Nutritional Effects on Beef Heifer Development, Puberty and Subsequent Reproduction

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Introduction

Pregnancy success in the first breeding season of a heifer is primarily determined by the time at which puberty occurs relative to the start of her breeding season. Thereafter, the female's ability to rebreed in subsequent years and remain in the herd, and hence her lifetime productivity is influenced by timing of pregnancy in the first breeding season. The physiological endpoint of puberty is influenced by factors related to management of the annual cycle of beef production as well as the physiology and genetics of the female.

Beef production in almost all situations is seasonal in nature in order to coordinate feed resources with the nutrient requirements of the dam, and to some extent, the requirements of her calf. In the temperate regions of North America, most beef cows calve in late winter/early spring to match peak lactation (two to three months post-calving) with peak growth of cool-season grasses and other grazed forages. Some producers in these regions calve in the fall to take advantage of better weather for calving, fall pasture growth and/or traditionally greater calf prices at weaning in the spring. In the southern regions of the USA, fall and winter calving are much more prevalent as a result of the growth patterns of forages used in these regions. Regardless of the calving season employed, the time at which female cattle, including heifers, must become pregnant each year is constrained by this seasonal cycle, with typical breeding seasons being 2 to 4 months in duration.

A majority of *Bos taurus* heifers from breeds such as Angus, Hereford, Simmental, and Charolais are expected to calve for the first time at 22 to 24 months of age (at which time they are referred to here as primiparous cows) and at approximately 12-month intervals thereafter until 6 to 10+ years of age. To provide additional time for primiparous cows to recover from their first calving in preparation for their second breeding, they are often bred to calve 3 to 4 weeks before the multiparous cows in the same herd. This requires that heifers become pregnant for the first time at 12 to 15 months of age assuming a gestation period of slightly less than 9.5 months (280 to 285 days) and accounting for often more than two months variation in the birth date of heifers selected to serve as replacements. Thus, consideration of seasonal constraints implies that puberty should occur within this time frame. However, there are other

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factors that impact recommendations as to when puberty should occur relative to the first breeding season in heifers.

It has been demonstrated that conception rate of heifers increased by approximately 21% (Byerley et al., 1987; Perry et al., 1991) from their first ovulation to their third estrous cycle. It has also been shown that timing of conception in the first breeding season impacts lifetime productivity. Beef heifers that conceived early during their initial breeding season and calved as two-year-old females had a greater probability of becoming pregnant as primiparous cows (Burris and Priode, 1958), had greater lifetime production reflected in greater weaning weights, and tended to calve earlier in subsequent years (Lesmeister et al., 1973) compared with females that conceived later in their first breeding season. Hence, age at which puberty occurs and timing of this event relative to the breeding season will impact the time of conception in the first breeding season, lifetime productivity, and economic efficiency of beef production.

Economics of Age at First Calving

Considering the nature of seasonal beef production and the impact of time of puberty on conception in the first breeding season and lifetime productivity, a logical question is whether waiting to mate heifers at 18 or 24 months of age will circumvent many of these challenges. This question was a topic of discussion in the USA in the 1900s with regard to *Bos taurus* heifers in the temperate regions of the USA. The author of the first scientific paper found on this subject (McCampbell, 1921) concluded that the cow "never fully recovers from the shock of calving at this (2 years of age) age" and that "when a beef cow calves at 2 years of age, neither she nor her calves (in subsequent years) will be as large as they would have been had she dropped her first calf at 3 instead of 2 years of age." However, after this report, most subsequent research demonstrated an advantage of calving at 2 versus 3 years of age relative to lifetime productivity. Heifers that calved at 2 years of age had a reduced calving rate of approximately 14% at 3 and 4 years of age as compared with heifers that calved first at 3 years of age but performed similarly thereafter (Withycombe et al., 1930). However, heifers that calved first at 2 years of age produced an average of 0.7 more calves than those calving first at 3 years of age by the time all cows were 6.5 years of age. The first calves from heifers were lighter at weaning than from older cows whether they calved first at 2 or 3 years of age, but no differences existed thereafter. A detailed economic analysis in this paper indicated that the difference in profit at the end of 4 years was $36.15/cow. This difference translates to approximately $500/cow in 2013!

