Effect of Nutritional Management, Trace Mineral Supplementation, and Norgestomet Implant on Attainment of Puberty in Beef Heifers[1]

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ABSTRACT: We conducted a study to evaluate the influences of nutritional management, trace mineral supplementation, and exogenous progesterone on attainment of puberty in beef heifers. Heifers (n = 180) were assigned at weaning to blocks and treatments. Treatments included two dietary regimens (corn silage vs pasture + oatlage), trace mineral supplementation, and puberty induction strategy (with or without progestin implant). Heifers that received pasture + oatlage were managed on grass-legume pastures from October 14 until December 14 and were then placed in pens and fed an oatlage-based diet through May 1994. Heifers fed the corn silage-based diet were housed in pens throughout the study. Norgestomet was implanted in half of the heifers on April 11 for 10 d. Progestin implant increased ($P < .05$) the number of heifers that had attained puberty by the end of the study, compared with nonimplanted heifers (89% vs 71%). Trace mineral supplementation did not affect percentage of heifers that reached puberty before the implant period. Plasma copper levels were below recommended levels in heifers fed oatlage-based diets without trace minerals. We conclude that heifers can be placed on regrowth in irrigated pastures during the fall and still make acceptable gains for attainment of puberty the following spring and that progestin treatment can aid in inducing heifers to reach puberty.

Key Words: Beef Heifers, Puberty, Copper, Zinc, Progesterone

J. Anim. Sci. 1998. 76:2177–2181

Introduction

Age at puberty is a significant factor in the lifetime production of beef cows (Lesmeister et al., 1973). Nutrition is an important factor in heifer development, and a variety of nutrients are involved in proper growth and reproductive maturation (Patterson et al., 1992). Exogenous hormones have also been used as a management tool to stimulate the onset of puberty. The response to exogenous progestin administration can be modified by nutrition at the time of administration (Gonzalez-Padilla et al., 1975).

Trace element supplementation is often recommended for breeding cattle on account of implications of impaired reproduction in subclinically deficient cattle. Saxena et al. (1991) found a correlation between serum copper and zinc concentrations and age at puberty in crossbred heifers, but Small et al. (1997) did not find serum Zn, Cu, or Mn concentrations to be related to first-service conception rates in cattle. Serum concentrations of minerals are not always well related to mineral status of the animal, however. Evidence of direct effects of trace element deficiencies on reproduction in controlled experiments are somewhat limited. Engel et al. (1964), Arthington and Corah (1993), and Vaughan et al. (1994) all failed to observe a response to copper supplementation on reproductive performance in cattle. Phillippo et al. (1987) reported an increased age at puberty for beef heifers fed a high-molybdenum diet. Copper status was lowered in these heifers, and heifers fed high-iron diets also had a lowered copper status but did not exhibit a delayed puberty. DiCostanzo et al. (1986) did report improved first-service conception rate in cows and heifers fed corn silage diets either with Mn or with Mn, Cu, and Zn, compared with unsup-

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Received October 27, 1997.
Accepted April 14, 1998.

plemented controls. The objective of this study was to determine the influence of nutritional management, trace mineral supplementation, and exogenous progestin on attainment of puberty in beef heifers.

Materials and Methods

Heifers (n = 180) were assigned at weaning to blocks and treatments. Blocks included heifers of two sire breeds, Hereford-cross (n = 113) and Simmental-cross (n = 67); Simmental-cross heifers were 42 d older than Hereford-cross heifers, which averaged 187 d of age at the start of the study. Treatments included two dietary regimens (corn silage vs pasture + oatlage), trace mineral (**TM**) supplementation (with or without supplemental Cu, Mn, and Zn sulfates), and puberty induction strategy (with or without progestin implant). Combinations of diet and mineral treatments were assigned to each of two pens of 22 to 23 heifers, and implants were assigned to half of the individuals within each pen.

Heifers receiving pasture + oatlage were managed on four pastures of bromegrass (*Bromus inermus*) and birdsfoot trefoil (*Lotus corniculatus*) (two pastures) or bromegrass and alfalfa (*Medicago sativa*) (two pastures) from October 14 until December 14, 1993. One pasture of each trefoil or alfalfa mix received mineral that contained Cu, Zn, and Mn, and the other received mineral without Cu, Zn, and Mn. During the pasture phase, pasture heifers had free access to mineral treatment, and the amount of mineral that disappeared from feeders was measured. Pasture + oatlage heifers were placed in pens on December 15 and fed an oatlage-based diet (Table 1). Pen groupings of heifers remained the same as pasture groupings. Heifers on the corn silage-based diet (Table 1) were placed in pens on October 14 and remained there until May 27. As a result of greater than anticipated rates of gain, diets were adjusted on March 3, 1994 (Table 1). Mineral was increased from 57 to 85 $\text{g}\cdot\text{heifer}^{-1}\cdot\text{d}^{-1}$ at the time of the diet change. Mineral was top-dressed on the feed given to heifers in the pens. Cattle were weighed initially, at pasture removal (d 56), and once a month throughout the remainder of the study.

