* 43(Suppl. 3):450–456.
- Lalman, D. L., M. K. Petersen, R. P. Ansotegui, M. W. Tess, C. K. Clark, and J. S. Wiley. 1993. The effects of ruminally undegradable protein, propionic acid, and monensin on puberty and pregnancy in beef heifers. *J. Anim. Sci.* 71:2843–2852.
- Lamb, C. S., and J. Eadie. 1979. The effect of barley supplements on the voluntary intake and digestion of low quality roughages by sheep. *J. of Agri. Sci.* 92: 235–241.
- Lapierre, H., and G. E. Lobley. 2001. Nitrogen Recycling in the Ruminant: A Review. *J. of Dairy Sci. Suppl.* 84: E223–E236.
- Larson, J. E., K. N. Thielen, B. J. Funnell, J. S. Stevenson, D. J. Kesler, and G. C. Lamb. 2009. Influence of a controlled internal drug release after fixed-time artificial insemination on pregnancy rates and returns to estrus of nonpregnant cows. *J. Anim. Sci.* 87:914–921.

- Laster, D. B., G. M. Smith, and K. E. Gregory. 1976. Characterization of biological types of cattle. IV. Post weaning growth and puberty of heifers. *J. Anim. Sci.* 43:63–70.
- Laster, D. B., H. A. Glimp and K. E. Gregory. 1972. Age and weight at puberty and conception in different breeds and breed-crosses of beef heifers. *J. Anim. Sci.* 34:1031–1036.
- Laurenz, J. C., F. M. Byers, G. T. Schelling, and L. W. Greene. 1991. Effects of season on the maintenance requirements of mature beef cows. *J. Anim. Sci.* 69:2168–2176.
- Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. *J. Anim. Sci.* 36:1–6.
- Little, W., C. B. Mallinson, D. N. Gibbons, and G. J. Rowlands. 1981. Effects of plane of nutrition and season of birth on the age and body weight at puberty of British Friesian heifers. *Anim. Prod.* 33:273–279.
- Lobley, G. E. 1993. Species comparisons of tissue protein metabolism: Effects of age and hormonal action. *J. Nutr.* 123:337–343.
- Lobley, G. E., D. Bremner, R. Nieto, T. Obitsu, A. Hotston Moore, and D.S. Brown. 1998. Transfers of N-metabolites across the ovine liver in response to short-term infusion of an amino acid mixture into the mesenteric vein. *Br. J. Nutr.* 80:371–379.
- Loosli, J. K., H. H. Williams, W. E. Thomas, F. H. Ferris, and L. A. Maynard. 1949. Synthesis of amino acids in the rumen. *Science.* 130:144–145.
- Lynch, J. M., G. C. Lamb, B. L. Miller, R. T. Brandt Jr., R.C. Cochran, and J.E. Minton. 1997. Influence of timing of gain on growth and reproductive performance of beef replacement heifers. *J. Anim. Sci.* 75:1715–1722.
- Macrae, A. I., D. A. Whitaker, E. Burrough, A. Dowell, and J. M. Kelly. 2006. Use of metabolic profiles for the assessment of dietary adequacy in UK dairy herds. *Vet. Rec.* 159:655–661.
- Maeng, W. J., C. J. Van Nevel, R. L. Baldwin, and J. G. Morris. 1976. Rumen microbial growth rates and yields: Effect of amino acids and protein. *J. Dairy Sci.* 59:648–655.
- Martin, J. L., K. A. Vonnahme, D.C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. *J. Anim. Sci.* 85:841–847.
- Martin, L. C., J. S. Brinks, R.M. Bourdon, and L.V. Cundiff. 1992. Genetic effects on beef heifer puberty and subsequent reproduction. *J. Anim. Sci.* 70:4006–4017.

- Matizha, W., N. T. Ngongoni, and J. H. Topps. 1997. Effect of supplementing veld hay with tropical legumes *Desmodium uncinatum*, *Stylosanthes guianensis* and *Macroptilium atropurpureum* on intake, digestibility, outflow rates, nitrogen retention and live weight gain in lambs. *Anim. Feed Sci. Technol.* 69:187–193.
