INFLUENCE OF DIET ON MAMMARY DEVELOPMENT AND PUBERTY OF BEEF HEIFERS

By

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INFLUENCE OF DIET ON MAMMARY

DEVELOPMENT AND PUBERTY

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"Commit to the Lord whatever you do, and your plans will succeed."

Proverbs 16:3

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CHAPTER I

INTRODUCTION

Two traits that have major influences on the productivity of beef heifers are age at first calving and weaning weights of calves. Nutrient intake after weaning, during gestation and after parturition greatly influences pubertal development and milk production.

Nutrition can affect performance of heifers directly by increasing weight gain or body mass, or indirectly by alterations in body composition or metabolic signals. Although nutrition is a major factor that influences productivity of beef heifers, other factors can modulate the effects of nutrition on performance of heifers.

Management and environmental factors may influence the time of onset of puberty. Alterations in the growth curve may hasten or delay the onset of puberty and may influence mammary development and subsequent milk production. As the onset of puberty is delayed, heifers may not cycle until the breeding season or possibly miss the breeding season entirely. In ideal situations it is recommended to have heifers cycling 3 weeks prior to the breeding season. When puberty is delayed and heifers do not conceive during the breeding season overall production profitability may decrease.

Nutritional effects on pubertal development of beef heifers have been evaluated in numerous studies for decades. Economic trends in the cattle market has put pressure on producers to maximize production and minimize feed and labor input.

The understanding of the influence of nutrition on puberty and mammary development will result in the development of management practices to improve the profitability of beef production.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Nutritional effects upon pubertal development of beef heifers have been the topic of numerous studies over the decades. Economic trends in the cattle market put pressure on producers to maximize production and minimize economic input.

Successful replacement heifer operations make nutrition a priority to ensure heifers have initiated estrous cycles before the start of the breeding season, conceive at 14 to16 months of age, and calve as two year olds (Farrell, 1982; Gregory et al., 1978). By calving early, this maximizes the lifetime production potential of the cow (Cundiff et al., 1974).

Numerous factors influence the onset of puberty in beef heifers. Although the mechanism that modulates or regulates puberty has yet to be fully determined, the metabolic status of the animal is a critical component in triggering the cascade of events resulting in the first estrus (Schillo et al., 1992)

The ability of nutrition to influence the onset of puberty may be limited by age, weight and genotype of the heifer (Cundiff, 1986; Laster et al., 1979; Short et al., 1994). However, without proper nutrition, these factors may result in much variation in the time at the initiation of cyclicity.

To describe and understand the cascade of events associated with puberty, puberty itself must be defined. Puberty has been defined as the time at which an animal can reproduce itself (Robinson, 1977). The exact mechanism by which puberty is initiated is not known in the beef heifer. It is understood that it involves a dynamic chain of physiological events, which culminate in the onset of estrous cycles and a functional corpus luteum (Kinder et al., 1987).

The primary event associated with the onset of puberty is the prepubertal increase in pulsatile luteinizing hormone (LH) secretion. During the prepubertal period, estradiol has a negative feedback effect upon the secretion of LH, however; shortly before the initiation of puberty, estradiol receptors decline and this negative feedback response is reduced (Day et al., 1987). The metabolic status of the heifer may also signal or influence the gonadotropin releasing hormone (GnRH) pulse generator in the hypothalamus to start the increase in pulsatile LH (Schillo, 1992).

Another important facet of the replacement heifer operation takes place after puberty and a successful breeding season. The careful planning and feeding of replacement heifers will influence the rest of their production life. After calving, heifers must receive adequate energy to continue growing, and successfully wean the heaviest calf possible. Mammary development in beef heifers is critical as milk production greatly influences pounds of beef weaned. A well-planned nutritional program enhances the growth and efficiency of the bovine mammary gland, and influences subsequent milk production.

The effect of nutritional intake prior to first pregnancy on mammary development and subsequent milk production is not established. Time of nutritional supplementation relative to growth phase of the mammary gland, may influence gland development.

It has been suggested that creep feeding high energy diets to replacement heifers may compromise subsequent milk production through excess fat deposits in the udder (Hixon et al., 1982; Buskirk et al., 1996). High-energy diets after weaning may not contribute to deleterious effects upon mammary gland development and milk production (Marston et al., 1995), and can even increase milk production of beef heifers (Buskirk et al., 1995). The ability of nutritional manipulation (ad libitum vs restricted intake) to influence mammary development in postpubertal heifers is reduced when compared to prepubertal heifers, suggesting that nutrition may influence critical growth phases in mammary gland development (Sejrsen et al., 1982).

Factors Influencing Puberty

Weight and Age at Puberty. The onset of puberty is associated with the attainment of a critical body weight in most species. In rats (Kennedy and Mitra, 1963), and humans (Frisch et al., 1971), a minimal or critical body weight is an essential component for the onset of puberty. Although a minimal body weight is associated with the initiation of puberty in heifers, the critical weight for breeds with different mature weights has not been clearly established. It has been suggested, as a basic rule of thumb, that puberty will occur when beef heifers are approximately 65% of their mature weight (Arjie and Wiltbank 1974; Maas, 1987). Zebu cattle experience puberty at later ages and heavier weights than British breeds (Gregory et al., 1979). Fajersson (1991) suggested that puberty occurred in Zebu cattle at 55% of mature weight while Brown Swiss cattle managed under the same conditions matured at 40% of their mature weight. Breeds of cattle selected for milk production experience puberty at younger and often lighter weights than beef breed contemporaries (Martin et al., 1992). Red Poll cattle, which have a greater potential for milk production than the Angus with similar mature weights, achieve puberty at a younger age and lighter weight (Gregory et al., 1997).

genetic variation within a breed due to individual sire and dam lines that can influence the age at puberty in beef heifers (Laster et al., 1979).

Evidence from tropical breeds (Fajersson et al., 1991), breeds selected for milk production (Martin et al., 1992), and crossbred cattle (Yelich et al., 1995) indicates that although weight is a very important factor in the achievement of puberty, it is not the sole regulator of puberty, and age may limit the onset of puberty. The critical weight theory may be a useful tool for estimating the onset of puberty in some purebred beef heifers, however it is less reliable in some commercial herds composed of a variety of breeds.

Heterosis influences age at puberty. Crossbred heifers reach puberty at younger ages and heavier weights than their straight-bred contemporaries (Wiltbank et al., 1966; Arije and Wiltbank, 1971; Martin et al., 1992). With the tremendous representation of crossbred cattle in today's commercial cowherds and variability in weights of different breeds at puberty, a single relative percentage of mature weight for the onset of puberty may not exist (Laster et al., 1972).

Weight and age of heifers at the time of puberty is influenced by genetics, nutrition, and rate of gain. Heifers on a high level of nutrition prior to weaning are younger and heavier than their contemporaries at puberty (Wiltbank et al., 1966; Arije and Wiltbank, 1971; Laster et al., 1972). Heifers fed to have increased rates of gain during the post-weaning period experience puberty at younger ages and heavier weights (Arije and Wiltbank, 1971; Patterson et al., 1991; Yelich et al., 1995). Age and weight are both critical regulators of puberty, but they are not sole regulators of the process because they can be influenced by many factors.

Body Composition at Puberty. Another theory that has been scrutinized is that puberty is achieved at a specific body composition. In humans (Frisch, 1990), evidence for a critical body composition at puberty has been demonstrated. Women experiencing amenorrhea (professional dancers and athletes) can be within a normal weight range, but may lack body fat. This condition can usually be reversed and normal ovarian function resumed with weight gain.

A critical body composition for the attainment of puberty has not been established in cattle. Post-weaning nutrition alters body composition at puberty in beef heifers (Yelich et al., 1995). Heifers on rapid rates of gain are younger, heavier, and fatter at puberty (Brooks et al., 1985; Yelich et al., 1995; Hall et al., 1995).

Hall et al. (1995) found that puberty did not occur at similar body compositions or metabolic hormone concentrations in heifers of different frame sizes on different rates of gain. Others have also found that puberty does not occur at a constant body composition in beef heifers (Brooks et al., 1985; Yelich et al., 1995). Percentage body fat is important as a function of physical weight and may reflect the nutritional status of that heifer, but it is not the sole regulator of puberty and the onset of puberty may be limited by age (Yelich et al., 1995).

