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# Incidence of Precocious Puberty in Developing Beef Heifers<sup>1,2,3</sup>

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**ABSTRACT:** The objectives of this study were to determine the incidence of precocious puberty and effect of exposure to a bull on the incidence of precocious puberty in beef heifers. The experiment was conducted using 120 heifers during 1990 and 1991. Heifer calves were randomly assigned to be pastured in the presence ( $n = 30$  heifers/yr) or absence ( $n = 30$  heifers/yr) of a bull starting at  $140 \pm 14$  d of age for the duration of the study. Heifers were  $402 \pm 14$  d of age at the time the study was completed. Blood samples were collected weekly to determine the age of onset, duration and cessation of luteal function. Heifers were considered to have exhibited a precocious

puberty when the onset of luteal function was before 300 d of age. There was no effect of exposure to a bull on the incidence of precocious puberty, and therefore the data were pooled. The incidence of precocious puberty was greater ( $P < .02$ ;  $X^2 = 5.5$ ) in 1990 (25.0%; 15 of 60) compared with 1991 (8.3%; 5 of 60). There was no effect of year on age of precocious puberty ( $194 \pm 12.4$  d of age), duration of cyclic luteal function ( $65 \pm 10.5$  d), or the age at resumption of anestrus ( $260 \pm 15.3$  d of age). Precocious puberty does occur in developing beef heifers; as many as 25% of heifers have transient luteal function before 300 d of age. However, exposure to a bull has no effect on the incidence of precocious puberty.

Key Words: Bovine, Heifers, Puberty, Development, Cattle

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## Introduction

Management efforts devoted to selecting heifers for an earlier age at puberty may not be advantageous in some respects. Heifers reaching puberty at a young age while suckling their dams are often exposed to fertile bulls during the dam's breeding season or to intact male calves before weaning. Exposure to fertile bulls during this time period could result in heifers becoming pregnant at a very young age and calving as

yearlings. These heifers usually conceive late in the breeding season and calve late or after the normal calving season as yearlings. Heifers that calve as yearlings are of smaller body size than heifers calving at 2 yr of age. Heifers calving with inadequate body size have a greater propensity for dystocia than larger heifers. This results in an increase in labor for assistance with calving, an associated increase in time required for postpartum recovery and possible loss of the calf and(or) heifer (Laster et al., 1973; Short et al., 1994). The combination of small body size and increased dystocia may result in the majority of these animals failing to conceive during the following breeding season (Short et al., 1994). In addition, precocious puberty in heifers that are destined to be sold as market animals can result in heifers becoming pregnant before entering the feedlot. Pregnant feedlot heifers have decreased feed efficiency and growth rate compared with nonpregnant heifers (Stanton et al., 1988; Walker et al., 1988). The increased labor costs and decreased salable product are factors in lower prices paid for heifers than for steers.

The primary objective was to determine the percentage of developing beef heifers that exhibit precocious puberty. An additional objective was to determine whether exposure to a mature bull affects the incidence of precocious puberty in beef heifers.

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## Materials and Methods

The experiment was conducted during 1990 and 1991 at the Cow/Calf Unit of the University of Nebraska Agricultural Research and Development Center located at Ithaca. Heifers from a composite breed (MARC III; 25% Angus, 25% Hereford, 25% Red Poll and 25% Pinzgauer) were used over the 2-yr period (60 heifers/yr). Heifer calves at  $140 \pm 14$  d of age were randomly assigned to be pastured with their dams and with or without mature epididymal ligated bulls (1 bull/15 heifers) for the duration of the study. To prevent heifers from becoming refractory to a single bull, a new bull was rotated into the pasture each month. This ensured that heifers were not exposed to an individual bull for more than 2 mo. The same four bulls were used each year. After weaning on October 12 of each year, heifers were maintained on pasture within their group and supplemented as needed with a corn-based diet and prairie hay to gain approximately .6 kg/d.

