EFFECTS OF NUTRITION ON AGE AND WEIGHT AT PUBERTY IN BEEF HEIFERS

By

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TABLE OF CONTENTS

Chapter

Chapter Page

LIST OF TABLES

FORMAT OF THESIS

This thesis is prepared as outlined by the Oklahoma State University graduate college style manual. This thesis is presented in the Journal of Animal Science style format. The use of this format allows for independent chapters to be suitable for submission to scientific journals. Each paper is complete in itself with an abstract, introduction, materials and methods, results and discussion, implications and literature cited section.

CHAPTER I.

INTRODUCTION

Although the entire mechanism by which puberty occurs in beef heifers is not yet understood, manipulation of the onset of puberty can affect the cow herd's profitability and productivity. Cows that calve early as two year-olds raise significantly more pounds of calf through out their lifetime (Lesmeister et al., 1973) and rebreed earlier (Burris and Priode, 1958).

To optimize reproductive efficiency, heifers must breed by 14 months of age to calve at 24 months. However, in cow-calf systems that graze spring-born heifer calves on dormant native range during the winter, achieving sufficient weight gains prior to the breeding season can be difficult and expensive. In general, increasing energy intake of beef heifers hastens puberty (Wiltbank et al., 1969), as well does the use of monensin and high concentrate rations (McCartor et al., 1979; Moseley et al., 1982).

The goal of this research was to investigate possible supplementation and feeding regimens that could affect puberty and possibly lower feed input costs. Chapter two contains a review of the literature concerning nutritional effects on puberty. Chapter three contains the results of a two-year study involving the use of monensin and 4-Plex (copper lysine, manganese methionine, zinc methionine, and cobalt glucoheptonate, Zinpro Corporation, Edina, MN), in supplements given to heifers grazed on dormant native range.

Chapter four contains the results of a one-year study that involved using a combination of supplements on native range and short-term feeding of high-energy rations to manipulate puberty. Finally, chapter five summarizes all of the research.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Puberty is defined as the time at which animals have become capable of reproducing themselves (Robinson, 1977). In cow-calf systems that have a restricted breeding season, the age at which heifers attain puberty can have a tremendous impact on the productivity and efficiency of the cow herd. Cows that calve early as two year-olds raise significantly more pounds of calf throughout their lifetime (Lesmeister et al., 1973) and rebreed earlier (Burris and Priode, 1958). Since cow-calf operations typically wean calves on a certain day as opposed to a certain age, having first-calf heifers calve early in the calving season also means weaning more total pounds of calf.

Physiology Prior to Puberty

The anterior pituitary and ovaries are capable of responding to exogenous hormones when the heifer is one month old (Seidel et al., 1971), and combinations of estrogens and progestins can induce ovulation and the formation of a corpus luteum prior to the normal age of puberty (Gonzalez-

Padilla et al., 1975; Short et al., 1976), suggesting that the maturation needed for the onset of puberty occurs in the brain and/or hypothalamus.

The most studied model for the onset of puberty is the gonadostat hypothesis proposed by Ramirez and McCann (1963). They proposed that low levels of estrogen produced by the ovaries in the prepubertal heifer delays the maturation of the hypothalamo-hypophyseal axis. As heifers approach puberty, the negative feedback effects of estrogen declines, allowing for an increase in the release of luteinizing hormone (LH) and follicle stimulating hormone (FSH). The release of these gonadotropins stimulates follicular growth, resulting in higher levels of estradiol needed to stimulate the ovulatory LH surge.

In a review, Schillo (1992) summarized that the timing of pubertal estrus in heifers is related to the increase in LH pulse frequency due to lower negative feedback effects of estradiol. Ovariectomy at one month of age increased circulatory LH in heifers (Odell et al., 1970), although the rise in LH secretion is more gradual in prepubertal than post-pubertal heifers (Kiser et al., 1981). Schillo et al. (1982) found that supraphysiological concentrations of estradiol inhibited LH secretion in prepubertal heifers, with more inhibition found at four months of age than at eight to twelve months of age. Day et al. (1984) also found that the negative feedback of estradiol on LH secretion declines during the last four months prior to puberty. LH pulse frequency rises from 1 pulse per 6 hours 50 days prior to puberty to 1 pulse per hour at puberty, and the number of receptors for 17B-estradiol in the anterior and medial basal hypothalamus declined as heifers get closer to puberty (Day et al., 1987).

Level of nutrition can influence LH release, as high versus moderate levels of metabolizable energy (ME) enhanced the pulsitile release of LH, and increased plasma urea nitrogen and insulin levels (Day et al., 1986). Restricting dietary energy can also depress LH secretion (Day et al., 1984). Schillo (1992) suggests that nutrition influences puberty via intermediary metabolism, either with specific metabolites, such as glucose, non-esterified fatty acids (NEFA), insulin, insulin-like growth factor I (IGF-I), growth hormone (GH) and tyrosine, or by total metabolic fuel availability.

Effects of Diet on Puberty

Energy. Schillo et al. (1992) summarized that the timing of puberty is more related to the total growth prior to puberty than the rate or timing of growth. Heifers that had all of their post-weaning gain at the beginning, end, or evenly throughout the post-weaning period did not differ in age and weight at puberty (Clanton et al., 1983). Restricting dietary energy intake can increase the age and weight at puberty (Short and Bellows, 1971). But, heifers that have higher weaning weights and higher rates of gain pre-weaning were found to be younger and heavier at puberty (Arije and Wiltbank, 1971). Heifers fed a higher energy diet that resulted in them gaining .45 kg/d more than low energy fed heifers reduced age and increased weight at puberty in both crossbred and straightbred heifers (Wiltbank et al., 1969). Feeding heifers to heavier target weights decreased age at puberty and increased weight at puberty (Patterson et al., 1991; Wiltbank et al., 1985), resulting in heifers that calved 17 d earlier and had weaning weights that were 13.6 kg higher (Wiltbank et al., 1985). However, McShane et al. (1991) found that increasing energy intake can decrease age at puberty without affecting weight at puberty. Moseley et al. (1982) divided heifers into above and below average weaning weight groups and fed them to gain at the same rate (.55 and .56 kg/d). Both groups of heifers were pubertal at the same age, but the lightweight heifers were 22 kg lighter at puberty, suggesting that the heavy-weight heifers were limited by age at puberty and the light-weight heifers were limited by weight.

In heifers grazing dormant winter range, increasing supplemental energy independent of supplemental protein increased pregnancy rates without altering age and weight at puberty or body condition score (Marston et al., 1995). Marston et al. (1995) also increased the level of 20% crude protein (CP) supplement fed and found that age at puberty was not affected, but heifers fed the higher level of supplement were heavier at puberty.