Rate of Gain. Rate of gain post weaning can have a tremendous impact upon the induction of puberty. Post weaning rates of gain can hasten the onset of puberty resulting in heifers that are younger, heavier, and have greater BCS than those heifers on a low rate of gain (Yelich et al., 1995). Since rate of gain influences body weight at a given age, it is difficult to separate the effect of rate of gain from actual weight.

Subsequent production may be altered by heifers on a high rate of gain prepubertally; however, it is not clear how this impacts production longevity. Rapid prepubertal weight gain prior to weaning may have deleterious effects upon subsequent milk production (Buskirk et al., 1996). Feeding high-energy diets after weaning may not affect (Marston et al., 1995; Pirlo et al., 1997), or may increase (Buskirk et al., 1995) subsequent milk production.

Economical production requirements of replacement heifers emphasize growth rates so heifers that will attain a target weight by the onset of the breeding season. Heifers raised on a high plane of nutrition from weaning to 12 mo can conceive earlier, calve at two years of age at a greater BCS, have greater lifetime production, and will rebreed sooner after calving than heifers with delayed puberty (Fleck et al., 1980). Obtaining these goals can require additional feed inputs. Therefore, producers continually seek low cost nutritional resources to accomplish these goals at the lowest possible cost. As a result, various feeding programs have received considerable attention.

Time of Nutritional Supplementation. The time of nutritional supplementation can influence puberty. Feeding trials commencing directly after weaning, rather than trials that begin several months prior to puberty, can yield variable results. Because nutritional supplementation is expensive, it is paramount that it is done during a period that will produce more heifers that are cyclic. Both the age and weight of heifers should be considered, as they are critical for the initiation of estrous cycles. It is established that heifers must be old enough, as well as heavy enough, for the permissive chain of events prior to the onset of puberty to occur.

Creep feeding heifers before weaning can result in heifers that are younger at the time of puberty, but they may have lower productivity in subsequent years (Serjsen et al., 1982; Capuco et al., 1995; Buskirk et al., 1996). Waiting until heifers are older to initiate a feeding program, allows flexibility in the feeding schedule to adjust for the availability or cost of feed, weather etc. without compromising growth. The net result can be heifers that are ready to cycle before the beginning of the breeding season. Clanton et al. (1983) evaluated this type of flexibility with beef heifers using feeding programs commencing at 45 days postweaning until the start of the breeding season. The feeding strategies allowed for weight gain at the beginning, end, or constant gain throughout the feeding treatment. The diet fed to all heifers were the same, but the intakes were adjusted to achieve the weight gain requirements for each group. Heifers in all groups were similar in age at the onset of puberty (Clanton et al. 1983). This demonstrates that the time of supplementation may not be as important as age and overall weight gain in the initiation of puberty.

The method of "stair step feeding" is achieved by a period of rapid growth, utilizing a high-energy diet that exceeds NRC's requirements by 20-30%, followed by a period of slow growth at 70% of NRC's requirements. Then heifers are fed to achieve rapid growth by supplying 20-30% more than NRC's recommendation for energy during the remainder of the feeding period (Park et al., 1998; Grings et al., 1999). Recently, a great interest in stair-step feeding has been initiated. When beef heifers (n=208) of three sire breeds were grown on a stair-step feeding regime, there were differences in growth, age at puberty, and milk yield due to breed potentials, but dietary treatments did not influence the onset of puberty (Grings et al., 1999). This suggests that this feeding method may not be beneficial to enhance pubertal development. Additional research is necessary to evaluate the effect of the "stair-step" method for allowing flexibility in management systems to achieve efficient heifer development.

A delayed growth program may decrease costs but still achieve the gains necessary for heifers to initiate estrous cycles prior to the breeding season. Lynch at al. (1997), demonstrated that when crossbred beef heifers experienced the majority of their growth at either the beginning or end of the feeding period, they had the same BW and age at puberty as heifers that were on the high rate of gain for the entire feeding period.

A short term high energy feeding regime for 60 d prior to the start of the breeding season can reduce age and weight at puberty and be a favorable management tool (Floyd, 1995; Purvis et al., 1996). Age and weight at puberty can be influenced by short term feeding. Feeding a high concentrate diet to crossbred heifers for 60 days prior to the start of the breeding season increased the number of pubertal heifers as compared with their contemporary controls (Marston et al., 1995). Not only did these heifer experience puberty at a younger age, there were no deleterious effects upon milk production.

*Source of Energy.*The primary energy source of a diet may contribute to the initiation of puberty. Purvis et al. (1998) evaluated the effect of timing and type of energy source 30 to 60 days prior to the beginning of the breeding season. Heifers were fed diets that differed only in their primary source of energy (corn versus corn distillers grain) for thirty or sixty days prebreeding. Heifers fed the diet consisting primarily of corn (more starch) had increased luteal activity prior to and at the beginning of the breeding season vs heifers on the low starch diet. However, diet was confounded with activity of the heifers. Those heifers on a high starch diet were fed in a dry lot and low starch diets were fed in a pasture. Marston et al. (1995), with an experiment with similar genotype and nutritional treatments as Purvis et al. (1998), also speculated that source of energy and the reduction of acetate : propionate ratio in the rumen may hasten the initiation of puberty in beef heifers. The source of energy in the diet, as a means to hasten the initiation of puberty, is a management consideration that requires further research.

Metabolic Signals. Nutrition plays an important role in altering the pulsatile secretion of luteinizing hormone (LH), which is necessary for ovarian follicular development and the first ovulation at puberty (Kinder et al. 1987). Food deprivation in rats (Bronson, 1986), and cattle (Day et al., 1986; Imakawa et al., 1986; Bossis et al., 1999) decreased pulsatile LH in normal cyclic females. This reduction in LH secretion in both rats (Bronson, 1986) and beef heifers (Day et al., 1986; Hall et al., 1994) can be reversed with increased nutrition.

Other hormones and metabolic signals may aid in initiating the cascade of events required for the onset of puberty, however a definitive signal to start the GnRH pulse generator has not been identified. In the presence of increased nutrition, several metabolites and hormones increase prior to the onset of puberty. Increases in insulin-like growth factor-I (IGF-I), glucose, and insulin are related to an increased plane of nutrition. When Yelich et al. (1995), fed a high-energy diet to heifers from 8 months of age until the time of puberty, concentrations of IGF-I, glucose, and insulin in plasma were greater than for heifers gaining at a lesser rate. Conversely, concentrations of nonesterified fatty acids (NEFA) and growth hormone (GH) were less in heifers gaining at a greater rate. The complex interactions of metabolites and hormones in the regulation of the onset of puberty are not fully understood. The total energy balance of an animal may mediate the roles of metabolites and hormones in initiating puberty.

Management and Environmental Factors

Ionophores. Ionophores are feed additives that alter the propionate : acetate ratio in the rumen of cattle. A popular ionophore currently used in the cattle industry is monensin. Monensin increases the propionate produced in the rumen, which in turn has a positive influence on LH secretion (Randel et al., 1982). Age at puberty can be decreased with the use of monensin in heifers with above average weaning weights (Moseley et al., 1982). The effect of monensin in stimulating reproductive maturation may be limited by weight, as heifers with below average weaning weights did not have a decrease in a age at puberty when fed monensin (Moseley et al., 1982). Floyd (1995) found that monensin enhanced pubertal development of heifers if they were gaining at least 0.3 kg/d.

Effect of Season and Photoperiod on Puberty. The effect of season and duration of photoperiod on reproduction have been well documented in sheep (Karsch et al., 1984; Foster et al., 1985). Seasonal influences on puberty in beef cattle are not conclusive. Fall and spring born beef heifers, raised in natural outdoor environments for the first six months of life, were exposed to periods of spring and summer or fall and winter in environmental chambers (Schillo et al., 1983). The heifers exposed to spring and summer conditions were younger at puberty regardless of season of birth. These spring and summer conditions may be environmental clues that enhanced the initiation of puberty. The longer days of spring and summer could decrease the secretion of melatonin by the pineal gland, which could alter pituitary function.