Blood samples were collected weekly from the start of the study through  $402 \pm 14$  d of age via jugular venipuncture. Blood samples were placed immediately on ice and allowed to clot at 4°C for 24 h. Serum was separated by centrifugation and stored at -20°C until concentrations of progesterone were determined by RIA (Bergfeld et al., 1996). Heifers were determined to have luteal function when concentrations of progesterone exceeded 1 ng/mL for two consecutive samples or above 2 ng/mL in one sample with continued cyclic profiles in the concentrations of progesterone indicative of estrous cycles. In previous work with prepubertal heifers, circulating concentrations of progesterone greater than 1 ng/mL were from ovarian luteal tissue and not from adrenal sources (Berardinelli et al., 1980). After initiation of luteal function, heifers were determined to have returned to an anestrous state if concentrations of progesterone in three consecutive samples were below 1 ng/mL. Heifers within this herd have previously been reported to reach puberty at an average of  $451 \pm 24$  and  $427 \pm 38$  d of age (mean  $\pm$  SD; Wolfe et al., 1989 and Roberson et al., 1991, respectively). Heifers were considered to have had a precocious puberty when luteal function was initiated before 300 d of age. This age was selected because it is greater than three standard deviations from the average age of puberty ( $451 \pm 24$  and  $427 \pm 38$  d of age) that has been previously reported in this herd (Wolfe et al., 1989 and Roberson et al., 1991, respectively). In addition, heifers from this herd were anestrous when previous studies were initiated around 300 d of age (Wolfe et al., 1989; Roberson et al., 1991).

The study was conducted in a completely randomized block design (Steel and Torrie, 1980). The frequency of precocious puberty was analyzed by chi square using CATMOD procedures of SAS (1985).

Data for the time of initiation of precocious puberty, duration of cyclic luteal function, time of cessation of cyclic luteal function, and average daily weight gain were analyzed using the GLM procedure of SAS (1985).

## Results

Exposure of heifers to bulls had no effect on the frequency or age at precocious puberty, and therefore data were pooled within year. Frequency of precocious puberty was greater ( $P < .02$ ;  $X^2 = 5.5$ ) in 1990 (25.0%; 15 of 60) than in 1991 (8.3%; 5 of 60; Table 1). Progesterone profiles of four heifers are depicted in Figure 1. Concentrations of progesterone in a representative heifer that attained puberty at a typical age for this herd are depicted in Figure 1a. Concentrations of progesterone in heifers in which precocious puberty was detected are depicted in Figures 1b through 1d. Each heifer that exhibited precocious puberty had a transient increase in concentration of progesterone indicative of cyclic luteal function. In all heifers that had a precocious puberty, cyclic luteal function ceased before the end of the study.

There was no effect of year on age at initiation of precocious puberty ( $194 \pm 12.4$  d of age), duration of cyclic luteal function ( $65 \pm 10.5$  d), or the age at cessation of cyclic luteal function ( $260 \pm 15.3$  d of age). At completion of the study ( $402 \pm 14$  d of age), the percentage of heifers that had not initiated cyclic luteal function was 55% (33 of 60) in 1990 and 82% (49 of 60) in 1991. During the study, heifers in 1990 had a greater ( $P < .05$ ) average daily BW gain compared with heifers in 1991 ( $.75 \pm .03$  vs  $.57 \pm .02$  kg/d, respectively; Figure 2).

## Discussion

When restricted breeding seasons are used, heifers must calve by 2 yr of age to obtain maximum lifetime productivity in the current cow-calf production systems in the United States (Ferrell, 1982). Heifers that reach puberty at a younger age and have three or more estrous cycles before the start of the breeding season have a greater probability of conceiving early in their first breeding season than contemporaries (Byerley et al., 1987). Because cows having their first calf at 2 yr of age have a longer postpartum period of anestrus, it is advantageous to have heifers conceive early in the breeding season and therefore have a greater opportunity to initiate estrous cycles before the next breeding season (Lesmeister et al., 1973). Age at puberty is therefore an important reproductive trait in developing replacement or breeding heifers.