When an increase in energy intake results in heifers that are younger and heavier at puberty, heifers will also be fatter (Yelich et al., 1995). Yelich et al. (1995) proposed that there was both a minumum age and weight at puberty. The heifers with higher rates of gain surpassed the minumum weight at puberty prior to reaching the minimum age. As the weight at puberty increased, so did body fat. Hopper et al. (1993) found that heifers that were fed to produce a higher rate of gain were heavier and fatter at puberty, tended to be younger, and had a larger longissimus dorsi muscle. Breed differences were observed, as the Angus heifers were fatter and had more muscle than did the Santa Gertrudis heifers. This study also supports the theory that there is not a level of body fat at which puberty occurs.

Hall et al. (1993) found that heifers fed at a higher rate of gain (1.0 vs .6 kg/d) had carcasses that contained less moisture, and more fat and fat-free organic matter. Since the heifers fed to gain 1.0 kg/d were 29 days younger, they concluded that puberty does not occur at a constant body composition.

Ionophores and Concentrates. Age and weight at puberty can be affected by using diets which increase the relative proprotion of propionate produced in the rumen. Increasing concentrate:roughage ratio in the diet from 20:80 to 50:50 and feeding 200 mg/d of monensin with the 20:80 high roughage diet both reduced age and weight at puberty compared to controls (McCartor et al., 1979). The authors attributed the reduction in age and weight of puberty to the decrease in the acetate:propionate ratio found in both the higher concentrate and monensin diets. An increase in propionate production and the reduction in age at puberty has also been seen in other studies (Dufour 1975; Moseley et al., 1977; Moseley et al., 1982). In a review, Sprott et al. (1988) found that monesin reduced age at puberty in trials where the average daily gains exceeded .4 kg/d.

Purvis et al. (1993) found that age at puberty was decreased independent of weight gain by feeding monensin or administering an anthelmintic.

Marston et al. (1995) fed heifers grazing dormant native range .9 kg/d of a 40% CP supplement until 60 d prior to the beginning of breeding. The heifers were then fed a high concentrate ration in a drylot at a target rate of gain so that they would weigh the same as heifers fed 2.7 kg/d of a 20% CP supplement after weaning. Heifers on both treatments weighed the same and had the same body condition score at the beginning of breeding, but the heifers fed the high concentrate ration were 27 d younger at puberty. Heifers fed the high concentrate ration were 18 and 38 kg lighter at puberty in years one and two than heifers fed 2.7 kg/d of a 20% CP supplement. Feeding the high concentrate ration also increased the percentage of heifers pubertal prior to the breeding season by 45%. Since heifers have a higher conception rate on their third estrus compared to their first (Byerley et al., 1987), this would allow for more heifers to be bred in the early part of the breeding season.

The proposed mechanism by which monensin and high concentrate rations influence the onset of puberty is by increasing the relative amount of propionate produced by microbes in the rumen. Rutter et al. (1983) found that prepubertal heifers infused with propionate into the abomasum responded better to a GnRH challenge than did controls which were infused with water. Heifers with an increased production of propionate had an increase in the amplitude of LH released during the preovulatory surge of LH following treatment with estradiol (Randel et al., 1982). In contrast, Lalman et al. (1993) top-dressed supplements with propionic acid and found no difference in age at puberty. However, the production of volatile fatty acids in the rumen were not measured, and feeding propionic acid may not mimic the change in ruminal fermentation that occurs when heifers are fed monensin or high concentrate diets.

An increase in relative production of propionate may not be the only mechanism by which monensin can affect puberty. An increase in propionate production in the rumen does not account for all of the increase in feed efficiency (Schelling, 1984) in cattle fed monensin. Feeding monensin has increased the amount of bypass protein from 22 to 55% (Bergen and Bates, 1984. Thirty to 50% of ^{14}C-labeled monensin fed to ruminants was absorbed into the blood stream (Donoho, 1984). Armstrong and Spears (1988) administered monesin intravenously and found that it increased glucose and free fatty acid (FFA) concentrations compared with heifers administered a vehicle or lasalocid. They also found that concentration of insulin was first depressed for 120 minutes, but then increased to concentrations greater than those of control or lasalocid heifers. Monensin also lowered both growth hormone (GH) and LH secretion in steers (Armstrong and Spears, 1988). In a review, Schillo et al. (1992) summarized that fatty acids and GH may inhibit puberty, while IGF-I, insulin, and tyrosine may stimulate the onset of puberty. Feeding monensin and high concentrate feeds may affect puberty via increased propionate production and alteration of intermediary metabolites.

Feeding of the ionophore lasalocid to Brahman bulls increased the amplitude of LH secreted after administration of GnRH (Rutter et al., 1991). They also found that when the first sperm cells were detectable in the ejaculate, bulls fed lasalocid released more LH and testosterone than did control bulls. Goerhing et al. (1984) found that lasalocid reduced age at puberty of heifers gaining .34 kg/d, but did not affect puberty of heifers gaining .57 kg/d.

Protein. Increasing crude protein in a diet fed ad libitum from 12.8% (adequate) to 16.4% CP in isocaloric diets increased dry matter and crude protein intakes in Brown Swiss and Zebu heifers, but did not affect age or weight at puberty (Fajersson et al., 1991). Supplementing heifers consuming low-quality roughages with undegradable intake protein (UIP) above NRC requirements improved feed efficiency, but delayed puberty by 10 d ($P<.10$) compared with control heifers (Lalman et al., 1993). Oyedipe et al. (1982) fed Zebu heifers isocaloric diets with 19.2, 13.4, and 8.3% CP. They found that the age at puberty was 570, 641, and 704 d for the high, medium, and low CP-fed heifers. The restriction of dietary protein plays a part in delaying puberty, but increasing CP intake above requirements for heifers is probably not needed and uneconomical.

Trace Minerals. Documentation of the effects of trace mineral deficiencies on puberty in the literature is lacking. However, Bentley and Phillips (1951) found that puberty was delayed when heifers were fed a basal diet deficient in manganese (7 ppm) compared with heifers which received at diet with adequate amounts of manganese (30 ppm). Deficiencies of dietary copper can be influenced by dietary molybdenum (Corah and Ives, 1991). Phillippo et al. (1987) found that adding 5 ppm of molybdenum, which decreases the availability of dietary copper, delayed the onset of puberty by 8 weeks, reduced pregnancy rates by 60%, and reduced the amplitude of the ovulatory LH peak compared with a control diet with no added molybdenum.

Effect of Season on Puberty

Season has an important role in determining pubertal age. Schillo et al. (1983) used heifers born near the vernal and autumnal equinoxes. These heifers were raised outdoors for the first six months of their life. The heifers were then exposed in environmental chambers to ambient temperatures and photoperiod of either spring and summer or fall and winter. They found that September-born heifers were younger at puberty than March-born heifers. Heifers exposed to the spring-summer environmental conditions were younger at puberty regardless of the season of their birth.