Male Exposure Proceeding Puberty. The effect of bull exposure prior to puberty may hasten the initiation of the first estrous cycle in beef heifers. The social component of beef cattle can influence many aspects of beef cattle management practices. In 1982, Izard and Vandenbergh hypothesized that the oronasal exposure to pheromones in bull urine would hasten the onset of puberty in beef heifers. Roberson et al. (1987) found a significant decrease in age at puberty occurred when heifers were exposed to bulls as compared with contemporaries not exposed. Roberson et al. (1991) demonstrated that heifers on both moderate and high weight gain achieved puberty at younger ages than contemporaries on the same dietary treatments without bull exposure. Social interactions can play important roles in regulating reproductive activity.

Mammary Gland Development

Function and Development of the Mammary Gland. The bovine mammary gland has an important function, whether it is for milk production for commercial purposes, or to provide nutrients for a suckling calf. Through genetic selection for milk production the efficiency and functionality of the mammary gland of the modern dairy cow has been greatly increased (Akers, 2000).

The gross anatomy of the mammary gland is similar in mammals except for the structures removing milk from the major ducts of the gland. In the bovine, the ducts empty into the gland cistern, which is connected to the teat cistern. The streak canal, located at the bottom of the teat cistern, facilitates milk ejection.

Milk synthesis occurs in alveoli, which contain the primary secretory cells (epithelial cells) in the mammary gland. Groups of alveoli are arranged in lobules, which are connected to a series of ducts, which provide a system for milk ejection.

Mammary growth occurs in distinct phases in dairy heifers (Sinha and Tucker, 1969). These same changes are hypothesized to also occur in beef heifers, although the time for the accelerated growth may be slightly altered due to the attainment of puberty at an older age in beef than dairy heifers (Gregory et al., 1978). Mammary development prior to the onset of puberty is characterized by general gland expansion and further development of smooth muscle and teat sphincters. Prepubertal development of the gland may be dependent on estrogen and growth hormone (GH) (Purup et al., 1993), and influenced by growth factors produced by the gland (Akers, 2000; Weber et al., 2000).

Breed Differences. Dairy cattle breeds have the greatest milk production because they have been genetically selected for this trait. With the intense selection for milk production, the mammary glands of dairy breeds have been changed to support greater milk volume and secretion. The differences in milk production potential of beef and dairy breeds are clearly demonstrated in a study comparing Herefords and Holsteins. Mammary gland mass of the dairy breeds was 3.3 times greater, and dairy breeds produced 5.7 times more milk than beef breeds. (Keys et al., 1989). The mammary glands of dairy breeds also contained twice the total amount of DNA as beef breeds (Keys et al., 1989). It is important to keep in mind when considering these results, that Herefords are among the lowest milk producers and Holsteins have the greatest production. Differences between dairy and beef breeds may not be as dramatic if dual-purpose cattle were compared.

Estrogen. Estrogen is a regulator of puberty and mammary development. Prior to the onset of puberty, the negative feedback effect of estrogen on the pituitary and hypothalamus is decreased, thereby increasing LH pulse frequency to prepare for follicle development and ovulation in rats (Ramirez and McCann, 1963). As LH in serum of heifers increases, this results in the development of a dominant follicle, and the production of increased amounts of estrogen. This time of increased estrogen coincides with the allometric growth phase of the mammary gland at the time of puberty (Sinha and Tucker, 1969). Traditionally, estrogen is associated with mammary duct growth at puberty (Sud et al., 1968), and during gestation, the synergistic effect of estrogen and progesterone enhance mammary duct and alveolar growth (Tucker, 1987). The synergy between estrogen and progesterone also facilitates mammary development by enhancing DNA synthesis in the mammary gland in mice (Bresciani, 1965). Mammary development is inhibited in heifers ovariectomized at 2.5 months of age (Purup et al., 1993), but can be restored with estrogen replacement (Cowie, 1949). Estrogen implants have been used to examine the effect of estrogen in relation to accelerated growth rates, mammary development, and subsequent production. Holstein heifers, with estradiol implants from 4.5 months of age to approximately 9.5 months of age on an accelerated growth rate (1 kg/d), had increased teat growth during treatment, and a 5.2% decrease in fat corrected milk yield during the first lactation as compared with non-implanted heifers (Lammers et al., 1999).

Progesterone. Progesterone increases mammary growth in feedlot heifers (Young et al., 1969), but inhibits lactogenesis in the periparturient cow (Tucker, 1981). Progesterone also affects mammary development by blocking prolactin receptor synthesis, and competing with glucocorticoids for glucocorticoid receptor sites in the mammary gland (Tucker, 1981). Pritchard et al., (1972), examined the effect of melengestrol acetate (MGA, an oral progestin) on mammary development of dairy heifers from 2.5 months of age to first estrus or 120 cm wither height (considered breeding height). Heifers were assigned to a standard grain diet (.9kg/d) or a high grain diet (4.5 kg/d) with or without MGA. Rapid mammary growth before puberty confirms earlier studies (Sinha and Tucker, 1969). Concentrations of DNA in the mammary gland were increased in MGA treated heifers as compared with control heifers. Heifers supplemented with MGA and on a high grain diet had a 60% increase in DNA concentration, and heifers with MGA on a lower grain diet had 30% greater DNA concentration than controls.

Prolactin. Prolactin in combination with growth hormone, IGF-I, estradiol 17-2, and progesterone stimulates mammary development (Tucker, 1981; Akers, 2000). Changes in prepubertal pituitary prolactin concentrations are related to the changes in mammary growth prior to puberty. Between 2 to 3 months of age, prolactin increases 333% in the pituitary of Holstein heifers with greater concentration of prolactin highest at 9 months of age (Sinha and Tucker, 1969). Pritchard et al. (1972), confirmed these results utilizing Holstein heifers on high and low grain diets. During the estrous cycle, Prolactin concentrations increase and are responsible for mammary epithelium development (Tucker, 1981).

Bromocriptine (dopamine-2-receptor agonist), a powerful prolactin inhibitor, drastically reduced prolactin in plasma and prolactin receptor concentrations in mammary parenchyma during the third trimester of gestation in gilts (Farmer et al., 2000). In an earlier study (Farmer et al., 1998), milk production was decreased in sows given bromocriptine commencing prior to parturition until 31 days post partum.

Growth Hormone (GH). It is generally agreed that estrogen and growth hormone are key factors that influence early mammary development (Akers, 2000). During development, GH is critical for pubertal, ductile development, and udder volume in heifers (Sejrsen et al., 1986). Administration of recombinant growth hormone (bST) to pubertal heifers enhances mammary development (Sejrsen et al., 1986; Radcliff et al., 1997) and increases milk production after parturition (Bauman et al., 1993). Exogenous GH administration enhances mammary development by increasing the proportion of mammary parenchymal tissue, DNA, and protein (Radcliff et al., 1997; Sejrsen et al., 2000).

Increased GH concentrations have been noted in animals with increased milk yield potentials (Barnes et al., 1985), and have been positively correlated to increased milk production (Akers, 2000). Holstein Friesian cows had increased circulating GH concentrations as compared with Hereford x Friesian cows during lactation (Hart et al., 1975). Holsteins selected for high milk yield had greater concentrations of GH in serum as compared with controls (Kazmer et al., 1986). Though energy balance differed throughout the stages of lactation, there was no difference in energy balance between high milk yield and control cows, thus suggesting that the difference in GH was due to selection for high milk yield.

The direct effect of GH on mammary development requires further investigation, but recent studies indicate that GH mediates growth factors in the mammary gland (Purup et al., 2000). Purup et al., (1995) theorized that GH influences the mammary gland through IGF-I, because GH alone did not stimulate mammary cell growth in vitro, and the mammary gland lacks specific receptors for GH (Akers, 1985). Weber et al., (2000) suggested that bST administration in combination with high feeding levels increases IGF-I in serum and increases synthesis of IGF binding proteins. Although it is not established how somatotropin regulates mammary tissue IGF-I synthesis, it is established that increased IGF-I is dependant on nutrition in heifers.