- Matras, J., S. J. Bartle, and R. L. Preston. 1991. Nitrogen utilization in growing lambs: Effects of grain (starch) and protein sources with various rates of ruminal degradation. *J. Anim. Sci.* 69:339–347.
- Matton, P. V., V. Adalakoun, Y. Coutur, and J.J. Dufour. 1981. Growth and replacement of the bovine ovarian follicles during the estrous cycle *J. Anim. Sci.* 52:813–820.
- McCann, J. P., and W. Hansel. 1986. Relationships between insulin and glucose metabolism and pituitary-ovarian functions in fasted heifers. *Biol. Reprod.* 34:630–641.
- McCartor, M. M., R. D. Randel, and L. H. Carroll. 1979. Effect of dietary alteration of ruminal fermentation on efficiency of growth and onset of puberty in Brangus heifers. *J. Anim. Sci.* 48:488–494.
- McShane, T. M., K. K. Schillo, M. J. Estienne, J. A. Boling, N. W. Bradley, and J. B. Hall. 1989. Effects of recombinant DNA derived somatotropin and dietary energy intake on development of beef heifers: Concentrations of hormones and metabolites in blood sera. *J. Anim. Sci.* 67:2237–2244.
- Mertens, D. R. 1977. Dietary fiber components: Relationship to the rate and extent of ruminal digestion. *Fed. Proc.* 36:187–192.
- Minson, D. J., and R. Milford. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature pangola grass (*Digitaria decumbens*). *Aust. J. Exp. Agric.* 7:546–551.
- Moe, P. W. 1979. Associated effects of feedstuffs. Pages 177–198. *Pacific Northwest Anita. Nutr. Conf.*
- Morrison, C. D., J. A. Daniel, B. J. Holmberg, J. Djiane, N. Raver, A. Gertler, and D. H. Keisler. 2001. Central infusion of leptin into well-fed and undernourished ewe lambs: Effects on feed intake and serum concentrations of growth hormone and luteinizing hormone. *J. Endocrinol.* 168:317–324.
- Moseley, G., and I. R. Jones. 1979. Some factors associated with the difference in nutritive value of artificially dried red clover and perennial ryegrass for sheep. *Br. J. Nutr.* 42:139–145.
- Moseley, W. M., M. M. McCartor, and R. D. Randel. 1977. Effects of monensin on growth and reproductive performance of beef heifers. *J. Anim. Sci.* 45:961–968.

- Mosi, A. K., and M. H. Butterworth. 1985. The voluntary intake and digestibility of combinations of cereal crop residues and legume hay for sheep. *Anim. Feed Sci. Technol.* 12:241–251.
- Mould, F. L., and E. R. Ørskov. 1983. Manipulation of rumen fluid pH and its influence on cellulosis in sacco, dry matter degradation and the rumen microflora of sheep offered either hay or concentrate. *Anim. Feed. Sci. Technol.* 10:1–14.
- Mould, F., E. R. Ørskov, and S. O. Mann. 1983. Associative effects of mixed feeds. 2. The effect of dietary additions of bicarbonate salts on the voluntary intake and digestibility of diets containing various proportions of hay and barley. *Anim. Feed. Sci. Technol.* 10:15–30.
- Myer, B., L. Warren, J. Eckert, D. Hancock, A. Blount, and C. Olson. 2009. Perennial peanut: Forage nutritional composition and feeding value. University of Florida, Gainesville, FL: IFAS Extension AN–234.
- Nakazato, M., N. Murakami, Y. Date, M. Kojima, H. Matsuo, K. Kangawa, and S. Matsukura. 2001. A role for ghrelin in the central regulation of feeding. *Nature* 409:194–198.