The pattern of melatonin secretion by the pineal gland has an intergral part in the reproduction of seasonal breeders (Schillo et al., 1992). Age at puberty was decreased in late winter-born heifers when they were given melatonin to simulate short days during the summer (Tortonese and Inskeep, 1991).

Summary

Puberty occurs in beef heifers as the hypothalamo-hypophyseal axis escapes the negative feedback of estrogens and secretes more LH. Increasing the amount of energy fed to heifers will decrease age at puberty but not weight at puberty. Feeding monensin or high concentrate diets can decrease age and weight at puberty. A shift of ruminal fermentation towards more propionate production and most likely a change in the intermediary metabolism could cause the hastening of puberty when these types of diets are fed. Feeding crude protein above requirements is not beneficial.

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CHAPTER III.

EFFECTS OF MONENSIN AND 4-PLEX ON THE GROWTH AND PUBERTY OF BEEF HEIFERS

Abstract

Sixty spring-born beef heifers in trial one and sixty-four in trial two were fed 2.27 kg/d of a Soybean meal-based 25% CP supplement while grazing dormant native range in winter (November to April). Heifers in trial one were fed either 0 (CON) or 200 mg/d of monensin (MON). Heifers in trial two were allotted in a 2 X 2 factorial arrangement of treatments to receive 0 or 14.2 g/d of 4-Plex (copper lysine, manganese methionine, zinc methionine, and cobalt glucoheptonate) and 0 or 200 mg/d of monensin (CON, 4PLEX, MON, and COMB). In trial one, MON did not influence age and weight at puberty or ADG. In trial two, MON reduced age at puberty by 17 d ($P<.05$) compared with CON and COMB heifers, and 4PLEX heifers were intermediate in age at puberty. Weight at puberty was not influenced by treatments. More MON heifers were pubertal on May 1 than CON or COMB (52 vs 22 and 17%; $P<.05$), with 4PLEX being intermediate (44%). The MON and COMB heifers had greater winter gains than CON heifers (.37 and .36 vs .31 kg/d; $P<.05$), but were not different from 4PLEX heifers (.34 kg/d). The CON heifers gained more than COMB heifers during spring (May-June) breeding (1.08 vs .93 kg/d; $P<.05$) with MON and 4PLEX intermediate. The MON heifers had reduced gains during the non-supplemented period compared with CON (.72 vs .83 kg/d; $P<.01$). Age at puberty may be decreased by feeding monensin on dormant native range when weight gain is adequate.

Key Words: Monensin, trace minerals, puberty.

Introduction

Lifetime productivity of beef cows is related to age at first calving. Cows which calve early as 2-yr-olds raise significantly more pounds of calf during their lifetime (Leismeister et al., 1973) while rebreeding earlier (Burris and Priode, 1958). In a review, Sprott et al. (1988) reported that a greater percentage of heifers fed monensin were puberal 40 days prior to breeding compared with controls. Moseley et al. (1977) and McCartor et al. (1979) found that monensin decreased age at puberty, and Purvis et al. (1993) and Moseley et al. (1982) found that MON reduced age at puberty independent of weight gain. McCartor et al. (1979) found that monensin reduced weight at puberty. In trials in which monensin reduced age at puberty, daily gains of the heifers were .4 to .6 kg/d (Sprott et al., 1988). Copper can be made insoluble and unavailable to the animal by thiomolybdates (Corah and Ives, 1991). Supplementing heifers with 4-Plex may make improve reproductive performance because of the increased bioavailability of the amino acid-trace mineral complexes. This trial was conducted to determine the effects of monensin and an organic/trace-mineral complex on age and weight at puberty of beef heifers.

Materials and Methods

These trials were conducted at the Range Cow Research Center, located twelve miles west of Stillwater, OK. Sixty spring-born Hereford or Hereford x Angus cross heifers were used in trial one and sixty-four in trial two.

Trial 1. Heifers grazed dormant tallgrass native pastures and were blocked by breed and weight and allotted to two treatments. All heifers were individually fed 2.27 kg/d of a 25% CP soybean meal-based supplement (Table I), prorated to a

5-d/wk feeding schedule in a covered stall barn. Treatments provided 0 (**CON**) or 200 mg/d of monensin (**MON**). Free-choice prairie hay (CP=4.4%) was offered from January 9 through March 29, 1993. All weights were taken after an overnight withdrawal (16 hr) of feed and water. Beginning (November 5, 1992), end of supplementation (April 27, 1993), and end of breeding (June 29, 1993) weights were calculated from an average of two weights taken twenty-four hours apart.

Beginning on April 27, all heifers were exposed in one pasture to two bulls for 60 d. Weekly blood samples were taken via tail venipucture beginning March 3, 1993. Blood samples were analyzed for progesterone (Bishop and Wettemann, 1993) to determine puberty. Puberty was defined as the first of two consecutive weekly plasma samples with progesterone greater than 1 ng/ml. Pubertal weights were calculated by a linear interpolation of weights just before and after the puberty date. Heifers with a concentration of progesterone greater than 1 ng/ml on the first sample on March 3 were determined to be pubertal on that date. The last blood sample was taken on June 22, one week before the end of the breeding season. Therefore, concentrations of progesterone for some heifers were never greater than 1 ng/ml but they became pregnant during the last week of breeding. For these heifers, conception dates were computed by subtracting 280 days from the subsequent calving date. Date of puberty was then estimated by adding 5 d to the estimated conception date to approximate when the concentration of progesterone would first be greater than 1 ng/ml.

Trial 2. Heifers were blocked by weight and breed and allotted to four treatments using a 2 x 2 factorial design. All heifers were fed 2.27 kg/d of the 25% CP supplement (Table II) that delivered 0 or 14.2g/d of 4PLEX (copper lysine, manganese methionine, zinc methionine, and cobalt glucoheptonate, Zinpro Corporation, Edina, MN) and 0 or 200 mg/d of MON (CON, MON, 4PLEX, and COMB). The calculated trace mineral content (NRC, 1984) of the control supplement met the requirements for trace minerals. Supplement feeding was conducted and heifer weights and blood samples were taken as described for Trial one. Supplementation began on November 2, 1993, and continued until April 12, 1994. All heifers were exposed to two bulls in one pasture from April 29 to June 29, 1994.

Statistical Analysis. The GLM procedure of SAS (1985) was used to conduct analysis of variance. For year one, the independent source of variation was the dietary treatment. Julian date of birth within each yr was used as a covariate in all models. Heifers which had not reached puberty by the end of the breeding season were excluded from the analysis of age and weight at puberty. The main effects of MON and 4PLEX and the interaction were in the model for trial 2 and Julian date of birth and initial weight were covariates. There was no year x MON interaction for daily gains after the end of supplementation, so these data were pooled over both years. In this model, year and dietary treatment were the independent sources of variation, with the Julian birth date as a covariate. Data for one heifer each in trial 1 and trial 2 were removed from the analyses for health reasons not related to treatments. When treatment effects were significant, means were separated with a t-test using the PDIFF option of SAS (1985).