Insulin-like Growth Factor-I (IGF-I). The role of Insulin-like Growth Factor – I on mammary development has not been completely defined, but it is suggested that IGF-I has paracrine, autocrine, and endocrine functions (Weber et al., 1999). In concert with GH, IGF-I may have systemic and local roles in the mammary gland (Purup et al., 2000; Weber et al., 2000). Numerous growth factors including IGF-I, may influence the mammary gland by mediating the effects of estrogen and GH, or by actions of their own (Purup et al., 2000). IGF-I and II influence mammary development by stimulating cell proliferation in vitro. Insulin-like growth factor – I binding proteins, primarily II and III, inhibit cell proliferation and demonstrate the control that binding proteins have at the cellular level (Purup et al., 2000).

Prepubertal heifers on high rates of gain (1.1 kg/d ADG) that were treated daily with bST had a 46% increase in IGF-I in the mammary gland as compared with high rate of gain controls (Weber et al., 2000). Insulin-like growth factor –I binding protein III also tended to increase when heifers were on the high gain and were treated with bST. This indicates that somatotropin and nutrient intake mediate local synthesis of IGF-I and binding proteins, thereby influencing mammary development.

Other Growth Factors. Growth factors can have stimulatory or inhibitory effects upon their particular sites of action. Growth factors in the bovine mammary gland are under investigation as to their exact role in mammary development. Growth factors may be mediators of hormones such as estrogen and GH, and may be responsible for mammary development (Purup et al., 2000). Insulin-like growth factor-I and II are considered influential factors for mammary cell proliferation (Purup et al., 2000). The epidermal growth factors (EGF's) also stimulate mammary cell growth, but not to the same extent as the IGF's (Purup et al., 2000). Members of the fibroblast growth factor family (FGF's) may stimulate mammary cell growth. Transforming growth factor beta - I (TGF beta-I), stimulates mammary cell growth in vitro at low concentrations, but has an inhibitory effect at greater concentrations (Purup et al., 2000; Ellis et al., 2000). TGF beta-I is a powerful local mammary growth factor that inhibits cell growth induced by IGF and EGF (Purup et al., 2000).

Nutritional and hormonal influence on mammary development. Nutrient intake and body energy stores regulate the onset of puberty and influences normal mammary development. These effects are probably mediated by the endocrine system.

Growth hormone is negatively correlated with nutrient intake in heifers. Restricted intake increases circulating GH concentrations in heifers (Granger et al., 1989; Armstrong et al., 1993; Yelich et al., 1995), steers (Moseley et al., 1988; McKinnon et al., 1993), and rams (Clarke et al., 1993). In contrast, decreased nutrient intake results in decreased concentrations of GH in serum of rats (Tannenbaum et al., 1979).

Concentrations of nonesterified fatty acids (NEFA) in plasma of heifers are negatively correlated with nutrient intake and body condition score (Vizcarra et al., 1998). Concentrations of NEFA in plasma increased with restricted intake (Yelich et al., 1995), or nutritionally induced anestrus (Richards at al., 1989).

Nutritional manipulation also influences insulin concentrations in plasma of ruminants (Richards et al., 1989). Crossbred prepubertal heifers on full feed to gain 1.36 kg/d, had greater concentrations of insulin than heifers fed to gain .68 kg/d (Yelich et al., 1995), and concentrations of insulin were positively correlated with BCS.

Concentrations of IGF-I increased with increased nutrient intake in ruminants. During times of increased nutrient availability, IGF-I concentrations increase and GH concentrations decrease (Yelich et al., 1995). When feed intake is restricted, concentrations of IGF-I decrease and concentrations of GH increase (Yelich et al., 1995). In ruminants, the positive relationship between IGF-I and GH uncouples during times of feed restriction (Granger et al., 1989; Armstrong et al., 1993). Decreased concentrations of IGF-I have been associated with delayed puberty in heifers on low quality hay versus heifers on hay plus supplement (Granger et al., 1989).

Compensatory growth and mammary development. Nutritional manipulation can have a profound effect upon mammary gland development. Stair-step compensatory growth pattern (a period of energy restriction followed by a period of refeeding) suggests an ability to alter the growth and efficiency of the mammary gland in rats

(Park et al., 1988) and heifers (Park et al., 1989; Carstens et al., 1997; Choi et al., 1997; Park et al., 1998).

Park et al., (1998), conducted an experiment with weanling female rats to determine the effects of a stair-step compensatory nutrition program. Rats on the compensatory dietary treatment had 3.8 times greater amounts of total DNA in the mammary gland as compared with controls (Park et al., 1988)

The lactational potential of dairy heifers (Park et al., 1989) and crossbred heifers (Park et al., 1998), were evaluated at first lactation after stair-step compensatory diet treatment. In both experiments, heifers with variable growth rates experienced an increase in milk production of 6% (Park et al., 1998) or 10 % (Park et al., 1989) greater than controls. Stair-step feeding regimes might influence mammary development and efficiency by influencing metabolic hormones. Growth hormone concentrations, that would normally be increased during periods of negative energy balance and reduced during times of increased energy availability, were increased during both energy restriction and refeeding (Park et al., 1989). The results reinforce the theory that stair-step compensatory feeding programs enhance mammary development and subsequent milk production (Park et al., 1998).

Nutrition and Subsequent Milk Production. Creep feeding can have detrimental effects upon subsequent milk production and lifetime productivity of beef heifers (Hixon et al., 1982; Buskirk et al., 1996). The impact of nutritional manipulation after weaning is not clearly defined. The period of rapid mammary growth of dairy heifers begins at approximately 3 months of age, with the greatest increase in growth between 5 to 9 months of age (Sinha and Tucker 1969). Thus, it has been suggested that the rate of mammary growth prepubertally may be altered by nutritional manipulation and this may alter subsequent milk production.

When beef and dairy heifers were fed high-energy diets after weaning, subsequent milk production was not impaired when compared with heifers on control diets (Capuco et al., 1995; Marston et al., 1995; Pirlo et al., 1997). The dietary treatments of heifers in these studies were initiated after the first critical growth phase of the mammary gland at approximately 5 to 12 months of age. Feeding high-energy diets for only one to two months during the latter portion of the growth phase does not appear to influence subsequent lactational performance.

Milk production was increased 10 % when weanling beef heifers (192 kg) were fed a high energy, corn-based diet for 136 days compared with heifers that were fed a lower energy corn-based diet (Buskirk et al., 1995). Post-weaning weight gains of lightweight heifers from both dietary treatments were .07-1.17 kg/d. Heifers with the greater post weaning gains also had greater subsequent milk production. Growth rates of dairy heifers can be increased by feeding diets with greater amounts of energy and protein, without detrimental effects on mammary development (Radcliff et al., 1997).

In a review, Sejrsen and Purup (1997) acknowledged the variability in results of experiments with regards to prepubertal nutrition and subsequent milk production. Several possibilities are suggested for the variation among studies: short treatment periods, variation in growth rates within treatment groups, high pretreatment growth rates, or treatment periods before or after the critical period. Evaluating the mammary gland often requires euthanasia of the animal to thoroughly quantify cell type and numbers. The influence of nutrition on mammary development and subsequent production are not well established and potential mechanisms have not been identified. Planning experiments to slaughter animals at the same physiological state will decrease the variability of results because the heifers would be at the same stage of mammary development.

Summary

The onset of puberty in beef heifers is under the control of a complicated cascade of events. Nutrition has a critical role in this formula by influencing body weight, age at puberty, and the availability of metabolic signals. The importance of good management and feeding practices is paramount for success in development of replacement heifers. Heifers must achieve at least 60% of their mature weight prior to the breeding season. A constant rate of weight gain may not be feasible or desirable because of availability or cost of feedstuffs. Acceptable weight gains to achieve puberty can be facilitated in rather short time frames of even 60 days, providing heifers have made acceptable weight gain earlier in the season. This allows producers to efficiently utilize available feed resources during the winter months. Increased nutrient intake has limitations if heifers are not old enough when started on a feeding program to hasten the initiation of puberty. Heifers could be heavy enough, but not old enough and this physiological limitation may result in a delay of puberty.

