JOINT ALPHARMA-BEEF SPECIES SYMPOSIUM: Considerations on puberty in replacement beef heifers

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ABSTRACT: Many important changes occur throughout reproductive development in beef heifers, including during the prenatal, early postnatal, and peripubertal periods. Wave-like patterns of follicular development have been observed in heifer calves as early as 2 wk of age. Some dramatic changes occur from about 2 to 5 mo of age, most notably the transient increase in LH secretion. Most components of the hypothalamic-pituitary-ovarian axis are fully competent by approximately 5 to 6 mo of age. Peripubertal changes include increases in LH secretion, estradiol production, follicular development, and reproductive tract size. Eventually, the process reaches the point that the initial ovulation is achieved. Heifers that reach puberty and experience multiple estrous cycles before the onset of their initial breeding season have a greater probability for early conception and optimal lifetime productivity. Attainment of puberty typically occurs at around 12 to 14 mo of age in beef heifers but varies greatly. Genetic differences and environmental factors contribute to this variation. In typical U.S. cow–calf operations, calves are generally weaned at approximately 200 d of age. The impact of postweaning management on age at puberty in heifers has been demonstrated, and there is considerable flexibility in the timing of gain from weaning to breeding. However, even when heifers are grown to the desired BW before the start of breeding, there remains a pronounced variation in the timing of puberty, which impacts pregnancy rates. Less attention has been focused on the impact of preweaning management on age at puberty. Heifer calves with increased growth rates from birth to weaning have reached puberty at earlier ages. Precocious puberty has also been induced in a majority of heifers with early weaning and feeding a high-concentrate diet. Nutritional control during early maturation in heifers exerts a substantial influence on the timing of puberty. Understanding the mechanisms involved in reproductive development increases our ability to effectively manage replacement beef heifers for optimal reproductive performance.

Key words: beef cattle, heifer development, puberty

INTRODUCTION

Development of beef heifers to become replacement breeding animals is extremely important for the beef cattle industry. To be successful, they need to demonstrate effective reproductive performance without excessive development costs. Many important steps contribute to the successful development of beef heifers, with one crucial aspect being the ability to reach puberty in a timely manner. Many aspects of reproductive development and the attainment of puberty in heifers have been effectively reviewed by others (Patterson et al., 1992; Day and Anderson, 1998). An overview of some of the highlights of reproductive development in beef heifers will be presented herein. Then a discussion of some considerations regarding management for effective reproductive development, including the postweaning period as well as the early maturation period, will follow.
REPRODUCTIVE DEVELOPMENT

Attainment of puberty is the culmination of a long process of reproductive development that starts well before birth of the beef heifer. This development consists primarily of the tissues and functions associated with the reproductive endocrine axis, including the hypothalamus, anterior pituitary, and ovaries. Communication and coordination among these components through hormonal and other signals allows for the acquisition and maintenance of reproductive functions and capabilities.

Prenatal Development

Reproductive development begins early during the prenatal period. Tanaka et al. (2001) observed the presence of primordial follicles by 74 d of gestational age in heifers. Primary, secondary, and early antral follicles were observed by 91, 120, and 150 d, respectively. Before birth, the number of primordial follicles reached approximately 6,000 and the number of early antral follicles reached approximately 40. Vesicular follicles were also observed by 250 d of gestational age in earlier work by Erickson (1966a). Concentrations of FSH and estradiol were detected around mid gestation and increased thereafter (Tanaka et al., 2001). These early events are an important part of ovarian and endocrine development in prenatal heifers.

Early Postnatal Development

Follicular development continues after birth, and the number of antral follicles has been reported to increase from approximately 8 within the first 10 d of life to a peak of approximately 60 at 180 d of age (Erickson, 1966b). Follicular development has been observed to occur in a wave-like fashion within the first month of life (Evans et al., 1994b). Dominant and subordinate follicles have been clearly identified in successive waves of follicle growth at this early age. The maximum diameter reached by dominant follicles has also been shown to gradually increase from 2 mo of age through 34 mo of age (Evans et al., 1994b).