A comprehensive international review of reports on age at first calving was provided by Morris (1980). Across experiments, lifetime production was either greater, or not significantly different, when heifers first calved at 2 versus 3 years of age, and overall, heifers calving at 2 years of age produced 0.7 more calves in their lifetime than if calving first at 3 years of age. The most comprehensive comparison of calving age in beef cattle was performed at the USMARC, Clay Center, NE, USA (Nunez-Dominquez et al., 1985, 1991). Cows were Angus, Hereford, or Shorthorn and F1 crosses of these breeds. The authors evaluated a wide array of production characteristics in this experiment. Two key findings were that heifers bred to calve at 2 years of age produced 138 kg more of weaned calf weight in their lifetime and that economic efficiency (output - input) was 6 to 8% greater than in heifers bred to calve for the first time at 3 years of age.

More than 95% of heifers in the northern and central USA, comprised mainly of *Bos taurus* breeds, calve first at 2 years of age, whereas less than 50% of heifers in Florida and about 35% in Texas calve later than 2 years of age (Short et al., 1994). Breed is an important consideration as many cattle in these regions are crossbreeds of *Bos taurus* and *Bos indicus*. For comparision, in Brazil, the beef industry is dominated by straightbred females of the *Bos indicus* breed, Nelore, due to its high tolerance to heat and parasites. A limitation for female cattle efficiency in Brazil is the age at first calving (for review, see Nogueira, 2004), and essentially all Nelore females currently calve for the first time at 3 to 4 years of age (Malhado et al., 2013). At present, Brazil slaughters approximately 23% of its national cattle population each year, whereas in the USA, this figure is more than 35% of the national cattle population. As a result maintenance cost of breeding and slaughter animals per kilogram of beef produced is proportionally greater in Brazil than the USA. While several factors influence this discrepancy, a major contributing factor to this inefficiency is the delay of 1 to 2 years in breeding age of heifers. Hence, in the southern regions of the USA where delayed breeding of heifers is practiced in some herds, some of this inefficiency is inherent to production systems in these regions.

Nutritional Control of Age at Puberty

Most beef heifers are weaned from their dams at 6 to 8 months of age and it has been clearly demonstrated that plane of nutrition from weaning to the onset of the breeding season can impact age at puberty (for reviews see Patterson et al., 1992; Bagley, 1993). Traditionally, the recommendation has been that heifers be fed to attain 60 to 65% of their expected mature body weight by the onset of the breeding season. Various strategies have been employed to achieve this end point such as constant body weight gains from weaning to breeding or nutritional restriction followed by greater nutrient intake and compensatory gain. Taken together, findings from many experiments suggest that flexibility exists in how this target weight is attained to achieve acceptable pregnancy rates. Recent research has suggested that development of heifers to 50 to 57% of mature body weight may present an economic advantage over developing heifers to 60 to 65% of mature body weight (for review, see Endecott et al., 2013). However further research is necessary to assess the relative effects of these two strategies on cow longevity and economic efficiency. While some disagreement exists as to the ideal target weight for heifers at the start of their first breeding season, without question nutritional management during this phase is crucial to breeding success.

It has been reported that rate of growth pre-weaning and early post-weaning has a more profound effect on reproductive success in the first breeding season than that immediately preceding the breeding season (Roberts et al., 2009). This finding is consistent with numerous earlier reports that indicated preweaning growth or weaning weight has a major impact on timing of puberty. Spontaneous precocious puberty (puberty before 300 days of age) occurs in up to 25% of *Bos taurus* beef heifers (Wehrman et al., 1996), and we have performed a series of experiments demonstrating that precocious puberty can be consistently induced by initiation of feeding a high-energy diet in beef heifers at approximately 3 months of age (Gasser et al., 2006 a,b,c,d; Table 1). Advantages of induction of precocious puberty in *Bos taurus* heifers in North America are limited given the seasonal schedule of beef production. Actually, precocious puberty in *Bos taurus* cowherds can be detrimental to efficiency of beef production due to precocious pregnancy and associated economic losses. However, in *Bos indicus* influenced cattle, opportunity exists to take advantage of this physiological response to nutritional intervention earlier in life to reduce age at calving in programs where heifers give birth after 2 years of age.

Table 1. The percentage of heifers that experienced precocious puberty and age at puberty[a]

		Early weaning, high concentrate diet (EWH)		Early weaning, control diet (EWC)	
Experiment	n	% Precocious puberty	Age at Puberty (d)	% Precocious puberty	Age at Puberty (d)
EXPT 1	18	89 (8/9)	262 ± 10	0 (0/9)	368 ± 10
EXPT 2	18	100 (9/9)	252 ± 9	56 (5/9)	308 ± 26
EXPT 3	10	80 (4/5)	275 ± 30	0 (0/5)	385 ± 14
EXPT 4	30	67 (10/15)	271 ± 17	20 (3/15)	331 ± 11

[a]Data from Gasser et al, 2006a, EXPT 1; 2006b, EXPT 2; 2006c, EXPT 3; and 2006d, EXPT 4.