Heifers that received norgestomet (Syncro-Mate-B, Sanofi Animal Health, Overland Park, KS) were implanted on April 11. The implant was removed on April 21. Heifers assigned to implant treatment received an implant regardless of pubertal status. We assumed that, under many management settings, producers would implant all heifers because pubertal status of individual animals would not be known. Puberty was evaluated by determining progesterone concentrations in serum samples collected at 7 d before implantation, at day of implantation, and at 11 and 18 d after implant removal. Blood was allowed to clot at 4°C for 4 h, and serum was harvested and stored at –20°C until analysis. Progesterone was assayed using a commercial coated-tube RIA (Diagnostic Products, Los Angeles, CA) using methods described by Bellows et al. (1991). Heifers were considered to be pubertal if they had at least one serum sample with a progesterone concentration greater than 1 ng/mL.

Table 1. Composition (DM basis) of diets and mineral supplements fed to heifers

	Silage type		Mineral mix
Item	Corn	Oat	
	% of DM		
Ingredient composition			
Dec. 16, 1993 to Mar. 3, 1994			
Corn silage	53.2		
Oat silage		62.2	
Alfalfa hay	20.2		
Barley	26.6	37.0	
Mar. 3, 1994 to May 27, 1994			
Corn silage	63.7		
Oat silage		82.2	
Alfalfa hay	27.8		
Barley	8.5	17.7	
Chemical composition			
Dec. 16, 1993 to Mar. 3, 1994			
CP, %	11.2	11.0	
NDF, %	48.8	49.7	
ADF, %	26.7	29.6	
Cu, ppm	5	3	600
Mn, ppm	39	41	1,400
Zn, ppm	20	19	2,000
Mo, ppm	.4	1.0	
S, %	.15	.18	
Rate of feeding, $\text{g}\cdot\text{heifer}^{-1}\cdot\text{d}^{-1}$			57
Mar. 3, 1994 to May 27, 1994			
CP, %	10.3	10.1	
NDF, %	55.4	62.7	
ADF, %	33.1	41.6	
Cu, ppm	6	3	600
Mn, ppm	41	54	1,400
Zn, ppm	23	19	2,000
Mo, ppm	.9	1.9	
S, %	.15	.19	
Rate of feeding, $\text{g}\cdot\text{heifer}^{-1}\cdot\text{d}^{-1}$			85

Blood for mineral analysis was collected by jugular venipuncture and placed into acid-washed tubes containing 100 μL of heparinized saline. Blood for mineral analysis was collected at the initiation of the study (October 14), at 1 wk before progestin implantation (April 4), at 19 d after implant removal (May 9), and at the end of the mineral supplementation period (May 27). After collection, blood was immediately placed on ice, centrifuged to obtain plasma, and stored at –20°C until analysis. Plasma Cu and Zn concentrations were determined with atomic absorption spectrophotometry (Model 5000, Perkin-Elmer, Norwalk, CT).

Statistical analyses were conducted using the GLM procedures of SAS (1990). The general linear models used for analysis included block, dietary regimen,

Table 2. Weights and average daily gain of heifers fed corn silage- or oatlage-based diets, with or without trace mineral (TM) supplementation

	Corn silage		Oatlage		
	–TM	+TM	–TM	+TM	SE
Weight, kg					
Initial	222	219	222	219	2.0
Final	343	350	339	343	2.5
ADG, kg/d					
d 1 to 56[ad]	.76	.82	.65	.73	.013
d 57 to 138[bd]	.65	.70	.85	.79	.009
d 138 to 225[cdef]					
Implant	.24	.38	.14	.20	.010
No implant	.33	.28	.12	.22	
d 1 to 225[fg]					
Implant	.52	.62	.52	.55	.006
No implant	.56	.56	.52	.55	

[a] Corn silage heifers were housed in lots. Pasture + oatlage heifers were grazing pastures.
[b] All heifers were in lots.
[c] Diets were changed on d 138.
[d] Diet effect ($P < .05$).
[e] Mineral × diet × implant interaction ($P < .01$).
[f] Tendency for a mineral × implant interaction ($P < .10$).
[g] Mineral × diet × implant interaction ($P < .05$).

mineral supplementation, implant strategy, and all treatment interactions. Implant strategy was included only in those models that tested variables estimated after progestin treatment. Pen within diet × mineral was the error term used for mineral, diet, and mineral × diet interaction terms, and implant main effect and interactions were tested with residual error terms.

Results and Discussion

During the first 56 d of the test, oatlage heifers were grazing pasture. The freely provided mineral disappearance rate during this period averaged 30 g·heifer^{-1}·d^{-1}. Heifers on pasture gained at a slower rate than heifers fed corn silage in pens during the first 56 d of the study (Table 2). When pasture + oatlage heifers were removed from pasture and placed in pens, they gained at a faster rate than corn silage-fed heifers up until diets were changed at d 138. After this time, interactions among diet, mineral, and implant occurred in rate of gain. Low rate of gain during d 138 to 225 for the oatlage-TM treatment was related to one pen of heifers that gained only .04 kg/d. No explanation is available for the low rate of gain for this pen. The other pen within that treatment gained .21 kg/d during this same period. The three-way interaction affected rate of gain throughout the trial. A greater rate of gain was observed for heifers fed corn silage + TM and implanted with progestin. Final weight of heifers did not differ as a result of treatments, however. Gengelbach et al. (1994) reported that cows and their calves fed a diet that contained 4 ppm Cu had weight gains similar to those of cows and calves that received an additional 10 ppm Cu, although cows without Cu supplementation showed decreased plasma copper concentrations during gestation.