The source of energy in the diet may play a role in puberty by providing critical metabolic signals. Diets with high starch may result in increased concentrations of glucose and/or IGF-I in blood, which in turn could provide signals to regulate the cascade of events preceding the start of puberty. Many components and factors, which regulate the onset of puberty, are controlled by nutrition and should be considered when making decisions about development of replacement heifers.

The important functions of the bovine mammary gland are influenced by physiological and nutritional factors. Dairy and beef cattle differ in genetic potential for milk production, but experience similar growth phases and patterns in mammary development.

Hormones such as estrogen, progesterone, GH, prolactin, and IGF are dominant hormones in mammary development. Estrogen and progesterone have important roles during prepubertal and peripubertal growth, and are responsible for early mammary development. Growth hormone and IGF-I, have important roles in mammary cell proliferation and DNA content and are directly influenced by nutritional manipulation. Recent discovery of the local synthesis of IGF-I and IGF-I binding proteins and the mediation of these factors by GH and nutrition will be the focus of future research.

The objectives of this research were (1) to determine if the source of energy influences pubertal development of beef heifers and (2) to determine if growth rate of heifers between 8 to12 months of age influences development of the mammary gland.

Table 1. Weight at puberty as a percentage of mature weight in cattle

Breed	puberty wt (lb)	mature wt- 3yr (lb)	% of mature weight- 3yr
Red Poll[a]	650	1105	59
Hereford[a]	695	1091	64
Angus[a]	697	1094	64
Limosin[a]	743	1213	61
Braunvieh[a]	732	1266	58
Pinzgauer[a]	739	1217	61
Gelbvieh[a]	745	1266	59
Simmental[a]	758	1272	60
Charolais[a]	814	1349	60
Average	730	1208	61
Brown Swiss[b]	691	1132	61
Brahman[b]	770	1203	64
Chianina[b]	713	1273	56
Jersey[b]	594	928	64
Maine Anjou[b]	724	1270	57
Sahiwal[b]	704	1067	66
South Devin[b]	673	1122	60
Tartentaise[b]	744	1127	60
Average	702	1140	62

[a] Adapted from Gregory et al., (1997).
[b] Adapted from Jenkins et al., (1991).

CHAPTER III

Effect of growth rate on mammary gland development at puberty in beef heifers

Abstract

The effect of three rates of gain on mammary development was evaluated in Angus x Hereford heifers (n=38). At 8 mo of age, heifers were allotted by body weight and age to three treatments: 1) full-fed (FF) to gain 1.36 kg/d; 2) limit-fed (LF) to gain 0.68 kg/d; 3) maintenance-full-fed (MFF) to gain 0.23 kg/d for 16 wk, then full-fed to gain 1.36 kg/d. Weekly blood samples were taken via tail venipuncture. Progesterone concentrations ≥ 1ng/mL in two consecutive weekly blood samples were considered the onset of puberty. Within 10 d after the onset of puberty, heifers were slaughtered. Mammary glands were removed and stored at -20°C until analyzed for DNA and fat. Mammary DNA (an estimate of the number of cells) was quantified in homogenized samples with Hoechst H 33258 dye with a fluorescence spectrophotometer. We previously reported (Yelich et al., 1995) that FF heifers were younger, heavier, and had greater carcass fat at puberty than LF and MFF heifers. Total fat in mammary glands was greater ($P < 0.001$) in FF heifers than in LF and MFF heifers, but total mammary DNA was not influenced by growth rate ($P > 0.10$). We conclude that rate of gain of beef heifers during 3 to 6 mo preceding puberty does not influence the number of cells in mammary tissue at puberty.

(Key Words: Beef Heifers, DNA, Mammary gland, Nutrition)

INTRODUCTION

A profitable heifer development program requires careful management of the herd to achieve early initiation of estrous cycles and conception, so heifers calve at two years of age. Feeding high-energy diets before puberty may increase the percentage of puberal heifers at the onset of the breeding season. Mammary growth may be reduced when Holstein (Serjsen et al., 1983; Capuco et al., 1995) and crossbred beef heifers (Buskirk et al., 1996) are fed high-energy diets before puberty. However, feeding high-energy diets after puberty does not influence growth of mammary tissue (Sejrsen et al., 1982). Buskirk et al. (1996) demonstrated that crossbred heifers had reduced milk production if fed high-energy diets for 112 d at approximately 4 to 6 mo of age. Although total mammary tissue was reduced when Holstein heifers were fed to gain rapidly between 4 to 6 mo of age, there was no decline in subsequent milk production (Capuco et al.; 1995). Buskirk et al. (1995) fed a high corn diet to cross-bred weanling heifers for 136 d and milk production was increased ($P < 0.01$) by 10% for high corn vs low corn diet heifers. Age at the time of nutritional treatment may account for variation in responses in mammary development (Serjsen and Purup, 1997). The objective of the current study was to determine the effects of three rates of gain after weaning on mammary gland development at puberty in beef heifers.

MATERIAL AND METHODS

At 8 mo of age, Angus x Hereford heifers (n=38), were allotted by body weights and age to three treatments: 1) full-fed (FF) to gain 1.36 kg/d; 2) limit-fed (LF) to gain 0.68 kg/d; and 3) maintenance-full-fed (MFF) to gain 0.23 kg/d for 16 wk, then full-fed to gain 1.36 kg/d (Yelich et al., 1995). Weekly blood samples via tail venipuncture were taken in tubes containing EDTA, and cooled to 4°C. Plasma was obtained by centrifugation (2500 x g) and stored at -20°C until analyzed for progesterone by radioimmunoassay (Bishop and Wettemann, 1993). Progesterone concentrations ≥ 1.0 ng/mL in two consecutive weekly blood samples was considered the onset of puberty.

Within 10 d after the onset of puberty, heifers were slaughtered; mammary glands were removed, and stored at -20°C. Glands were sliced, the external part containing only fat was removed, and remaining parenchymal tissue was ground and analyzed. Lipid and protein concentrations were quantified by ether extract and the Kjehldahl method (Yelich et al., 1995) respectively. Ground mammary tissue samples (150 mg plus 5 mL of phosphate buffer) were homogenized (Vertishear tissue homogenizer, Vertis Co. Gardner, New York), centrifuged at 14,000 x g for 25 minutes, and DNA was quantified in the supernatant (in aliquots of 50 and 80 μL) with Hoechst H33258 dye (25 μL) in a fluorescence spectrophotometer (Perkin-Elmer 650-40, wavelength-excitation 356 and emission 458) (LaBarca and Paigen, 1980). The effects of dietary treatment on mammary DNA, protein, and fat were analyzed by analyses of variance with the GLM procedure of SAS (SAS Inst INC., 1985).

RESULTS AND DISCUSSION

We previously reported (Yelich et al., 1995; Table 2) that FF heifers were heavier, younger, and had greater amounts of carcass fat than LF and MFF heifers. Total weight of the mammary gland was greater ($P < 0.0001$) for FF heifers (3.76 kg) vs LF (2.07 kg) and MFF (2.15 kg) heifers (Table 3). Consistent with previous research, FF heifers had greater ($P < 0.001$) amounts of fat in the udder than LF and MFF heifers (3.01, 1.59, 1.59 kg, respectively, Table 3). Total amount of DNA or DNA per gram of protein in the mammary gland was not affected by nutritional treatment ($P > 0.10$, and $P > 0.90$, respectively Table 3).

Factors such as age, breed, duration of nutritional treatment, and growth rate associated with treatment may influence mammary development in heifers before puberty (Serjsen et al., 2000). Heifers in this experiment were older at the time of treatment (approximately 8 mo of age) than heifers in previous studies (Buskirk et al., 1996; Capuco et al., 1995), suggesting that rapid weight gain of replacement heifers after weaning may not negatively alter mammary development. The timing of weight gain in this experiment may not have occurred in a critical phase of mammary growth, thus not detrimentally influencing mammary development. Although greater amounts of total fat were deposited in the udders of FF heifers, the udder was not a preferential site of fat deposition (4.5%, 4.2%, and 4.3%, Table 3) in relation to total carcass fat when FF, LF, and MFF heifers respectively, were compared. Total DNA in the mammary gland was not compromised by rapid weight gains in this experiment as had been suggested in other studies. We conclude the rate of gain of beef heifers during 8 and 12 months of age, does not influence the development of mammary tissue at puberty in beef heifers.