Improved management practices and selection for associated reproductive traits can enhance physiological processes related with attainment of puberty in an

Table 1. Characteristics of precocious puberty in developing beef heifers

|                           | No. of heifers | Heifers with precocious puberty |                | Age at precocious puberty <sup>a</sup> , d <sup>e</sup> | Age at anestrus <sup>b</sup> , d <sup>e</sup> | Duration of luteal function <sup>c</sup> , d <sup>e</sup> |
|---------------------------|----------------|---------------------------------|----------------|---|---|---|
|                           |                | n                               | % <sup>d</sup> |   |   |   |
| <b>1990</b>               |                |                                 |                |   |   |   |
| Bull exposed <sup>f</sup> | 30             | 7                               | 23.3           | 190 ± 16.3  | 256 ± 22.4                                    | 66 ± 20.6   |
| Nonexposed <sup>g</sup>   | 30             | 8                               | 26.7           | 220 ± 3.6   | 292 ± 27.7                                    | 73 ± 17.9   |
| Pooled                    | 60             | 15                              | 25.0           | 206 ± 14.8  | 275 ± 18.2                                    | 69 ± 13.1   |
| <b>1991</b>               |                |                                 |                |   |   |   |
| Bull exposed <sup>f</sup> | 30             | 3                               | 10.0           | 164 ± 25.1  | 210 ± 24.8                                    | 46 ± 23.7   |
| Nonexposed <sup>g</sup>   | 30             | 2                               | 6.7            | 150 ± 1.0   | 220 ± 29.0                                    | 70 ± 28.0   |
| Pooled                    | 60             | 5                               | 8.3            | 158 ± 14.2  | 241 ± 16.6                                    | 55 ± 16.8   |
| <b>Pooled<sup>h</sup></b> | 120            | 20                              | 16.6           | 194 ± 12.4  | 260 ± 15.3                                    | 65 ± 10.5   |

<sup>a</sup>Age at initiation of cyclic luteal function as indicated by circulating concentrations of progesterone.

<sup>b</sup>Age at cessation of cyclic luteal function.

<sup>c</sup>Period of time over which heifers had cyclic luteal function indicative on normal estrous cycles.

<sup>d</sup>The percentage of heifers exhibiting precocious puberty was affected by year ( $P < .02$ ;  $X^2 = 5.5$ ).

<sup>e</sup>Means ± SE.

<sup>f</sup>Exposed to a mature epididymal ligated bulls from 140 ± 14 d of age throughout the duration of the study.

<sup>g</sup>Not exposed to mature bulls during the study.

<sup>h</sup>Data pooled over year.

effort to maximize the number of heifers that reach puberty before initiation of the breeding season (Martin et al., 1992; Patterson et al., 1992; Kinder et al., 1994, 1995). Genetic selection for milk production in dams and scrotal circumference in sires can decrease the age at puberty of offspring (Martin et al., 1992). Development of heifers in the presence of a mature sterile bull is a management practice that decreases age at puberty (Roberson et al., 1991). Decreasing the age at puberty in heifers has beneficial effects on pregnancy rates of heifers during their first breeding season (Kinder et al., 1994, 1995).

Although decreased age at puberty has many beneficial effects, there are some disadvantages to heifers initiating estrous cycles at an early age. If heifers have a precocious puberty, there is a greater probability of their becoming pregnant before reaching optimum body size. This is detrimental to the heifer's performance, whether heifers are selected to enter breeding herds or feedlots. In the current study, precocious puberty occurred in as many as 25% of the heifers based on circulating patterns of progesterone. In the event that precocious puberty occurs, heifers may mate and become pregnant before 1 yr of age. Heifer number 0222 (Figure 1b) had increased concentrations of progesterone indicative of luteal function at 103 d of age and would have had the opportunity to become pregnant during the dam's breeding season. In some years previous to this study about 4% of the heifers from this herd became pregnant at approximately 5 mo of age. This information, combined with the knowledge that heifers of this herd were anestrous when previous studies were initiated at about 300 d of age (Wolfe et al., 1989; Roberson et al., 1991), was the stimulus for us to perform the present study.