Results and Discussion

Trial 1. Gains during supplementation were similar for CON and MON heifers (.24 kg/d) during supplementation. This gain was less than the .4 kg/d that Sprott et al. (1988) found in every report where an ionophore had affected puberty. Even though MON did not increase weight gain during the winter supplementation period, CON heifers gained .11 kg/d more than MON heifers ($P<.05$) during the breeding season when no supplements were fed.

MON did not increase daily gains during supplementation, most likely due to the variability in gains during the different monthly periods (Table III). Weather during the supplementation period of trial 1 was severe with extended periods of low ambient temperature and rain. As a result, winter gains were less than expected and heifers even lost weight in some periods. Between December 4 and January 4, MON heifers lost weight as CON heifers gained .11 kg/d (P<.05). However, between February 2 and March 5, when hay was fed free-choice and gains were greater than .5 kg/d, the MON heifers gained .13 kg/d more than CON heifers (P<.01). From March 5 to April 1, the period in which free choice prairie hay was no longer fed, all heifers lost weight, but there was no difference between gains of CON and MON heifers.

Treatment did not influence the percentage of heifers that were pubertal by April 1, May 1, or May 21 (Table III). However, more CON heifers compared with MON heifers tended to be puberal by June 29 (84% vs. 75%, P<.10). This difference may have occurred because MON and CON heifers had similar weight gains during supplementation but MON-fed heifers had reduced daily gains after the end of supplementation compared to with CON heifers. Reduced daily gains of MON heifers caused them to reach their minimum weight to achieve pubertal estrus at a later date than CON heifers.

Trial 2. A significant MON by 4PLEX interaction (P<.10) occurred for age at puberty and percentage of heifers pubertal by April 1 and May 1. Therefore the effects of the treatments and not the main effects were compared. Heifers fed MON and COMB treatments had greater daily gains (Table IV) during supplementation than CON (.37 and .36 vs .31 kg/d respectively; P<.05), but daily gains of MON, COMB, and CON heifers were not different from 4PLEX heifers (.34 kg/d). During the 2-wk period from the end of supplementation to the beginning of breeding, weight gains for CON, MON, 4PLEX, and COMB were similar. Heifers previously fed COMB gained .15 kg/d less than CON heifers (P<.02) during the breeding season. The COMB heifers had breeding season gains of .12 kg/d less than MON (P<.05) and .10 kg/d less than 4PLEX heifers (P<.10). An explanation for these gains is not apparent.

More MON-fed heifers were pubertal by April 1 (P<.05) than CON, 4PLEX, or COMB heifers (42% vs 8%, 16%, and 5% respectively). By May 1 (start of breeding) 52% of the MON heifers were pubertal, which was not different from 4PLEX (44%), but greater (P<.05) than for COMB (17%) and CON heifers (22%). Percentages of heifers showing pubertal by May 21 or June 29 (end of breeding) were similar for all treatments.

Heifers fed MON were 17 d younger at puberty than CON or COMB heifers (P<.05) and 4PLEX heifers were intermediate. Weight at puberty was similar for all treatments, suggesting that the advantage in the age at puberty given by feeding MON was a function of weight gain. Fewer COMB heifers were pubertal by April 1 and May 1 compared with MON heifers (5 and 17 vs 42 and 52%; P<.05), but we can not explain why 4PLEX would have negated the response seen by the MON heifers.

The effects of MON and CON for age at puberty, percent of heifers in pubertal by April 1 and May 1, and supplementation gain could not be pooled over the two trials because of yr by treatment interactions (P<.10). In year 1, winter gains may have been insufficient for MON to improve weight gains, but in year 2, environmental conditions were more desirable, which permitted greater gains and MON increased winter gains, reduced age at puberty, and increased the number of heifers that were puberal by the beginning of the breeding season.

Purvis et al (1993), Moseley et al. (1982), McCartor et al. (1979), and Moseley et al. (1977) found that an ionophore would reduce the age at puberty when a complete ration was fed. All of these trials had daily gains of at least .4 kg/d. We found a monensin response when heifers grazed dry native forage and were supplemented with protein and energy gained .31 kg/d (trial 2), but not with supplemented daily gains of .24 kg/d (trial 1). Weight gains during year one were not only less than in year two but were also more erratic with weight losses during some periods; this may have contributed to a failure to observe a gain response to monensin.

In trial 2, age at puberty, percent of heifers puberal by April 1 and May 1, and supplementation gain were similar for COMB and CON but less than for either the MON or 4PLEX. The interaction between MON and 4PLEX which causes the decreased daily gains cannot be explained.

Pooled Data

Because there was no year by treatment interaction, non-supplemented daily gains were pooled over the two years to analyze the effect of withdrawal of MON on daily gains (Table V). In period one (first 28 days without supplementation), CON heifers gained .15 kg/d ($P<.01$) more than MON heifers. Similarly, CON heifers tended to gain more than MON heifers during the second 28-d period following the end of supplementation (.08 kg/d, $P=.11$). Throughout the entire non-supplemented period, CON heifers gained .11 kg/d ($P<.01$) more than the MON-fed heifers. MON heifers consistently had reduced gains after supplementation ended compared with CON heifers even though MON improved supplemented gains in trial two but did not improve gains during the supplementation period in trial one. Monensin has been observed to reduce rumen turnover rate from 7 to 44% and to increase rumen fill from 9 to 24% in forage-based diets (Schelling, 1984). It is possible that increased rumen fill of MON-fed heifers accounted for an apparent reduced gain following MON withdrawal.

Implications

The use of monensin in supplements for replacement heifer grazing low-quality dormant winter forages can cause varying results. When winter daily gains exceed .3 kg/d, monensin may decrease age at puberty due to increased gains, and result in a greater percentage of heifers puberal before the beginning of the breeding season. Weight gains may be reduced after removal of monensin regardless of its effect during supplementation. Organic/trace-mineral complexes may not affect puberty in beef heifers consuming a diet not deficient in trace minerals.

Table I. Supplement Compostion on an as-fed basis (Trial 1).

Ingredient,%	Control	Monensin
Soybean meal	37.29	37.27
Wheat midds	56.45	56.41
Cane molasses	4.03	4.02
Dicalcium phosphate	0.58	0.58
Limestone	1.61	1.61
Vitamin A-30,000	0.04	0.04
Rumensin 60[a]	0.00	0.07

[a] 132 grams monensin/kg

Table II. Supplement Compostion on an as-fed basis (Trial 2).