IMPLICATIONS

It may be possible to take advantage of increased dietary intake and rapid weight gains of beef heifers between 8 and 12 mo of age to decrease age at puberty without deleterious effects on numbers of mammary cells at puberty. Additional research is needed to evaluate mammary development in beef heifers and if increased growth rate prior to puberty influences subsequent milk production.

Table 2. Effect of rate of gain on age, BW, and body condition score (BCS) at puberty in beef heifers[a]

	Treatment			
Measure	FF	LF	MFF	SE
Heifers, no	13	12	13	-
Puberty BW, kg	350[b]	305[c]	310[c]	13
Puberty age, d	370[b]	415[c]	403[c]	12
BCS at puberty	6.4[b]	5.6[c]	5.4[c]	0.2

[a] Adapted from Yelich et al., (1995).

[bc] Means differ ($P < 0.05$).

Table 3. Effect of rate of gain on mammary gland weight, total fat, percent lipid, total DNA, and DNA per gram of protein at puberty in beef heifers

	Treatment			
Measure	FF	LF	MFF	SE
Heifers, no	13	12	13	-
Weight, kg	3.76[a]	2.07[b]	2.15[b]	0.23
Fat, kg	3.01[a]	1.59[b]	1.59[b]	0.21
Lipid, %	4.5[a]	4.2[a]	4.3[a]	0.2
DNA, mg	306[a]	301[a]	457[a]	73.4
DNA per gram of protein, ng	18.9[a]	20.1[a]	20.3[a]	2.3

[ab] Means differ ($P < 0.05$).

CHAPTER IV

Reproductive performance of beef heifers fed high and low starch diets for 60 days before breeding

Abstract

Pubertal development was evaluated in sixty-nine Angus x Hereford heifers fed high or low starch diets for 60 d prior to the breeding season. All heifers were fed 0.9 kg/d of a 40% CP supplement from weaning in November until late February, and then heifers were randomly assigned to three treatments for 60 d prior to the breeding season. Control heifers (CON, n=23) grazed native grass pastures with 0.9 kg/d of a 40% CP supplement; low starch (LS, n=23) heifers were self-fed a distillers grain and soybean hull based diet in drylot, and high starch (HS, n=23) heifers were limit-fed a corn based high starch diet in drylot. During the feeding period, HS and LS heifers had greater ($P < 0.0001$) gains than CON heifers, and weighed 18 % more ($P < 0.0001$) than CON heifers at 75 d after treatment. Age and weight at puberty were not influenced ($P > 0.56$) by treatment for heifers that initiated puberty during the experimental period. By 4 wk after treatment, none of the CON heifers had initiated puberty ($P < 0.05$), while only 17% of the HS and 13% of LS heifers were pubertal ($P > 0.60$). By 8 and 12 wk after treatment the cumulative percentages of heifers with LA were greater ($P < 0.001$) for HS and LS than for CON heifers. At 12 wk after treatment, more ($P < 0.008$) HS heifers (78%) had LA than LS heifers (43%) and CON heifers (13%). Sixteen weeks after treatment there was a tendency ($P < 0.09$) for more HS heifers (78%) to have luteal activity than LS heifers (56%), and fewer (13%) CON heifers (13%) were pubertal compared with HS and

LS heifers. Pregnancy rate was not different ($P > 0.33$) for HS (65%) and LS (52%) heifers, but was reduced ($P < 0.0002$) for CON (13%) heifers.

Feeding a diet that contains a greater amount of starch for 60 d prior to the breeding season, compared with an isocaloric diet containing less starch, may result in a greater number of heifers ovulating in the breeding season.

(Key Words: Puberty, Heifers, Nutrition, Starch)

INTRODUCTION

Heifers that initiate estrous cycles prior to the breeding season have a greater ability to calve at two years of age and wean more pounds of beef in their reproductive lifetime than heifers that fail to achieve puberty by the breeding season (Lesmeister et al., 1973). Increased energy intake and growth rate after weaning can reduce age at puberty in beef heifers (Wiltbank et al., 1969; Arije and Wiltbank, 1971; McShane et al., 1989). Consumption of a high concentrate diet for 60 days prior to breeding may reduce age and weight at puberty (Marston et al., 1995). Feeding trials utilizing high concentrate diets reduce the acetate: propionate ratio in the rumen and may decrease age at puberty (Moseley et al., 1982). The effect of amount of starch in the diet on pubertal development has not been evaluated. High starch diets can increase the incidence of bloat (Cheng and Hironaka, 1973) and acidosis (Johnson et al., 1974) and limit feeding can be labor intensive and cost prohibitive. Self-feeding a high energy low starch diet, with corn distiller's grains substituted for corn, may reduce labor costs and still result in an optimum number of heifers cycling before the breeding season. The objective of this study was to determine the onset of puberty and pregnancy rate in beef heifers fed high or low starch diets for 60 days before the breeding season.

MATERIALS AND METHODS

Sixty-nine Angus x Hereford heifers born between February 5 and May 9, 1997, and weaned on October 7, 1997, were used in this experiment. Shrunk weights (feed and water restriction for 18h) were determined at weaning. From October to February 20, heifers grazed native grass pasture, had access to hay, and were fed 0.9 kg daily of a soybean based 40% CP supplement.

Shrunk body weights were taken February 20, 1998 and heifers were blocked by weight and assigned to treatments. Treatments were a complete high starch diet (HS, n=23), a complete low starch diet (LS, n=23), and range pasture with 0.9 kg/d 40% CP supplement (CON, n=23). HS and LS diets were formulated to result in similar caloric intakes and dietary protein in excess of NRC requirements. Feed ingredient and nutrient concentration and intake is presented in Table 4 and 5 respectively. Heifers fed HS and LS were acclimated to a drylot and treatment diets for 7 d. Heifers received 0.5 kg/d prairie hay and 3.6 kg/d of their respective diets for 3 d, 4 kg/d for 4 d, then the LS group had ad libitum access to feed and HS heifers were fed about 80% of estimated ad libitum intake each day. High starch and LS diets were fed for 60 d after the acclimation period commencing March 3, 1998. Shrunk body weights were taken after 28 d so daily intake for HS and LS heifers could be adjusted to achieve similar ADG. During May 4 to 9, heifers on all treatments were maintained together in a drylot with free access to water and hay. Full weights were taken on May 5, and shrunk body weights taken on May 8 and 9 were averaged for the final weight.

Blood samples were obtained every 7 d from March 16 to August 31 by tail venipuncture. Blood was collected into tubes containing EDTA, placed on ice, and centrifuged at 2600 x g within 4 h. Plasma was aspirated and stored at -20 °C until progesterone analyses (Bishop and Wettemann, 1993). Puberty was defined as the first of two consecutive plasma samples with greater than 1 ng/mL of progesterone. Weight at puberty was determined by extrapolation of monthly weights. Thirty-five heifers failed to achieve puberty by the end of the sampling period (HS, n=5; LS, n=10; CON, n=20). If a heifer did not ovulate by August 24, an estimated age and weight at puberty was assigned. Assigned weight at puberty was the heifer's weight on August 24 and assigned age at puberty was the age of the heifer on August 24.

Commencing May 9, heifers were exposed to two fertile bulls in the same native grass pasture until August 24. Heifers were not fed supplement during the early breeding season. Beginning July 1, all heifers were supplemented with 0.45 kg/hd/d of a 40% CP supplement to meet nutritional requirements. Pregnancy was determined by rectal palpation in October 1998.

Analyses of variance were conducted using the GLM procedure of SAS and means were compared by orthogonal contrasts (SAS Inst. Inc. Cary, NC).