We hypothesize that precocious puberty is a physiological phenomenon that results from differential timing of maturation of the inhibitory effects of 17 $\beta$ -estradiol on the hypothalamic-pituitary axis and the ability of the ovaries to secrete 17 $\beta$ -estradiol in response to gonadotropin stimulation. A delay in the maturation of the inhibitory effects of 17 $\beta$ -estradiol on the hypothalamic-pituitary axis would allow ovarian-derived 17 $\beta$ -estradiol to induce a surge of LH resulting in ovulation and formation of a functional corpus luteum. Heifers would continue to have estrous cycles until maturation of the inhibitory effects of 17 $\beta$ -estradiol on the hypothalamic-pituitary axis, and heifers would then return to a state of anestrus.

During early neonatal development in cattle (Evans et al., 1992), sheep (Foster, 1994), and swine (Wise, 1982) the hypothalamus is not responsive to inhibitory effects of 17 $\beta$ -estradiol and there are greater circulating concentrations of gonadotropins. Greater concentrations of gonadotropins result in an increase in the number and size of antral follicles in heifers during the neonatal period (Evans et al., 1992) and are associated with structural organization of the testes in bulls (Curtis and Amann, 1981). However, the greater ovarian follicular development is associated with only a small increase in circulating concentrations of 17 $\beta$ -estradiol during the neonatal period (Evans et al., 1994). As age of the heifer increases, concentration of 17 $\beta$ -estradiol produced by ovarian follicles increases (Evans et al., 1994). During this time period, the hypothalamus is capable of responding to treatment with exogenous 17 $\beta$ -estradiol, resulting in a preovulatory-like surge of LH in cattle (Staigmiller et al., 1979; Schillo et al., 1982) and sheep (Foster and Karsch, 1975; Foster, 1994).