Ingredient,%	Control	Monensin	4-Plex	Combination
Soybean meal	37.29	37.27	37.06	37.03
Wheat midds	56.45	56.41	56.09	56.05
Cane molasses	4.03	4.02	4.00	4.00
Dicalcium phosphate	0.58	0.58	0.58	0.58
Limestone	1.61	1.61	1.60	1.60
Vitamin A-30,000	0.04	0.04	0.04	0.04
Rumensin 60[a]	0.00	0.07	0.00	0.07
4-Plex[b]	0.00	0.00	0.63	0.63

[a] 132 grams monensin/kg

[b] 4-Plex (copper lysine, zinc methionine, manganese methionine, and cobalt glucoheptonate, Zinpro, Inc., Edina, MN)

Table III. Daily gains and reproductive function of heifers fed 0 or 200 mg/day of Monensin in 2.27 kg/d of a 25% CP supplement on dormant native range in year 1 (Trial 1).

Monensin	0 mg/d	200 mg/d	SE
No. of heifers	30	29	
Inital Weight, kg	199	201	18
ADG, kg			
Supplementation[a]	.24	.24	.01
11/6 to 12/4	.33	.31	.04
12/4 to 1/4	.11[c]	-.02[d]	.03
1/4 to 2/2	.44	.50	.04
2/2 to 3/5	.51[c]	.64[d]	.03
3/5 to 4/1	-.09	-.06	.05
4/1 to 4/27	.17	.12	.05
Breeding[b]	.72[c]	.61[d]	.02
Pubertal by, %			
April 1	3	1	3
May 1	9	5	4
May 21	24	22	9
June 29	84	75	6
Age at puberty, d	460	460	5
Weight at puberty, kg	276	270	4

[a] Period between 11/02/92 to 4/27/93

[b] Period between 4/27/93 to 6/29/93

[cd] Means within a row lacking a common superscript differ ($p<.05$).

Table IV. Effects of Monensin[a], 4-Plex[b], and Combination[c] on daily gains and puberty in year 2 (Trial 2) of heifers fed 2.27 kg/d of a 25% CP supplement on dormant native range.

Treatment	Control	Monensin	4-Plex	Combination	SE
No. of heifers	16	15	16	16	
Initial Weight	217	224	219	218	17
ADG, kg					
Supplementation[d]	.31[f]	.37[g]	.34[fg]	.36[g]	.01
11/2 to 11/30	.25	.36	.46	.22	.05
11/30 to 12/31	.28	.32	.22	.42	.06
12/31 to 1/25	.16	.22	.16	.21	.05
1/25 to 2/23	.44	.61	.49	.58	.05
2/23 to 3/23	.09	.09	.07	.07	.05
3/23 to 4/12	.76	.78	.70	.82	.07
Non-Supplementation					
4/12 to 4/27	.40	.22	.32	.21	.09
Breeding[e]	1.08[f]	1.05[fh]	1.03[fg]	.93[g]	.04
Pubertal by, %					
April 1	8[f]	42[g]	16[f]	5[f]	9
May 1	22[f]	52[g]	44[fg]	17[f]	11
May 21	52	69	65	50	13
June 29	100	91	100	88	5
Age at puberty, d	445[f]	428[g]	436[fg]	445[f]	6
Weight at puberty, kg	296	296	293	296	6

[a] Monensin fed at 200 mg/day.
[b] 4-Plex fed at 14.2 g/day (copper lysine, zinc methionine, manganese methionine, and cobalt glucoheptonate, Zinpro, Inc, Edina, MN)
[c] Monensin fed at 200 mg/day and 4-Plex at 14.2 g/day.
[d] Period between 11/2/93 and 4/14/94.
[e] Period between 4/27/94 and 6/29/94.
[fgh] Means within a row lacking a common superscript differ ($p<.05$).

Table V. Pooled Monensin effects on non-supplemented daily gains of heifers grazing native range after receiving 0 or 200 mg/d monensin in 2.27 kg/d of a 25% CP supplement in Trials one and two.

	Monensin		
	0 mg/day	200 mg/day	SE
No. of Heifers	62	60	
ADG, kg			
Period 1[a]	0.65[d]	0.50[e]	0.04
Period 2[b]	0.92	0.84	0.03
Non-supplemented[c]	0.83[d]	0.72[e]	0.02

[a]First 28 days without supplement (Year 1--April 28 to May 25, Year 2--April 12 to May 10).
[b]Second 28 days without supplement (Year 1--May 25 to June 22, Year 2--May 10 to June 8).
[c]Period from end of supplementation to end of breeding season (Year 1--April 28 to June 22, Year 2--April 12 to June 29).
[d,e]Means within a row lacking a common superscript differ (P<.01).

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CHAPTER IV.

EFFECTS OF TYPE OF DIET ON PUBERTY AND GROWTH OF BEEF HEIFERS

Abstract

Sixty-eight Hereford and Hereford X Angus heifers were used to evaluate the effect of type of diet on puberty. Heifers were blocked by pre-weaning treatment and intial weight and randomly assigned to four treatments that supplemented native range, used a combination of supplementation and drylot feeding for 60 or 30 d (Dry-60 and Dry-30; respectively), or used a combination of supplementation and self-feeding a lower starch for 30 d (Self-30). All heifers were fed .9 kg/d of a 40% CP supplement from November until diets were changed in late winter. One group of heifers recieved the .9 kg/d of a 40% CP supplement until the beginning of the breeding season (SBM). The Dry-60 and Dry-30 heifers began adaptation to a high-concentate diet on February 14 and March 14, respectively and were fed that diet for 60 and 30 d, respectively. Self-30 heifers were self-fed a high-energy diet in which corn distillers grains were substituted for corn and soybean meal for 30 d prior to the beginning of breeding on April 28. From February 14 to May 1, Dry-60 and Self-30 heifers gained faster than the SBM and Dry-30 heifers (.77 and .72 vs .46 and .56 kg/d; $P<.05$). The Dry-30, Dry-60, and Self-30 heifers had greater body condition scores than

SBM heifers (5.1, 5.3, and 5.2 vs 4.7, respectively; P<.05). Dry-60 heifers were puberal 24 and 22 d younger than Self-30 and SBM heifers (P<.05). Self-30 heifers were heavier at puberty (P<.05) than SBM, Dry-30, or Dry-60 heifers (320 vs 301, 287, and 289 kg). At the beginning of the breeding season, more Dry-60 heifers were puberal compared with SBM, Dry-30, and Self-30 heifers (31 vs 6, 7, and 0%, respectively; P<.05). Feeding a high concentrate diet for 60 d prior to the beginning of the breeding season reduced age and weight at puberty.

Key Words: Puberty, heifers, diet type.