- Nelsen, T. C., C. R. Long, and T. C. Cartwright. 1982. Postinflection growth in straightbred and crossbred cattle, II, relationships among weight, height, and pubertal characters. *J. Anim. Sci.* 55:293–304.
- Newman, Y. C., C. L. Mackowiak, A. R. Blount, and J. Ferrell. 2009. Perennial peanut: A quick reference. University of Florida, Gainesville, FL. IFAS Extension SS–AGR–319.
- Niderkorn V., R. Baumont, A. LeMorvan, and D. Macheboeuf. 2011. Occurrence of associative effects between grasses and legumes in binary mixtures on in vitro rumen fermentation characteristics. *J. Anim. Sci.* 89:1138–114.
- Niderkorn, V., and R. Baumont. 2009. Associative effects between forages on feed intake and digestion in ruminants. *Animal* 3:951–960.
- Nocek, J. E. and J. B. Russell. 1988. Protein and energy as an integrated system. relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. *J. of Dairy Sci.* 71(Suppl. 8):2070–2107.
- NRC, 1984. Nutrient Requirements of Beef Cattle. 6th Ed Natl. Acad. Press, Washington, DC.
- NRC. 2000. Nutrient Requirements of Beef Cattle. 8th Ed. Natl. Acad. Press, Washington, DC.

- Oba, M., and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: Effects on dry matter intake and milk yield of dairy cows. *J. Dairy Sci.* 82:589–596.
- Osuji, P. O. 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. *J. Range Manage.* 27:437–443.
- Patterson, D. J., L. R. Corah, J. R. Brethour, M. F. Spire, J. J. Higgins, G. H. Kiracofe, J. S. Stevenson, and D. D. Simms. 1991. Evaluation of reproductive traits in *Bos taurus* and *Bos indicus* crossbred heifers: effects of postweaning energy manipulation. *J. Anim. Sci.* 69:2349–2361.
- Patterson, D. J., R.C. Perry, G.H. Kiracofe, R. A. Bellows, R. B. Staigmiller, and L. R. Corah. 1992. Management considerations in heifer development and puberty. *J. Anim. Sci.* 70:4018–4035.
- Perry, R. C., L. R. Corah, R. C. Cochran, W. E. Beal, J. S. Stevenson, J. E. Minton, D. D. Simms, and J. R. Brethour. 1991. Influence of dietary energy on follicular development, serum gonadotropins, and first postpartum ovulation in suckled beef cows. *J. Anim. Sci.* 69:3762–3773.
- Petherick, J. C., R. G. Holroyd, V. J. Doogan, and B. K. Venus. 2002. Productivity, carcass and meat quality of lot-fed *Bos indicus* cross steers grouped according to temperament. *Aust. J. Exp. Agric.* 42:389–398.
- Plasse, D., A. C. Warnick, and M. Koger. 1968. Reproductive behavior of *Bos Indicus* females in a subtropical environment: Puberty and ovulation frequency in Brahman and Brahman x British heifers. *J. Anim. Sci.* 27:94–100.
- Poore, M. H., J. A. Moore, T. P. Eck, R. S. Swingle, and C. B. Theurer. 1993. Effect of fiber source and ruminal starch degradability on site and extent of digestion in dairy cows. *J. Dairy Sci.* 76:2244–2253.
- Rakestraw, J., K. S. Lusby, R. P. Wettemann, and J. J. Wagner. 1986. Postpartum weight and body condition loss and performance of fall-calving cows. *Theriogenology* 26:461–473.
- Ramirez, V. D, and S. M McCann. 1963. Comparison of the regulation of luteinizing hormone secretion in immature and adult rats. *Endocrinology* 72:452–464.
- Randel, R. D., and R. C. Rhodes, III. 1980. The effect of dietary monensin on the luteinizing hormone response of prepubertal heifers given a multiple gonadotropin-releasing hormone challenge. *J. Anim. Sci.* 51:925–931.
- Randel, R. D., L. M. Rutter, and R. C. Rhodes, III. 1982. Effect of monensin on the estrogen-induced LH surge in prepubertal heifers. *J. Anim. Sci.* 54:806–810.