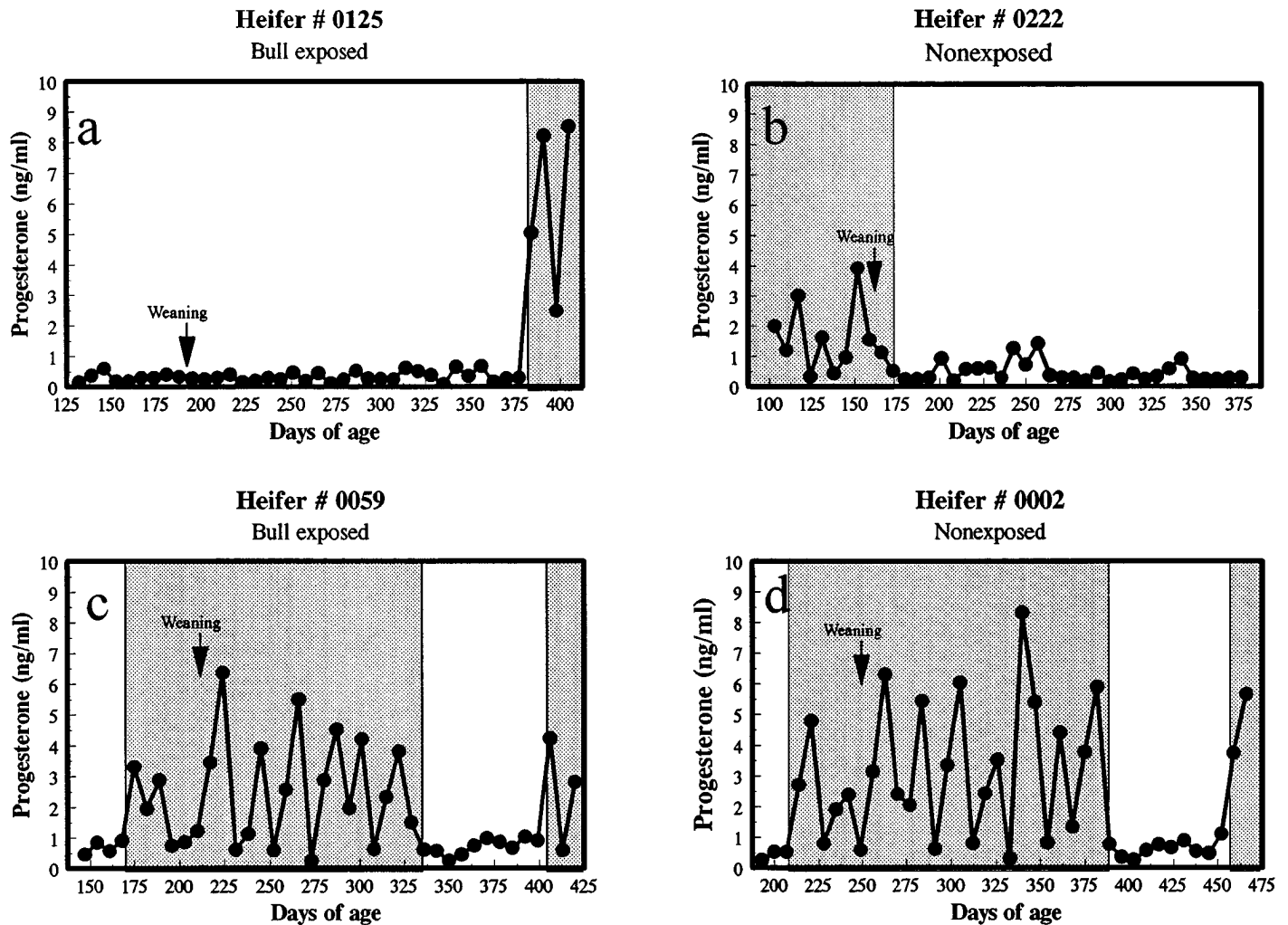


Figure 1. Representative progesterone profiles of developing beef heifers with either a typical (Figure 1a) onset of luteal function or a precocious (Figure 1b, c, and d) onset of luteal function. Shaded areas identify periods of time when heifers were determined to have cyclic luteal function indicative of estrous cycles. Arrow indicates heifers actual weaning date.

The amplitude of the  $17\beta$ -estradiol induced surge of LH is less during the neonatal period and becomes greater as age of the females increases (Foster and Karsch, 1975; Staigmiller et al., 1979; Foster, 1994). During the first few months after birth the hypothalamus does not respond to the inhibitory effects of  $17\beta$ -estradiol on the suppression of LH pulse frequency (Evans et al., 1992). Greater gonadotropin stimulation during the first few months of life leads to the greater ovarian follicular development during this period. However, ovarian follicles typically do not secrete enough  $17\beta$ -estradiol to induce a preovulatory-like surge of LH. As the heifer increases in age, the hypothalamus becomes sensitive to the inhibitory effects of  $17\beta$ -estradiol and pulsatile release of LH is less than during the neonatal period (Kinder et al., 1994, 1995). The  $17\beta$ -estradiol inhibition of pulsatile LH release ensures that heifers remain anestrous during the peripubertal period and subsequently attain puberty at a typical age.

The neonatal period during which  $17\beta$ -estradiol does not inhibit pulsatile LH release may be extended until later in life in heifers with precocious puberty. In heifers that exhibit precocious puberty, ovarian follicles may secrete sufficient amounts of  $17\beta$ -estradiol to stimulate a preovulatory surge of LH before the hypothalamus becomes hypersensitive to the inhibitory effects of  $17\beta$ -estradiol on pulsatile LH secretion. Therefore, a preovulatory surge of LH may occur with ovulation of an ovarian follicle. Typical estrous cycles may occur until the hypothalamus becomes hypersensitive to the inhibitory effects of  $17\beta$ -estradiol on pulsatile LH secretion. Average duration of this period would have been  $65 \pm 11$  days in the present study. The negative feedback action of  $17\beta$ -estradiol on the secretion of LH would have occurred at an average of  $260 \pm 15$  d of age during the 2 yr in the present study and would likely have resulted in cessation of estrous cycles. We hypothesize that when the hypersensitivity of the hypothalamus to gonadal  $17\beta$ -estradiol