Introduction

Heifers that calve early as two year-olds in a fixed calving season wean significantly more pounds of calf throughout their lifetime than heifers which calve later as two year-olds (Lesmeister et al., 1973). To calve early in the breeding season, heifers must conceive by 15 months of age. Timing of puberty is related to total growth prior to puberty (Schillo et al., 1992), and increasing energy intake and growth rate in heifers after weaning has reduced the age at puberty (Wiltbank, et al., 1969; Arije and Wiltbank, 1971; Wiltbank et al., 1985; McShane, et al., 1991). High concentrate diets which reduce the acetate:propionate ratio in the rumen (Dufour 1975, McCartor et al., 1979) or contain monensin (Moseley et al., 1977; Moseley et al., 1982; Purvis et al., 1993), have decreased age and weight at puberty. Feeding a high concentrate diet at a rate to achieve .9 kg/d gain for 60 d prior to breeding reduced both age and weight at puberty (Marston, et al., 1995). However, the effects of feeding a high concentrate diet for a period less than 60 d has not been evaluated.

Spring-born heifers grazing dormant native range require large amounts of energy supplements to gain enough weight to be pubertal prior to the start of the breeding season. Supplementing heifers with .9 kg/d of a high protein supplement until 60 days prior to the breeding and then limit-feeding heifers a high concentrate ration until the beginning of the breeding season may reduce overall feed costs. Using corn distillers grains as a substitute energy source in place of corn may allow a high energy ration to be self-fed due to a lower starch content in the corn distillers grains. The objective of this study was to determine if limit-feeding a high concentrate ration for 30 or 60 days or self-feeding a lower starch diet can influence puberty.

Materials and Methods

This trial was conducted at the Range Cow Research Center, located 20 km west of Stillwater, in North Central Oklahoma. Sixty-eight spring-born Hereford or Hereford x Angus heifers were used. Initial weight of the heifers was determined at weaning time in October after an overnight withdrawal from feed and water. Heifers were blocked by initial weight and pre-weaning nutritional treatment and randomly assigned to four treatments. One treatment consisted of growing heifers at a low rate of gain on dormant native range (SBM). Two treatments combined growing heifers at a low rate of gain on dormant forage followed by drylot feeding a high-concentrate diet in a drylot for 60 (Dry-60) or 30 d (Dry-30) just prior to the breeding season. The final treatment consisted of growing heifers at a low rate of gain on dormant native range and self-feeding a lower starch diet on native range.

All heifers grazed dormant native range and received .9 kg/d of a 40% CP soybean-meal based supplement (Table VI) from October 25 to the end of winter feeding (April 25, SBM) or until diets were changed in late winter. Heifers on the other treatments grazed the same pasture and were supplemented the same until they started their other dietary treatments. Native hay was provided free choice beginning on January 3 to all heifers that grazed the native range. Dry-60 heifers began adaptation to a corn-based high concentrate diet (Table VI) on February 14. Initially, Dry-60 heifers were fed 1.36 kg/d of the high concentrate ration and 4.5 kg/d of native hay. As amounts of the high concentrate feed increased, the amount of native hay fed was decreased. After adaptation, the Dry-60 heifers were limit-fed for 60 d to gain .9 kg/d. Dry-30 heifers began adaptation to the high concentrate diet on March 14, and were limit-fed for 30 d to gain .9 kg/d. Self-30 heifers were self-fed a lower starch ration (Table VI) for 30 d, beginning when the Dry-30 heifers ended their adaptation period (March

23). Self-30 heifers were fed separately from SBM heifers in a native range pasture.

Dry-60 and Dry-30 heifers were maintained in drylot pens and group-fed daily at 0800 in bunks. Initially, the high-concentrate feed and hay was fed in separate bunks at the same time, and one Dry-60 heifer died due to acidosis on February 28. Afterwards, hay was only fed after all the the high-concentrate feed was consumed, and the Dry-60 heifers were restarted on the adaptation to the high-concentrate ration. Once the heifers were adapted to the high-concentrate ration, .45 kg/heifer of native grass hay was fed after all feed was consumed. One Dry-30 heifer was removed during the adaptation period due to rumen acidosis, and another Dry-30 heifer was removed due to a broken jaw, which was not related to the diet.

A full weight was taken, at 0800 on April 25, and all heifers were placed in a drylot and fed native hay for 4 d to minimize differences in body fill. Weight at the beginning of breeding was determined by averaging weights taken on two consecutive days at the end of the 4-d period, after an overnight removal of feed and water.

Intermediate weights were taken after overnight removal of feed and water every 28 d until blood sampling began. Beginning on February 14, blood was obtained weekly via tail venipuncture and analyzed for progesterone (Bishop and Wettemann, 1993). Heifers were then weighed every 14 d until the end of the breeding season. Puberty was defined as the first of two consecutive weekly plasma samples with greater than 1 ng/ml of progesterone. Weight at puberty was determined by the weight taken on that day or the linear interpolation of the bi-weekly weights before and after the date at puberty. Two Dry-30, two Dry-60, and three Self-30 heifers did not become pubertal by the end of the breeding season, and were eliminated from the analysis of age and weight at puberty. Body condition scores were taken by four independent evaluators on April 27 (Wagner et al., 1988). Beginning April 28, all heifers were placed with two bulls in a single pasture for 60 d. Pregnancy was diagnosed by rectal palpation in October.

Analysis of variance was conducted using the GLM procedures of SAS (1985). Data were analyzed as a randomized complete block design. Heifers were blocked by pre-weaning nutrional treatment and initial weight, with dietary treatment being the independent source of variation. If the treatment effects were significant, means were separated with the PDIFF option of SAS (1985).

Results and Discussion

Initial weights on October 25 were similar for heifers on all treatments (Table VII). Treatments did not influence ($P>.10$) ADG from the beginning of the trial on October 25 to February 14, when the Dry-60 heifers began adaptation to the high concentrate diet (Table VII). From February 14, when the feeding regimen was changed for the Dry-60 heifers, to the beginning of the breeding season, Dry-60 and Self-30 heifers gained .31 and .26 kg/d more than the SBM heifers (P<.01), and .21 and .16 kg/d more than the Dry-30 heifers (P<.03). The higher than expected ADG of the Self-30 heifers is attributed to a relatively high average daily intake (9.7 kg/d). Because of the relatively short time on feed and moderate rate of gain, the Dry-30 heifers did not gain significantly more than the SBM heifers from February 14 to May 1 (.56 vs .46 kg/d; P>.10).