- Rasmussen, F. E., M. C. Wiltbank, J. O. Christensen, and R. R. Grummer. 1996. Effects of fenprostalene and estradiol-17 β benzoate on parturition and retained placenta in dairy cows and heifers. *J. Dairy Sci.* 79:227–234.
- Reed, B. K., Hunt, C. W., Sasser, R. G., Momont, P. A., Rode, L. M., Kastelic, J. P. 1997. Effect of forage: concentrate ratio on digestion and reproduction in primiparous beef heifers *J. Anim. Sci.* 75:1708–1714.
- Reynolds, C. K., H. F. Tyrrell, and P. J. Reynolds. 1991. Effects of diet forage-to-concentrate ratio and intake on energy metabolism in growing beef heifers: Net nutrient metabolism by visceral tissues. *J. Nutr.* 121:1004–1015.
- Reynolds, W. L., T. M. De Rouen and J. W. High. 1963. The age and weight at puberty of Angus, Brahman and Zebu cross heifers. *J. Anim. Sci.* 22:243 (Abstr.).
- Rhodes III, R. C., M. M. McCartor, and R. D. Randel. 1978. Effect of feeding protein protected lipids upon growth and reproductive development of yearling heifers. *J. Anim. Sci.* 46:769–777.
- Richards, M. W., R. P. Wettemann, and H. M. Schoenemann. 1989. Nutritional anestrus in beef cows: Body weight change, body condition, luteinizing hormone in serum and ovarian activity. *J. Anim. Sci.* 67:1520–1526.
- Rittenhouse, L. R., and R. L. Senft. 1982. Effects of daily weather fluctuations on the grazing behavior of cattle. *Proc. Annu. Meet. West. Sect. Am. Soc. Anim. Sci.* 33:305–307.
- Robertson, J. B., and P. J. Van Soest. 1975. A note on digestibility in sheep as influenced by level of intake. *Anim. Prod.* 21:89–92.
- Rutter, L. M., and J. G. Manns. 1987. Hypoglycemia alters pulsatile luteinizing hormone secretion in the postpartum beef cow. *J. Anim. Sci.* 64:479–488.
- Rutter, L. M., and R. D. Randel. 1984. Postpartum nutrient intake and body condition: Effect on pituitary function and onset of estrus in beef cattle. *J. Anim. Sci.* 58:265–274.
- Savio, J.D., L. Keenan, M. P. Boland, and J. F. Roche. 1988. Pattern of growth of dominant follicles during the oestrous cycle of heifers. *J. of Reprod. Fertil.* 83:663–671.
- Schams, D. E. Schallenberger, S. Gombe, and H. Karg. 1981. Endocrine patterns associated with puberty in male and female cattle. *J. Repod. Fertil.* 30:103–110.
- Schillo, K. K. 1992. Effects of dietary energy on control of luteinizing hormone secretion in cattle and sheep. *J. Anim. Sci.* 70:1271–1282.

- Senft, R. L., M. A. Stillwell, and L. R. Rittenhouse. 1987. Nitrogen and energy budgets of free-roaming cattle. *J. Range Manage.* 40:421–224.
- Senger, P.L. 2003. *Pathways of Pregnancy and Parturition*. 2nd ed. Cadmus Professional Communications. Bellevue, WA.
- Shaffer, K. S., P. Turk, W. R. Wagner, and E. E. D. Felton. 2010. Residual feed intake, body composition, and fertility in yearling beef heifers. *J. Anim. Sci.* 89:1028–1034.
- Shintani, M., Y. Ogawa, K. Ebihara, M. Aizawa-Abe, F. Miyanaga, T. T. Hayashi, G. Inoue, K. Hosoda, M. Kojima, K. Kangawa, and K. Nakao. 2001. Ghrelin, an endogenous growth hormone secretagogue, is a novel orexigenic peptide that antagonizes leptin action through the activation of hypothalamic neuropeptide Y/Y1 receptor pathway. *Diabetes* 50:227–232.