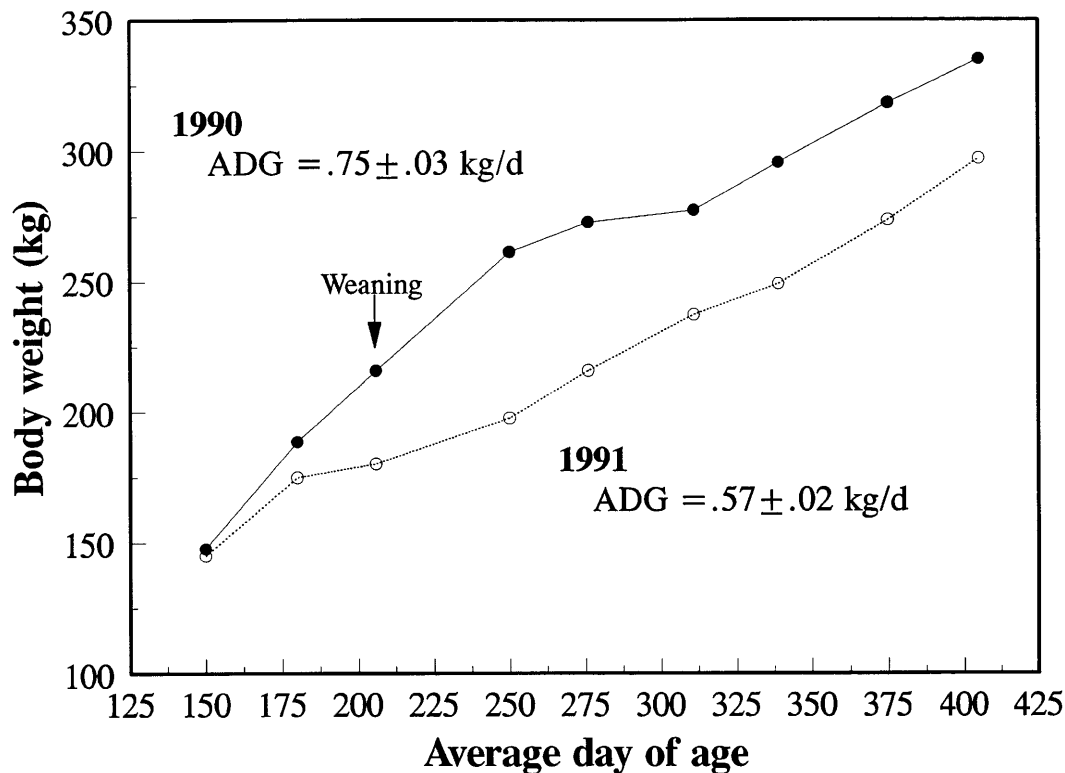


Figure 2. Average weight of developing beef heifers maintained on pasture and supplemented with a corn based diet and prairie hay. Arrow indicates weaning date.

increases, pulsatile secretion of LH is suppressed to the extent that heifers become anestrus. Later in life at approximately 12 to 14 mo of age, heifers attain puberty when they become less responsive to the  $17\beta$ -estradiol inhibition of pulsatile LH release and the typical pubertal process occurs (Kinder et al., 1994, 1995).

The incidence of precocious puberty may be related to growth rate of the heifers around the time of weaning, as evidenced by the increased incidence of precocious puberty in 1990 compared with 1991. One of the possible causes for the difference in incidence of precocious puberty could be the greater growth rate of heifers in 1990 compared with 1991. During 1990, the availability of forage was greater, which resulted in heifers gaining more weight during the 2 mo after weaning than the heifers in 1991. Greater growth rate resulted in an overall ADG of  $.75 \pm .03$  kg/d in 1990 compared with  $.57 \pm .02$  kg/d in 1991. Greater growth rate after weaning resulted in heifers attaining approximately the same body weight at 275 d of age in 1990 compared with 375 d of age in 1991. The greater growth rate and overall body weight in 1990 indicate that heifers were at a more advanced stage of physical maturation and may explain the greater incidence of precocious puberty in 1990 than in 1991. In the current study, incidence of precocious puberty was not affected by the presence of a bull. Therefore, precocious puberty may be a result of physiological

maturation related to growth and may be less responsive to other environmental cues that affect the typical pubertal process (Kinder et al., 1994, 1995).