Because of the increased daily gains prior to the breeding season, Dry-60 and Self-30 heifers weighed more at the beginning of the breeding season (May 1) than the SBM and Dry-30 heifers (292 and 291 vs 270 and 277 kg; P<.05). Dry-60 and Self-30 heifers also had greater body condition scores (P<.05) than SBM heifers (Table VII) at the beginning of breeding. Dry-30 heifers had a significantly greater body condition score than the SBM heifers (5.1 vs 4.7), but were thinner (P<.05) than the Dry-60 heifers (5.3). During the breeding season, SBM heifers had greater ADG than did the Dry-60 and Self-30 heifers (.89 vs .61 and .75 kg/d; P<.03). Marston et al. (1995) also found that heifers fed a high concentrate ration for 60 d and heifers which were supplemented with 2.7 kg/d of a 20% CP supplement before the beginning of breeding gained less during the breeding season than heifers which were fed .9 kg/d of a 40% CP during late winter. Dry-60 heifers gained .14 kg/d less than Self-30 heifers during the breeding season (P<.05).

Limit feeding the high concentrate diet to Dry-60 heifers reduced age at puberty by 24 d (P<.01), and weight at puberty by 31 kg (P<.01) compared with

Self-30 heifers. This effect on pubertal development occured even though daily gains, weight at the beginning of the breeding season, and body condition score at the beginning of the breeding season were not influenced by treatment (Table VII). Volatile fatty acids (VFA) were not measured, but the reduction in age and weight at puberty is most likey caused by a change in ruminal fermentation that resulted in a lower acetate:propionate ratio. A reduction in age and weight at puberty when a decrease in the acetate:propionate ratio has occurred has been reported in several other studies (Dufour 1975; Moseley et al., 1977; McCartor et al., 1979; Moseley et al, 1982). Marston et al. (1995) found that a feeding a high concentrate diet for 60 d reduced age at puberty by 37 d and weight at puberty by 18 kg in year one and 38 kg in year two. This occurred even though the heifers fed the high concentrate diet for 60 d had similar weights and body condition scores at the beginning of the breeding season compared with heifers fed 2.7 kg/d of a 20% CP supplement while grazing dormant native range. The greater response from feeding the high concentrate for 60 d found by Marston et al. (1995) may be attributed to the problems encountered in getting the Dry-60 heifers adapted to the high concentrate ration that resulted in their high concentrate-fed heifers being 18 kg heavier at the beginning of the breeding season than the Dry-60 heifers in our study. Dry-60 heifers had 31, 25, and 26% more heifers pubertal on May 1 than the Self-30, Dry-30, and SBM heifers ($P<.05$), respectively. However, treatment did not influence the percent of heifers puberal by May 23 or June 27.

The Dry-60 heifers were puberal 22 d earlier than SBM heifers (P<.05), but were not significantly lighter at puberty (289 vs 301 kg; P>.10). The SBM and Dry-30 heifers were 19 and 33 kg lighter, respectively at puberty than Self-30 heifers (P<.05). Age at puberty was similar for SBM, Dry-30 and Self-30 heifers (444, 437, and 446 d, respectively; P>.10) These results are similar to Moseley et al. (1982), where light-weight heifers had the same age at puberty as heavy-weight heifers, but were 22 kg lighter at puberty. This suggests that the SBM and Dry-30 heifers were limited by weight at puberty, whereas the Self-30 heifers were limited by age.

The Self-30 heifers gained .26 and .16 kg/d more than SBM and Dry-30 heifers from February 14 to May 1 (P<.01), weighed 21 and 14 kg more (P<.01) at the beginning of the breeding season. Self-30 heifers had a greater body condition scores (5.2 vs 4.7; P<.01) than SBM heifers, but was not significantly different from Dry-30 heifers.. However, Self-30 heifers did not initiate estrous cycles at a younger age or have a greater cumulative percentage of heifers puberal at the start of the breeding season, eventhough Self-30 heifers were 19 and 33 kg heavier (P<.05) at puberty than SBM and Dry-30 heifers, respectively. This conflicts with several other studies that suggest an increase in energy intake can result in heifers that are younger and heavier at puberty (Wiltbank et al., 1969; Arije and Wiltbank, 1971; Wiltbank et al., 1985; Patterson et al., 1991; Marston et al., 1995). However in these studies (Wiltbank et al., 1969; Arije and Wiltbank, 1971; Wiltbank et al., 1985; Patterson et al., 1991; Marston et al., The Dry-60 heifers were puberal 22 d earlier than SBM heifers ($P<.05$), but were not significantly lighter at puberty (289 vs 301 kg; $P>.10$). The SBM and Dry-30 heifers were 19 and 33 kg lighter, respectively at puberty than Self-30 heifers ($P<.05$). Age at puberty was similar for SBM, Dry-30 and Self-30 heifers (444, 437, and 446 d, respectively; $P>.10$) These results are similar to Moseley et al. (1982), where light-weight heifers had the same age at puberty as heavy-weight heifers, but were 22 kg lighter at puberty. This suggests that the SBM and Dry-30 heifers were limited by weight at puberty, whereas the Self-30 heifers were limited by age.

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Implications

Feeding a high concentrate diet for sixty days prior to the beginning of the breeding season can reduce age and weight at puberty compared with self-feeding heifers a lower starch diet containing corn distillers grains prior to breeding. Feeding the high concentrate diet also reduced age at puberty compared with heifers that were fed a 40% CP supplement while grazing native range. The puberal response to a short-term increase in energy intake further appears to be related to the source of energy because diets consisting primarily of grain elicited a puberty response but diets producing similar rates of gain from low-starch ingredients did not. Results from this study suggest that limit-feeding a high concentrate diet or a self-feeding a lower starch ration for thirty days may be insufficient to impact puberty. Management of very short-term feeding of high concentrate diets may be impractical.

Table VI. Composition and nutrient content of supplements and rations (percent of dry matter).

Item	SBM supplement	Drylot ration	Self-fed ration
Ingredient, %			
Rolled corn		73.26	48.84
Soybean meal (47% CP)	94.60	11.73	
Cottonseed Hulls		5.51	10.12
Alfalfa pellets		5.00	5.06
Cane molasses	3.35	2.64	3.79
Corn distillers grains			31.01
Limestone		1.47	.78
Dicalcium phosphate	1.95		
Salt		.33	.33
Deccox 6%[a]		.04	.04
Vitamin A-30,000[b]	.10	.02	.03
Nutrient level[c]			
Crude protein, %	46.45	14.43	15.18
Ne_m, Mcal/kg	1.87	2.08	2.01
Ne_g, Mcal/kg	1.26	1.32	1.28
Calcium, %	.60	.73	.49
Phosphorous, %	1.15	.32	.39

[a]decoquinate, Rhone-Poulenc Animal Health

[b]30,000 iu/lb

[c]Calculated based on NRC for Beef Cattle, 1984.

Table VII. Weights, daily gains, and body condition scores of SBM[a], Dry-30[b], Dry-60[c], and Self-30[d] heifers.