During the first few months of life in heifers, dramatic changes also occur in the secretion of gonadotropins. Multiple studies have described an early increase in circulating gonadotropin concentrations, predominantly LH, followed by a return to lesser concentrations (Schams et al., 1981; Evans et al., 1992, 1994a). The transient early increase in LH, generally around 3 to 4 mo of age, is followed by an increase in estradiol concentrations. Each of these changes provides evidence of the continuing development of the reproductive endocrine axis. After the early increase and decline in gonadotropins and associated increase in estradiol, heifers appear to enter a period during which LH concentrations reach a plateau. Hansen et al. (1983) reported that no changes were detected in LH concentrations from 22 to 34 wk of age in heifers. Perhaps in heifers this equilibrium state persists until the time that the appropriate signal is given to initiate the peripubertal period and the associated changes leading up to puberty. The signal for initiation of this phase of development is yet to be determined.

Peripubertal Development

Many important changes occur during the time just before puberty to facilitate the successful completion of this process and continued reproductive function thereafter. Many of these changes occur very rapidly during the peripubertal period, after remaining relatively unchanged for a time before this period in typical conditions. The maximum diameter of dominant follicles increases gradually during the few months leading up to puberty (Bergfeld et al., 1994; Melvin et al., 1999; Honaramooz et al., 2004) as does the duration of dominance of the dominant follicles or the interval between follicle waves (Evans et al., 1994). It appears as though follicle size may be related to timing of puberty. Bergfeld et al. (1994) observed that follicle size at puberty was not different between treatments that resulted in differing age at puberty in heifers. Melvin et al. (1999) also reported an increase in FSH and estradiol concentrations during successive follicle waves leading up to the time of puberty. In addition, the frequency of pulses of LH has been demonstrated to increase substantially as puberty approaches (Day et al., 1987). This is accomplished through decreasing estradiol negative feedback on secretion of LH that occurs during this same peripubertal period.

Initiation of Estrous Cycles

Eventually the heifer reaches the point where a surge of GnRH is released followed closely by a surge of LH leading to ovulation, the typical indication that puberty is complete. There is also evidence of continued maturation after the first ovulation, which is generally followed by a short luteal phase. The subsequent ovulation is often associated with the first exhibited estrus and commonly followed by the first estrous cycle of normal duration. However, estrous behavior without ovulation has been reported in some young heifers (Nelsen et al., 1985; Rutter and Rangel, 1986). Other heifers have been observed to experience precocious estrous cycles, including estrus and ovulation, before 10 mo of age (Wehrman et al., 1996). Conception rate of heifers has also been shown to increase during the first few estrous cycles after puberty (Byerly et al., 1987; Staglmiller et al., 1993).
MANAGING REPRODUCTIVE DEVELOPMENT

The effective management of reproductive development in heifers includes a number of important factors. Genetic selection and heterosis provide many potential benefits and should be emphasized in any heifer development program. Effective management of environmental factors is also essential, including such things as nutrition, health, hormonal treatments, and acclimation of animals to handling procedures.

Postweaning Period

A variety of management systems have been attempted with focus primarily on the postweaning period, typically after 6 or 7 mo of age in most U.S. beef cattle systems. Heifers at this age are generally in the static phase of reproductive development when estradiol negative feedback maintains relatively constant gonadotropin secretion, awaiting entry into the peripubertal phase that will lead to eventual completion of puberty (Day and Anderson, 1998). The common recommendation for developing beef heifers has been to feed them to achieve approximately 65% of their expected mature weight by first breeding, known as the target body weight approach. The goal is to promote high conception rates to first breeding at 13 to 15 mo of age by having a large proportion of heifers reach puberty by 30 to 45 d before onset of the breeding season.

Multiple studies have demonstrated considerable flexibility in the timing of BW gain to achieve the target weight. For instance, Lynch et al. (1997) observed similar first service conception rates and overall pregnancy rates when comparing heifers with an even rate of gain to heifers that were fed for initial lesser rate of BW gain followed by a greater rate of BW gain to reach similar target BW before breeding. A recent report provides further evidence to support the concept that heifers reach puberty at a reasonably consistent proportion of their projected mature BW (Freely et al., 2011). There is also evidence to indicate that heifers may be developed to 50 to 55% of mature BW before breeding without a significant decrease in overall pregnancy rate at the end of the breeding season (Patterson et al., 1991; Funston and Deutscher, 2004; Funston et al., 2012). However, conception rates early in the breeding season may be reduced with this type of development system (Patterson et al., 1989; Creighton et al., 2005).