- Short, R. E., and R. A. Bellows. 1971. Relationship among weight gains, age at puberty and reproductive performance in heifers. *J. Anim. Sci.* 32:127–131.
- Sirois J., and J. E. Fortune. 1988. Ovarian follicular dynamics during the estrous cycle in heifers monitored by real-time ultrasonography. *Biol. of Reprod.* 39:308–317.
- Soofi, R., G. C. Fahey Jr., and L. L. Berger. 1982. In situ and in vivo digestibility and nutrient intakes by sheep of alkali - treated soybean stover. *J. Anim. Sci.* 55:1206–1213.
- Spicer, L. A., C. B. Theurer, J. Sowe, and T. H. Noon. 1986. Ruminal and post-ruminal utilization of nitrogen and starch from sorghum grain, corn and barley-based diets by steers. *J. Anim. Sci.* 62:521–530.
- Staples, C. R., R. L. Fernando, G. C. Fahey, Jr., L. L. Berger, and E. H. Jaster. 1984. Effects of intake of a mixed diet by dairy steers on digestion events. *J. Dairy Sci.* 67:995–1006.
- Steiner, R. A. 1987. Nutritional and metabolic factors in the regulation of reproductive hormone secretion in the primate. *Proc. Nutr. Soc.* 46:159–175.
- Stewart, C. S., H. J. Flint, and M. P. Bryant. 1997. The rumen bacteria. *The Rumen Microbial Ecosystem*. Pages 113–175. P. N. Hobson and C. S. Stewart, ed. Chapman and Hall, London, UK.
- Stewart, T. S., C. R. Long, and T. C. Cartwright. 1980. Characterization of a five-breed diallel. III. Puberty in bulls and heifers. *J. Anim. Sci.* 50:808–820.
- Storm, E., and E. R. Ørskov. 1983. The nutritive value of rumen microorganisms in ruminant. 1. Large-scale isolation and chemical composition of rumen microorganisms. *Br. J. Nutr.* 50:463–470.

- Streeter, M. N., D. G. Wagner, F. N. Owens, and C. A. Hibberd. 1989. Combinations of high-moisture harvested sorghum grain and dry-rolled corn: Effects on site and extent of digestion in beef heifers. *J. Anim. Sci.* 67:1623–1633.
- Sunderland, S. J., M. A. Crowe, M. P. Boland, J. F. Roche, and J. J. Ireland. 1994. Selection, dominance and atresia of follicles during the estrous cycle of heifers. *J. Reprod. Fertil.* 101:547–555.
- Taniguchi, K., G. B. Huntington, and B. P. Glenn. 1995. Net nutrient flux by visceral tissues of beef steers given abomasal and ruminal infusion of casein and starch. *J. Anim. Sci.* 73:236–349.
- Temple, R. S., S. H. Fowler and J. S. Evans. 1961. Age of puberty in straightbred and crossbred heifers. A. I. Mimeo. Cir. Pages 61–65. Anita. Ind. Dept., Louisiana State Univ., Baton Rouge, LA.
- Ulyatt, M. J., D. W. Dellow, A. John, C. S. W. Reid, and G. C. Waghorn. 1986. Contribution of chewing during eating and rumination to the clearance of digesta from the ruminoreticulum. *Control of Digestion and Metabolism in Ruminants.* Pages 498–515. L.P. Milligan, W. L. Grovum, and A. Dobson, ed. Prentice-Hall, Englewood Cliffs, NJ.
- United States Department of Agriculture. 2011. 2011 Cattle Inventory Estimates. ISSN: 1948–9099.
- Vadiveloo, J., and W. Holmes. 1979. The effects of forage digestibility and concentrate supplementation on the nutritive value of the diet and performance of finishing cattle. *Anim. Prod.* 29:121–139.
- Verde, L. S., and A. Trenkle. 1987. Concentrations of hormones in plasma from cattle with different growth potentials. *J. Anim. Sci.* 64:426–432.