RESULTS

During the winter feeding period (November-February) before the start of nutritional treatments, all heifers gained 0.16 kg/d while grazing dormant native grass with 0.91 kg per d of a 40% CP supplement. High starch heifers consumed an average of 7.28 kg/d and LS heifers consumed 6.91 kg/d during the 60 d feeding period. Daily gains of high starch (1.18 kg/d) and low starch (1.10 kg/d) heifers were not different during treatment ($P > .10$), while control heifers gained substantially less (0.29 kg/d; $P < 0.0001$, Table 6). At 75 d after the end of treatment (July), HS and LS heifers maintained the increased weight achieved during the treatment period and weighed 18% ($P < 0.0001$) more than control heifers. A Body weight gains during the breeding season were influenced ($P < 0.018$) by previous treatments. Although body weights for HS and LS were not different after 75 d post treatment, the ADG during 75 d post treatment were greater ($P < 0.0005$) for LS heifers when compared with HS heifers (0.98 kg/d, 0.77 kg/d; respectively). Weight gain of CON during the first 75 d post treatment was not different ($P > 0.62$) from HS and LS heifers and averaged 0.90 kg/d (Table 6).

Age and weight at puberty for heifers that initiated ovarian cycles during the experimental period (May-August) were not influenced by treatment ($P > 0.05$, Table 7). Heifers that did not initiate puberty by August 24, 1998 were assigned that date as the onset of puberty (assigned pubertal heifers). Age at puberty for ovulatory and estimated nonovulatory heifers tended ($P < 0.10$) to be older for LS heifers than HS heifers. Both HS and LS heifers were younger ($P < 0.001$) at puberty than CON heifers (Table 7). Body weight at actual and estimated puberty of heifers was greater for LS than HS heifers ($P < 0.03$), and both HS and LS heifers were heavier than CON heifers ($P < 0.0001$).

At 4 wk after the end of treatment, the percentage of heifers with luteal activity (LA) was similar for HS and LS heifers; none of the control heifers had ovulated whereas 17% and 13% ($P < 0.05$) of the HS and LS, respectively, had ovulated (Table 8). The cumulative percentages of heifers with luteal activity (LA) by 8 and 12 wk after treatment were greater ($P < 0.001$) for HS and LS heifers compared with controls. By the 8 wk, 57% of HS heifers and only 22% of LS heifers had ovulated ($P < 0.004$). The cumulative percentage of HS heifers with LA at 12 wk (78%) was also greater ($P < 0.008$) than the percentage for LS heifers (44%). By 16 wk after treatment, there was a tendency ($P < 0.09$) for more HS heifers (78%) than LS heifers (56%) to have LA, and the cumulative percentages of HS and LS heifers with LA were greater ($P < 0.0001$) than for controls (Table 8).

There was a tendency ($P < 0.09$) for HS heifers to initiate ovarian cycles 2.5 wk earlier than LS heifers. The number of weeks from the start of the breeding season (May 9) until the onset of luteal activity were not different ($P > 0.10$) when HS and LS heifers were compared with controls, however only 13% of control heifers initiated luteal activity. Control heifers had a greater ($P < 0.001$) interval from the start of treatment to the initiation of luteal activity than HS and LS heifers (15.9 wk vs 12.7 wk, and 9.0 wk, respectively), when ovulatory and estimated nonovulatory heifers were compared. High starch heifers initiated LA 3.7 wk earlier than LS heifers ($P < 0.01$), and 6.9 wk earlier than control heifers ($P < 0.001$).

Pregnancy rates (Table 8) for HS and LS heifers were not different ($P > 0.33$), however only 13% of control heifers became pregnant compared with 58% of heifers on LS or HS treatments ($P < 0.0002$).

DISCUSSION

After weaning, in October 1997, heifers consumed dormant native pasture and 0.91 kg per d of a 40%CP supplement. Prairie hay was fed during periods when standing forage was covered with ice or snow and ambient temperatures were less than 0° C or temperatures were less than 5° C and precipitation was occurring at 1200 h. Heifers on all treatments had similar ADG ($P > 0.45$; 0.16 kg/d) during the winter-feeding period. Body weight gains were less than anticipated, as the winter of 1997 was colder than average. This same wintering diet had been used in previous studies (Floyd, 1995; Marston et al., 1995) with satisfactory gains for heifers of with similar weaning weights. The colder and wetter winter required greater energy to maintain adequate weight gains. Heifer weights were not monitored during the winter feeding period. More frequent monitoring of BW during the winter may have been a useful management tool to adjust the supplemental protein and energy provided to heifers. Increasing supplemental energy to prepubertal heifers grazing dormant winter pasture can increase pregnancy rates without affecting weight or body condition score at puberty (Marston et al., 1995).

Although weaning weights of the heifers used in this trial were similar to weights at the Range Cow Research Center in previous years, heifers weighed 25 kg less at the beginning of treatment in February than heifers in previous years (Floyd, 1995; Marston et al., 1995). Throughout this study, heifers were lighter than in previous similar studies and age at puberty and pregnancy rates were adversely affected by the lack of weight gain. High starch and LS heifers had similar ($P > 0.17$) gains (1.18 kg/d, 1.10 kg/d, respectively) during treatment; however, the rate of gain was inadequate to make up the deficit from the previous winter. High starch and LS heifers had greater ($P < 0.0001$) gains during the treatment period than CON heifers.

High starch and LS heifers were heavier (18%) than CON heifers at 75 d after the end of nutritional treatments. Rate of gain of heifers during treatment influenced gain during the first 75 d after treatment. HS heifers had the least gain (0.77 kg/d), LS heifers had the greatest gains (0.98 kg/d), and CON heifers were intermediate (0.90 kg/d). The ADG for heifers on all treatments were greater than previous studies (Floyd, 1995; Marston et al., 1995) for similar heifers grazing summer native pasture, and may be due to better quality of forage than in previous years. Greater daily gains for heifers that had previously consumed less starch, may be related to differences in rumen microbes for heifers with different percentages of starch in diets. Greater amounts of starch in diets could cause a greater propionate to acetate ratio in the rumen (Firkins et al., 1991). While age and weight at puberty for heifers initiating estrous cycles were not influenced by treatment ($P > 0.10$), heifers in this study were 30 to 40 d older at puberty than heifers with similar genotypes in previous studies (Floyd, 1995; Marston et al., 1995; Purvis et al., 1996; Yelich et al., 1995). Weight at puberty was similar to previous studies, suggesting that the delay in the onset of puberty for heifers in this study was mediated by weight. These heifers were old enough but not heavy enough to initiate ovarian cycles. The number of heifers achieving puberty was minimal for HS, LS and CON treatments (17, 13, and 3 respectively, Table 8). Estimated ages and weights at puberty, for nonovulatory heifers at the end of the study (August 24), were used to evaluate treatment effects. Actual plus assigned age at puberty tended ($P < 0.10$) to be younger for HS than LS heifers, and CON heifers were older than HS and LS heifers ($P < 0.001$). Weight at puberty was less ($P < 0.0001$) for CON than for HS and LS. Using estimated age and weight at puberty would be expected to bias results to a younger and lighter weight. Since fewer CON than LS and HS heifers were pubertal at the end of the experiment, the bias would be greatest for CON heifers. Although treatment did not influence the BW of heifers at actual puberty, when BW of heifers using actual and estimated time of puberty were compared, HS heifers were lighter than LS heifers.

The cumulative percentages of heifers with LA by 8 and 12 wk after treatment were greater ($P < 0.001$) for HS and LS heifers than control heifers, and more HS than LS heifers had LA. Heifers of similar genotype and similar dietary treatments in previous studies (Floyd, 1995; Marston et al., 1995) had greater numbers of heifers with LA by 8 wk after treatment than HS and LS heifers in this study. By 16 wk after treatment, more HS and LS heifers had initiated ovulatory cycles than control heifers, and there was a tendency for more HS than LS heifers to be cycling. The differences in onset of puberty for HS and LS heifers suggest an influence of dietary starch since diets were formulated to result in similar caloric intake, exceed NRC requirements for protein, and weight gains were monitored to result in similar gains during treatment. These results indicate that further investigation is needed, since the response to amount of dietary starch may be dependent on previous nutritional intake and/or actual body weight. The response of heifers in this study may have been altered by the lighter initial weights at the time of treatment. It should be determined if isocaloric diets containing more starch will have a beneficial effect on pubertal development in heifers with a greater body weight at the initiation of treatments.