Early Maturation Period

Less attention has been focused on the influence of the early maturation period on reproductive development of beef heifers, which occurs between birth and typical weaning time. However, in studies that have focused on this period of development, an influence of preweaning growth rate on age at puberty has been reported (Wiltbank et al., 1966; Patterson et al., 1992; Buskirk et al., 1995). Madgwick et al. (2005) found that treatment with GnRH from 4 to 8 wk of age advanced puberty in heifers. Additionally, Wiltbank et al. (1966) determined that preweaning BW gain more consistently influenced age at puberty than postweaning BW gain. It appears the early maturation period may have more impact than previously considered.

As noted previously, spontaneous puberty has been observed to occur before 10 mo of age in some heifers (Wehrman et al., 1996), and the incidence was greater when growth rate around the time of weaning was also greater. Heifers that are weaned early and fed a high-energy diet have also exhibited a substantially increased incidence of precocious puberty (Day and Anderson, 1998). This precocious puberty occurs during the age that is typically part of the static phase of development in heifers. These observations have led to an interest in determining whether precocious puberty could be consistently induced in heifers and observing the developmental changes associated with such puberty.

A series of experiments was designed to test the ability to induce precocious puberty in heifers and to determine the underlying mechanisms responsible for the precocious attainment of puberty (Gasser et al., 2006a,b,c,d). A model consisting of early weaning (i.e., at 2 to 4 mo of age) and feeding a high-concentrate diet was used for these experiments. This method resulted in increased BW gain. Additionally, precocious puberty was induced in a vast majority of heifers and, consequently, mean age at puberty was substantially reduced. Heifers that achieved precocious puberty did so at lesser BW than those that did not achieve precocious puberty. In addition, subsequent estrous cycles continued after precocious attainment of puberty.

In the first experiment (Gasser et al., 2006d), heifers that were weaned early and fed the high-concentrate diet exhibited a greater frequency of LH pulses leading to precocious attainment of puberty. In the second experiment (Gasser et al., 2006c), ovarian maturation was accelerated during the same period leading up to puberty. This was evidenced by increased maximum diameter of dominant ovarian follicles, increased duration of waves of ovarian follicular development, and increased peak estradiol concentrations during follicle waves. In the third experiment (Gasser et al., 2006b), estradiol-implanted and ovariecotomized heifers that were weaned early and fed the high-concentrate diet exhibited a reduction of estradiol negative feedback on LH secretion at a younger age, which was similar to the age at which ovary-intact heifers on the same diet attained puberty. It was concluded from these results that advancement of the decline in estradiol negative feedback on secretion of LH is the mechanism by which early weaning and feeding a high-concentrate diet induces precocious puberty in heifers.
Essentially, the peripubertal period of development in heifers was shifted to a younger age with this model.

A fourth experiment was conducted to determine the relative effects of timing of feeding the high-concentrate diet on age at puberty in early-weaned heifers (Gasser et al., 2006a). It was discovered that feeding the high-concentrate diet for a period of only 10 wk after early weaning successfully advanced puberty to an extent similar to that of continuous feeding of the high-concentrate diet after early weaning. A similar effect may be possible without early weaning because normal-weaned heifers have shown the ability to spontaneously achieve puberty at an early age, but this has yet to be tested specifically. These experiments provide evidence that nutritional control during the early maturation period in heifers exerts substantial influence on timing of puberty.

SUMMARY AND CONCLUSIONS

Many important events occur throughout reproductive development of beef heifers, including during the prenatal and early postnatal periods. Although flexibility exists in the timing of postweaning BW gain for reproductive development, consideration of preweaning nutrition and management may increase the potential for effective control of puberty. The attainment of puberty before 10 mo of age in heifers may not be “precocious” after all but rather an expression of genetic potential for puberty under the right environmental conditions. With this understanding, there is potential to test additional management options for effective control of puberty in heifers, which could possibly provide useful applications among different breeds and cattle production systems.

LITERATURE CITED