- Waghorn, G. C., I. D. Shelton, and V. J. Thomas. 1989. Particle breakdown and rumen digestion of fresh ryegrass (*Lolium perenne* L.) and lucerne (*Medicago sativa* L.) fed to cows during a restricted feeding period. *Br. J. Nutr.* 61:409–423.
- Wagner, J. J., K.S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature hereford cows: estimation and effect on daily metabolizable energy requirement during winter. *J. Anim. Sci.* 66:603–612.
- Waldman, R. C., W. J. Tyler, and V. H. Brungardt. 1971. Changes in the carcass composition of Holstein steers associated with ration energy levels and growth. *J. Anim. Sci.* 32:611–619.
- Warnick, A. C., W. C. Burns, M. Koger, and M. W. Hazen. 1956. Puberty in English, Brahman and crossbred breeds of beef heifers. Pages 95–101. *Proc. of Southern Agric. Workers.*

- Wertz-Lutz A. E., T. J. Knight, R. H. Pritchard, J. A. Daniel, J. A. Clapper, A. J. Smart, A. Trenkle, and D. C. Beitz. 2006. Physiology, endocrinology, and reproduction: circulating ghrelin concentrations fluctuate relative to nutritional status and influence feeding behavior in cattle. *J. Anim. Sci.* 84:3285–3300.
- Wickersham, T. A., E. C. Titgemeyer, R. C. Cochran, E. E. Wickersham, and E. S. Moore. 2008. Effect of frequency and amount of rumen-degradable intake protein supplementation on urea kinetics and microbial use of recycled urea in steers consuming low-quality forage *J. Anim. Sci.* 86:3089–3099.
- Wiley, J. S., M. K. Petersen, R. P. Ansotegui, and R. A. Bellows. 1991. Production from first-calf beef heifers fed a maintenance or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. *J. Anim. Sci.* 69:4279–4293.
- Wiltbank, J. M., K. E. Gregory, L. A. Swiger, J. E. Ingalls, J. A. Rothlisberger, and R. M. Koch. 1966. Effects of heterosis on age and weight at puberty in beef heifers. *J. Anim. Sci.* 25:744–751.
- Wiltbank, J. N., C. W. Kasson, and J. E. Ingalls. 1969. Puberty in crossbred and straight bred beef heifers on two levels of feed. *J. Anim. Sci.* 29:602–605.
- Woody, H. D., D. G. Fox, and J. R. Black. 1983. Predicting net energy value of corn silage varying in grain content. *J. Anim. Sci.* 57:710–716.
- Yelich, J. V., R. P. Wettemann, H. G. Dolezal, K. S. Lusby, D. K. Bishop, D. K., and L. J. Spicer. 1995. Effects of growth rate on carcass composition and lipid partitioning at puberty and growth hormone, insulin-like growth factor I, insulin, and metabolites before puberty in beef heifers. *J. Anim. Sci.* 73: 2390–2405.
- Young, B. A. 1983. Ruminant cold stress: Effect on production. *Can. J. Anim. Sci.* 57:1601–1607.

BIOGRAPHICAL SKETCH

Kalyn M. Bischoff was born in Spearfish, South Dakota, to Gary and Paula Bischoff. She grew up on her family's cow-calf operation in southeastern Montana where she was actively involved in 4-H and FFA. Kalyn graduated from Hulett High School, Hulett, Wyoming in 2004 and began her educational career at Northwest Junior College where she received her associates in agricultural communications. After graduations she moved to Stillwater, Oklahoma where she completed her Bachelor of Science degree in the field of Animal Science at Oklahoma State University. Upon graduation, she moved to Florida to work in Dr. Cliff Lamb's research program, where she has focused her studies on replacement heifer development and applied reproductive strategies in beef cattle. She was also a teaching assistant for various animal science reproduction courses. She will begin her PhD in August of 2011 in Dr. Lamb's program at the University of Florida.