Item	SBM	Dry-30	Dry-60	Self-30	SEM
number of heifers	17	15	16	17	
Weight, kg					
October, intial	209	207	200	202	4.5
February 14	237	238	237	239	2.5
February 28	232	235	241	236	2.8
March 14	242	245	238	246	2.9
March 28	243	241	253	251	3.7
April 11	252	246	263	268	5.3
April, full weight[e]	275^{g}	278^{gh}	291^{hi}	299^{i}	5.2
May, beginning of breeding[f]	270^{g}	277^{g}	292^{h}	291^{h}	4.5
July, end of breeding	324^{g}	327^{gh}	329^{hi}	336^{h}	4.4
Average daily gain, kg					
October 25 to February 14	.27	.27	.26	.29	.02
February 14 to May 1	$.46^{g}$	$.56^{g}$	$.77^{h}$	$.72^{h}$	.05
March 14 to May 1	$.51^{a}$	$.68^{b}$	1.14^{c}	$.92^{d}$	.06
May 1 to July 1	$.89^{g}$	$.80^{gh}$	$.61^{i}$	$.75^{h}$	.04
October 25 to July 1	$.55^{g}$	$.56^{gh}$	$.56^{hi}$	$.60^{h}$	.02
Body Condition Score					
May 1	4.7^{g}	5.1^{h}	5.3^{i}	5.2^{hi}	.04

[a] Heifers fed .9 kg/d of a 40% CP supplement until April 25.
[b] Heifers fed .9 kg/d of a 40% CP supplement until March 14, then fed a high concentrate ration in a drylot.
[c] Heifers fed .9 kg/d of a 40% CP supplement until February 14, then fed a high concentrate ration in a drylot.
[d] Heifers fed .9 kg/d of a 40% CP supplement until March 24, then self-fed a high fiber-high energy based ration in a native range pasture.
[e] Full weight taken on April 25.
[f] Average of two shrunk weights taken after equalization of fill.
[g,h,i] Means within a row without a common superscript differ, $P<.05$

Table VIII. Reproductive data for SBM[a], Dry-30[b], Dry-60[c], and Self-30[d] heifers.

Item	SBM	Dry-30	Dry-60	Self-30	SEM
Age at puberty, d	444[e]	437[ef]	422[f]	446[e]	5
Weight at puberty, kg	301[e]	287[e]	289[e]	320[f]	13
Pubertal by, %					
April 10	0.0	6.7	12.5	0.0	5.5
May 1	5.8[e]	6.7[e]	31.3[f]	0.0[e]	7.8
May 23	41.2	73.3	81.3	58.8	12.7
June 27	100.0	86.7	93.8	82.4	7.5
Pregnancy rate, %	88.2	80.0	93.8	82.4	9.4

[a] Heifers fed .9 kg/d of a 40% CP supplement until April 25.

[b] Heifers fed .9 kg/d of a 40% CP supplement until March 14, then fed a high concentrate ration in a drylot.

[c] Heifers fed .9 kg/d of a 40% CP supplement until February 14, then fed a high concentrate ration in a drylot.

[d] Heifers fed .9 kg/d of a 40% CP supplement until March 24, then self-fed a high fiber-high energy based ration in a native range pasture.

[e,f] Means within a row without common superscripts differ, $P<.05$

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CHAPTER V.

SUMMARY OF THE EFFECTS OF NUTRITION ON PUBERTY AND GROWTH IN BEEF HEIFERS

Nutrition plays an enormous role in heifer development programs. Producers must not only provide heifers adequate nutrition after weaning to get heifers pubertal prior to the start of the breeding season, but also to do it economically.

In the first experiment, the response to adding monensin to range supplements varied between years. In the first year, the weight gains of both control and monensin heifers fluctuated greatly. This could be the reason no response to monensin was found. Daily gains during supplementation were low (.24 kg/d) for both the monensin and control heifers. This level of daily gain was less than expected, and as a result the percent of heifers pubertal at the beginning of the breeding season (5 and 9%, respectively) and the percent pregnant (55 and 65%, respectively) was unacceptably low.

In the second year, weight gains of all heifers were more consistent. Monensin increased daily gains by .06 kg/d and reduced age at puberty by 17 days compared with control heifers. It cannot be explained why heifers fed both monensin and 4-Plex were older at puberty than monensin heifers. No response was found by adding 4-Plex to the supplement. However, the calculated trace mineral content of the supplement fed the control heifers met all trace mineral requirements of the heifers.

Feeding large amounts of energy supplements to heifers grazing dormant native range can be expensive, and as seen in trial 1 of the first experiment, this type of heifer development program does not always produce acceptable results. *Feeding heifers that are grazing dormant native range small amounts of a high-* protein supplement until 60 days prior to the beginning of the breeding season and then limit-feeding a high concentrate ration so that the heifers meet a target weight at the beginning of the breeding season may lower total feed costs.

Short-term feeding of high concentrate diets for 60 days can decrease both age and weight at puberty, most likely by reducing the acetate:propionate ratio of ruminal fermentation. Even though the Dry-60 heifers encountered acidosis problems and reduced gains during adaptation, age at puberty was still reduced by 22 and 24 days and had 25.5 and 31.3% more heifers pubertal at the beginning of the breeding season when compared with SBM and Self-30 heifers, respectively. For this to be practically applied, producers must have a target weight to obtain by the start of breeding. Currently, it is estimated that heifers become pubertal at 65% of their mature weight, so this could be used as a target weight for replacement heifers at the start of breeding.

Although Self-30 heifers weighed the same as the Dry-60 heifers at the start of breeding, they were 24 days older and 31 kg heavier at puberty. This could be attributed to the Self-30 heifers being self-fed for only 30 days or to a decrease in the acetate:propionate ratio that should have occurred by feeding the high concentrate ration. Feeding heifers a high concentrate ration in drylot for 30 days may be too short of a time to impact puberty and to have heifers achieve the minimum weight needed for puberty to occur.

APPENDIX

APPENDIX A

AVERAGE DAILY INTAKES (KG/D, AS-FED) OF DRY-60 AND DRY-30 HEIFERS IN DRYLOT BY WEEK

	Dry-60[a]		Dry-30[b]	
Week beginning	Concentrate	Native hay	Concentrate	Native hay
February 14	2.79	4.16		
February 21	5.73	.97		
February 28	3.43	.45		
March 7	5.31	.45		
March 14	5.45	.45	3.64	.45
March 21	5.56	.45	4.99	.45
March 28	5.66	.45	5.57	.45
April 4	5.80	.45	5.67	.45
April 11	5.89	.45	5.91	.45
April 18	5.95	.45	6.14	.45

[a] Heifers fed .9 kg/d of a 40% CP supplement until February 14, then fed a high concentrate ration in a drylot.

[b] Heifers fed .9 kg/d of a 40% CP supplement until March 14, then fed a high concentrate ration in a drylot.

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