One hundred one heifers were pubertal before progestin implantation. This number was not affected ($P > .10$) by diet or TM supplementation. Of the remaining 79 heifers not pubertal before implantation, 76% of the implanted and 29% of the unimplanted prepubertal heifers attained puberty (implant effect, $P < .001$) within 18 d after implant removal. There was a diet × mineral interaction at this time (Table 3) because the percentage of heifers pubertal was similar for corn silage- and oatlage-fed heifers when there was no TM supplementation, but adding TM increased the percentage pubertal with corn silage and decreased the percentage pubertal with oatlage diets. Other researchers have found positive effects of TM supplementation on age at puberty in heifers. However, management interactions have been noted. Floyd et al. (1995) found an interaction of TM supplementation and monensin treatment on days to puberty in beef heifers. Monensin and TM supplementation

Table 3. Least squares means for the effect of diet and trace mineral (TM) supplementation on puberty in heifers prepubertal before the progestin implant period (n = 79; SE = 5.09)

Diet[a]	–TM	+TM
	% Pubertal before implant	
Corn silage	51.5	64.6
Pasture + oatlage	60.4	33.8

[a] Diet × mineral interaction ($P < .05$).

Table 4. Plasma mineral concentrations of heifers fed corn silage- or oatlage-based diets, with or without trace mineral (TM) supplementation

	Corn silage		Oatlage		
Mineral	−TM	+TM	−TM	+TM	SE
	ppm				
Copper					
Preimplant[a,b]	.96	.88	.38	.73	.028
Postimplant[c,d]	.83	.86	.30	.74	.012
Final[c,e,f]					.009
Implant	.80	.82	.26	.61	
No implant	.76	.76	.27	.64	
Zinc					
Preimplant	1.13	1.18	1.10	1.10	.018
Postimplant	1.00	.99	.96	.93	.013
Final	1.03	1.07	1.07	1.03	.014

[a] Effect of diet ($P < .05$).
[b] Tendency for diet × mineral interaction ($P < .10$).
[c] Effect of mineral and diet ($P < .01$).
[d] Diet × mineral interaction ($P < .05$).
[e] Diet × mineral interaction ($P < .01$).
[f] Tendency for diet × implant interaction ($P < .10$).

decreased age at puberty when fed separately but had no effect when fed in combination.

Progestin implant increased the number of heifers pubertal by the end of the study on May 9, 18 d after removal of implants. Including the heifers pubertal before implantation, 89.2% of the implanted heifers in the study were pubertal by May 9, compared with 71.2% of those not implanted ($P < .01$, SE = 2.96). Estrus synchronization programs in heifers may be more successful when used with heifers that have reached puberty before treatment (Plugge et al., 1990). Use of a progestin to trigger puberty before synchronization treatment may improve the number of heifers pubertal before synchronization and, hence, number of animal successfully synchronized. Miller and Wagner (1991) found that heifers treated with a progestin before puberty had increased conception to a synchronized estrus relative to those not treated with progestin.

Plasma Zn concentrations were not affected by diet in this study; plasma Cu levels were below recommended levels in heifers fed oatlage-based diets without TM (Table 4). This diet contained only 3 ppm Cu, and Cu availability has been reported to be decreased in silages compared with fresh or dry forages (Ho et al., 1977). Even though the corn silage-based diet contained only 5 ppm Cu, compared with the NRC recommended level of 8 ppm, plasma Cu was within acceptable ranges for adequate animal health. However, plasma Cu decreased from .98 to .79 ppm during the last 53 d of the supplementation period. Some changes in Cu status may have been occurring during the latter parts of the study. Dietary Mo ranged from .4 to 1.9 ppm (Table 1). The Cu:Mo ratios were 6.7 to 12.5 in the corn silage-based diet and 1.6 to 3.0 in the oatlage-based diet. Even though Mo levels were relatively low in the oatlage diet, the Cu:Mo ratios were also low as a result of associated low Cu concentrations. A ratio of 2.0 is often considered a critical level in terms of Cu bioavailability (Miltmore and Mason, 1971). The low dietary Cu and associated higher dietary Mo levels could explain the very low serum Cu concentrations that were observed in the oatlage heifers.

Implications

Progestin treatment can aid in inducing heifers to reach puberty and may decrease age at first breeding. Heifers can be placed on regrowth in irrigated pastures during the fall and still make acceptable gains for attainment of puberty and breeding the following spring. Trace mineral supplementation did not affect attainment of puberty in heifers, although plasma copper levels were quite low in one treatment.

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