Pregnancy rates for HS and LS heifers were greater ($P < 0.002$) than for CON heifers. The decreased pregnancy rates for heifers on all treatments compared with other studies (Floyd, 1995; Marston et al., 1995) may have resulted from the late initiation of LA. Byerley et al., (1987) found that pregnancy rates increased when heifers were bred on the third estrous cycle rather than at the pubertal estrus. Many of the heifers had recently initiated estrous cycles later in the breeding season. We conclude that feeding a diet that contains greater amounts of starch and similar amounts of energy may result in a greater percentage of heifers ovulating in the breeding season.

IMPLICATIONS

Feeding high or low starch diets for 60 days prior to the breeding season will decrease age at puberty if spring born heifers do not gain sufficient weight during the winter after weaning. Isocaloric diets containing greater amounts of starch may hasten puberal development of heifers compared with diets containing less starch. Improvements in pubertal development associated with feeding high starch diets may not be profitable since digestive problems may occur if daily intake is not controlled.

Table 4. Composition of high[a] and low[b] starch diets and supplement[c] fed to heifers (as-fed basis)

Item Ingredient, As-fed %	Supplement or Diet High Starch	 Low starch	 40% Supplement Cube
Soybean meal	11.00	-	94.60
Soybean hulls	-	35.00	-
Corn dent no. 2	64.50	37.00	-
Cottonseed hulls	10.00	-	-
Molasses	2.50	-	3.35
Dicalcium phoshate	-	-	1.95
Limestone	1.00	1.00	-
Corn distillers grain	-	27.00	-
Alfalfa pellets	11.00	-	-

[a] Heifers limit-fed in drylot for 60 days.

[b] Heifers self-fed in drylot for 60 days.

[c] Heifers fed 0.9 kg/d of supplement while grazing native pasture for 60 days.

Table 5. Nutrient concentration and intakes of high and low starch diets

Item	High Starch	Low Starch
Nutrient Concentration		
NE_m, Mcal/kg	1.89	2.07
NE_g Mcal/kg	1.25	1.41
CP, %	14.5	16.2
Starch, %	43.6	24.8
Nutrient Intake		
Average dietary intake, kg/d	7.28	6.91
NE_m, Mcal/kg	13.76	14.3
NE_g Mcal/kg	9.1	9.7
CP, kg	1.06	1.12
Starch content, kg	3.17	1.71

[a]Calculated from NRC (1984 and 1996).

Table 6. Effect of high starch and low starch diets on body weight (BW) and average daily gain (ADG) of beef heifers

Item	Treatment[a]			SE	Contrast (P-value)	
	HS	LS	CON		CON vs HS and LS	HS vs LS
Heifer, no	23	23	23			
Feb. 20 BW, kg	203.0	201.2	202.2	5.1	1.0	0.80
April 2 BW, kg	236.8	240.4	219.8	5.1	0.004	0.60
May 9 BW, kg	283.0	279.6	229.6	5.4	0.0001	0.64
July 22 BW, kg	329.5	338.3	283.6	5.8	0.0001	0.30
Pretreatment (Weaning-Feb)						
ADG, kg/d	0.14	0.18	0.16	0.04	0.94	0.45
Treatment (March-April)						
ADG, kg/d	1.18	1.10	0.29	0.09	0.0001	0.17
Post treatment (May-July)						
ADG, kg/d	0.77	0.98	0.90	0.08	0.62	0.0005

[a] HS= High starch; LS= Low starch; CON= Control.

Table 7. Effect of high starch and low starch diets on age and weight at puberty of beef heifers

	Treatment[a]				Contrast (P-value)	
Item	HS	LS	CON	SE	CON vs HS and LS	HS vs LS
Puberty-Ovulatory heifers[b]						
Age, d	468 (17)[c]	471 (12)	489 (3)	12	0.43	0.49
Body weight, kg	312.2 (16)	322.4 (11)	307.6 (3)	9.1	0.55	0.35
Puberty-Ovulatory and assigned ovulatory heifers[d]						
Age, d	476 (19)	498 (17)	525 (14)	10	0.001	0.10
Body weight, kg	312.7 (22)	328.0 (22)	295.8 (23)	5.0	0.0001	0.03

[a]HS = High starch; LS = Low starch; CON = Control.
[b]Includes heifers that were pubertal during the sampling period (May-August).
[c]Number of observations in parentheses.
[d]Includes heifers that were pubertal during the sampling period and nonpubertal that were assigned the last sampling period as the pubertal date.

Table 8. Effect of high and low starch diets on the percentage of heifers with luteal activity by week after treatment, weeks to luteal activity, and pregnancy rate

	Treatment[a]				Contrast (P-value)	
Item	HS	LS	CON	SE	CON vs HS and LS	HS vs LS
Heifer, no	23	23	23	-		
Luteal activity[b] by week after treatment, %				-		
4 wk (June)	17	13	0	-	0.05	0.60
8 wk (July)	57	22	4	-	0.001	0.004
12 wk (August)	78	44	13	-	0.0001	0.008
16 wk (August 24)	78	56	13	-	0.0001	0.09
Weeks to luteal activity[c]- Ovulatory heifers	6.3	8.8	8.3	1.3	0.72	0.09
Weeks to luteal activity[d]-Ovulatory and assigned ovulatory	9.0	12.7	15.9	1.0	0.001	0.01
Pregnancy rate, %	65	52	13	-	0.0002	0.33

[a] HS = High starch; LS = Low starch; CON = Control.

[b] The first of two weekly plasma samples with greater than 1 ng of progesterone per mL.

[c] Includes heifers that were pubertal during the sampling period (May-August).

[d] Includes heifers that were pubertal during the sampling period and nonpubertal that were assigned the last sampling period as the pubertal date.

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Chapter V

Summary and Conclusion

Nutrition is a key element in beef heifer development programs. In order for heifers to reach puberty at 12 to 14 month of age and conceive during the breeding season, adequate energy needs to be provided after weaning.

Age and weight at puberty are directly affected by nutrition and can hasten or delay the onset of puberty. Nutrition prior to puberty may also affect mammary gland development, which may influence a cow's future milk production, and weaning weights of calves. Rate of body weight gain could adversely influence mammary gland development. If rapid weight gains occur after weaning, increased fat deposit and decreased DNA could influence future milk production.

A feeding strategy in which heifers are provided high energy diets for 60 days prior to breeding can decrease age and weight at puberty. Feeding for a short time period after 8 months of age may also reduce undesirable effects of rapid body weight gain on the mammary development and subsequent milk production.

Feeding high starch diets may increase the incidence of bloat and acidosis, therefore require more intensive management practices to prevent heifer losses or a decline in productivity. Limit feeding a high starch diet may result in decreased acetate: propionate ratio in the rumen, which may enhance pubertal development, through production of metabolic signals.

In experiment 1, heifers on a high rate of gain from 8 to 12 months of age were younger and heavier at puberty with increased amounts of fat in the mammary gland, than limit fed and control heifers. The amount of DNA present in the mammary gland was not influenced by nutritional treatment. This suggests that although rate of gain for these heifers were increased, mammary development was not altered and more heifers may be pubertal during the breeding season.

Heifers in experiment 2 began the treatment period in sub optimal condition from the preceding harsh winter. Feeding 0.9 kg/d of a 40% CP supplement while heifers graze dormant native grass may not provide heifers with adequate energy to gain sufficient weight during a harsh winter. Occasionally weighing or obtaining a body condition score of heifers may be a useful tool to assess heifer condition in order to make dietary adjustments during the winter feeding period. Heifers on a diet with similar energy but increased starch experienced puberty 2.5 wk earlier than heifers on lower starch diets. More high starch heifers initiated puberty during the breeding season and tended to have increased pregnancy rates than heifers on low starch and control diets. The results in experiment 2, suggest that amount of starch in the diet for short feeding periods may influence age at puberty and increase the number of heifers initiating puberty during the breeding season.

VITA 2

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Master of Science

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