Genotype also influences sexual maturation in heifers. Breeds selected for greater milk production have a younger age at puberty than breeds selected for greater growth rates (Laster et al., 1976, 1979). Therefore, genotype may influence the number of heifers that exhibit a precocious puberty. The MARC III composite breed used in this study has been selected for maternal traits such as milk production. Therefore, the incidence of precocious puberty may not be as great in animals not selected for milking ability.

Genetic selection for precocious puberty may be effective at increasing the incidence of puberty at these young ages without altering the timing at which the inhibitory effect of  $17\beta$ -estradiol occurs preceding the onset of estrous cycles at typical ages when puberty occurs. Currently, there is not enough known about the endocrine mechanism associated with the onset of precocious puberty to determine its relationship to the onset of puberty at an age when puberty is typically expected to occur. Therefore, there is no evidence to support the theory that heifers that undergo precocious puberty will be the first heifers that initiate estrous cycles later in life.

Future work should focus on the endocrine aspects that lead to precocious puberty. Relationships between precocious puberty and time of onset of estrous cycles

at typical ages in heifers should also be evaluated. Evidence from the present study raises the question concerning when puberty should be considered to have occurred in heifers that exhibit precocious puberty. The possibility of precocious puberty needs to be considered when studies are undertaken to evaluate age at puberty in heifers.

### Implications

Incidence of precocious puberty may be related to internal physiological cues and be less responsive to environmental cues that are associated with typical pubertal processes. Precocious puberty does occur in developing heifers; as many as 25% of heifers exhibit transient cyclic luteal function before 300 d of age. Producers should consider the possibility of precocious puberty in heifers when making management decisions such as prolonged breeding seasons or delayed castration of male contemporaries.

### Literature Cited

- Berardinelli, J. G., R. A. Dailey, R. L. Butcher, and E. K. Inskeep. 1980. Source of progesterone prior to puberty in beef heifers. *J. Anim. Sci.* 49:1276.
- Bergfeld, E.G.M., F. N. Kojima, A. S. Cupp, M. E. Wehrman, K. E. Peters, V. Mariscal, T. Sanchez, and J. E. Kinder. 1996. Changing dose of progesterone results in sudden changes in frequency of LH pulses and secretion of  $17\beta$ -estradiol in bovine females. *Biol. Reprod.* 54:546.
- Byerley, D. J., R. B. Staigmiller, J. G. Berardinelli, and R. E. Short. 1987. Pregnancy rates of beef heifers bred either on puberal or third estrus. *J. Anim. Sci.* 65:645.
- Curtis, S. K., and R. P. Amann. 1981. Testicular development and establishment of spermatogenesis in Holstein bulls. *J. Anim. Sci.* 53:1645.
- Evans, A.C.O., G. P. Adams, and N. C. Rawlings. 1994. Follicular and hormonal development in prepubertal heifers from 2 to 36 wk of age. *J. Reprod. Fertil.* 102:463.
- Evans, A.C.O., W. D. Currie, and N. C. Rawlings. 1992. Effects of naloxone on circulating gonadotropin concentrations in prepubertal heifers. *J. Reprod. Fertil.* 96:847.
- Ferrell, C. L. 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. *J. Anim. Sci.* 55:1272.
- Foster, D. L., 1994. Puberty in the sheep. In: E. Knobil and J.D. Neil (Ed.) *The Physiology of Reproduction* (2nd Ed.). p 411. Raven Press, New York.
- Foster, D. L., and F. J. Karsch. 1975. Development of the mechanism regulating the preovulatory surge of luteinizing hormone in sheep. *Endocrinology* 97:1205.
- Kinder, J. E., E. G. M. Bergfeld, M. E. Wehrman, K. E. Peters, and F. N. Kojima. 1995. Endocrine basis for puberty in heifers and ewes. In: R. J. Scaramuzzi, C. D. Nancarrow, and C. Doberska (Ed.). *Reproduction in Domestic Ruminants III*. p 393. *Journals of Reproduction and Fertility Ltd.*, Cambridge, U.K.
- Kinder, J. E., M. S. Roberson, M. W. Wolfe, and T. T. Stumpf. 1994. Management factors affecting puberty in the heifer. In: M. J. Fields and R. S. Sand (Ed.) *Factors affecting calf crop*. p 69. CRC Press, Boca Raton, FL.
- Laster, D. B., H. A. Glimp, L. V. Cundiff, and K. E. Gregory. 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. *J. Anim. Sci.* 36:695.
- Laster, D. B., G. M. Smith, L. V. Cundiff, and K. E. Gregory. 1979. Characterization of biological types of cattle (cycle II) II. Postweaning growth and puberty of heifers. *J. Anim. Sci.* 48:500.
- Laster, D. B., G. M. Smith, and K. E. Gregory. 1976. Characterization of biological types of cattle. IV. Postweaning growth and puberty of heifers. *J. Anim. Sci.* 43:63.
- Lesmeister, J. L., R. A. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. *J. Anim. Sci.* 36:1.
- Martin, L. C., J. S. Brinks, R. M. Bourdin, and L. V. Cundiff. 1992. Genetic effects on beef heifer puberty and subsequent reproduction. *J. Anim. Sci.* 70:4006.
- Patterson, D. J., R. C. Perry, G. H. Kiracofe, R. A. Bellows, R. B. Staigmiller, and L. R. Corah. 1992. Management considerations in heifer development and puberty. *J. Anim. Sci.* 70:4018.
- Roberson, M. S., M. W. Wolfe, T. T. Stumpf, L. A. Werth, A. S. Cupp, N. Kojima, P. L. Wolfe, R. J. Kittok, and J. E. Kinder. 1991. Influence of growth rate and exposure to bulls on age at puberty in beef heifers. *J. Anim. Sci.* 69:2092.
- SAS. 1985. *SAS User's Guide: Statistics (Version 5 Ed.)*. SAS Inst. Inc., Cary, NC.
- Schillo, K. K., P. J. Hansen, L. A. Kamwanja, D. J. Dierschke, and E. R. Hauser. 1982. Influence of season on sexual development in heifers: Age at puberty as related to growth and serum concentrations of gonadotropins, prolactin, thyronine and progesterone. *Biol. Reprod.* 28:329.
- Short, R. E., R. B. Staigmiller, R. A. Bellows, and R. C. Greer. 1994. Breeding heifers at one year of age: Biological and economic considerations. In: M. J. Fields and R. S. Sand (Ed.) *Factors Affecting Calf Crop*. p 55. CRC Press, Boca Raton, FL.
- Staigmiller, R. B., R. E. Short, and R. A. Bellows. 1979. Induction of LH surges with  $17\beta$ -estradiol in prepubertal beef heifers: An age dependent response. *Theriogenology* 11:453.
- Stanton, T. L., C. P. Birkelo, B. W. Bennett, and D. E. Flack. 1988. Effect of abortion on individually fed finishing heifer performance. *Agric-Practice* 9(1):15.
- Steel R.G.D, and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach* (2nd Ed.). McGraw-Hill Publishing Co., New York.
- Walker, C. E., C. P. Birkelo, T. L. Stanton, D. E. Flack, B. W. Bennett, and R. L. Cravens. 1988. Pregnancy effects on feed intake, gain, and feed efficiency of finishing heifers. *Agric-Practice* 9(4):13.
- Wise, M. E. 1982. Pubertal development of the gilt: Characterization of gonadotropic and gonadal hormones and the negative and positive regulation of LH and FSH. Ph.D. Dissertation. Univ. of Nebraska-Lincoln, Lincoln, NE.
- Wolfe, M. W., T. T. Stumpf, M. S. Roberson, P. L. Wolfe, R. J. Kittok, and J. E. Kinder. 1989. Estradiol influences on pattern of gonadotropin secretion in bovine males during the period of changed responses to estradiol feedback in age-matched females. *Biol. Reprod.* 41:626.

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