Reproductive Technologies to Advance Age at Puberty

It is obvious that plane of nutrition, both postweaning and preweaning, can advance age of spontaneous puberty in heifers but variation in occurrence of this event is inherent in all groups of replacement females for a wide variety of reasons. The economic advantages of heifers becoming pregnant during the first part of their first breeding season have been clearly demonstrated. Thus, in order to optimize efficiency of each group of replacement females, it is important that all heifers reach puberty before or very early in their first breeding season. The challenge of attaining this endpoint is heightened since the identity of the heifers which have surpassed this threshold, and those that have not, is unknown. Even with excellent nutritional management, in most situations it is impossible, or not economically feasible, to provide a level of nutrition that ensures that all heifers reach this endpoint at the start of the season. Fortunately, hormonal technologies currently exist that can induce puberty in prepubertal heifers while at the same time synchronize estrus in postpubertal heifers within a group. This standardization of reproductive status provides most heifers an excellent chance to become pregnant early in their first season.

Some *Bos taurus* in temperate regions of the US have not attained puberty at 12 to 15 months of age and the proportion varied from 6% to 81% between individual groups of heifers (Lucy et al., 2001). In Nelore cattle in Brazil, the proportion of heifers that were prepubertal at initiation of the breeding season, at approximately 24 months of age, exceeded 60% (Claro Jr. et al., 2010). If heifers fail to conceive in their first breeding season, whether at 1 or 2 years of age, then management options for them are limited. Either the non-pregnant heifer is fed an additional year with no return or she is removed from consideration as an animal to enter the breeding herd and instead is fed and marketed for slaughter. Most approaches, worldwide, to induce puberty in heifers use of an exogenous treatment with the hormone progesterone (normally produced by the ovary of females), either alone or in combination with other compounds such as gonadotropin-releasing hormone (**GnRH**), estradiol or equine chorionic gonadotropin (**eCG**) that aid in inducing ovulation. These induction protocols rely on the fact that progesterone treatment activates the reproductive system to result in puberty (Anderson et al., 1996; Day and Anderson, 1998). During and after the progesterone treatment, secretion of the hormone luteinizing hormone (**LH**) will increase, ovarian follicles are stimulated to grow, and the female ovulates spontaneously or in response to a second exogenous stimulus. The efficacy of these approaches has been well documented in *Bos taurus* heifers approximately 12 months of age (Rasby et al., 1998) and in Nelore heifers that were 24 months of age (Rodrigues et al., 2013). Typically, more than 80% of prepubertal heifers were induced to ovulate with the progestin treatment. In *Bos taurus* heifers, pregnancy to artificial insemination (**AI**) at the beginning of the breeding season did not differ between prepubertal and postpubertal heifers that were induced/synchronized with progesterone-based timed AI programs (Lamb et. al., 2006). Acceptable reproductive performance during the ensuing breeding season following induction of puberty with progesterone-based programs has been demonstrated in numerous reports with both *Bos taurus* and *Bos indicus* females. It is important to consider that hormonal induction of puberty is most effective in heifers that are approaching their spontaneous occurrence of puberty. In other words, there are age limits before which it is not possible to effectively induce the first ovulation with pharmacological manipulation (Hall et al., 1995), and these approaches are not a substitute for proper heifer development and nutritional management.

“Precocious” Breeding in *Bos indicus* Heifers

Reduction of the age at which heifers enter into production increases their lifetime productivity and improves economic efficiency. This increased efficiency could be realized in *Bos indicus* influenced heifers in the southern US, of which many still calve at 2.5 to 3 years of age. An even greater impact could be realized in countries such as Brazil, where essentially all heifers calve for the first time at 3 or 4 years of age. We (M.L. Day, M.P. Carvalho, R.A.C. Martins, A. D. P. Rodrigues, J. L. M. Vasconcelos, L. H. Cruppe unpublished) have been working in Brazil for the past 7 years to determine if an aggressive program of nutritional and hormonal intervention in Nelore (n = 2,345; n

= 433 in 2012–2013) and Nelore x Angus crossbred heifers (n = 414, 2012-2013; n = 738, 2013-2014) would result in acceptable pregnancy rates in heifers bred with timed AI at 12 to 15 months of age. Across these years, heifers were fed a variety of corn silage-based diets beginning at weaning (6 to 9 months of age) with approximate target weights at AI of 300 kg for Nelore heifers and 340 kg for Nelore x Angus heifers. In each year, heifers received a progestin based induction protocol that commenced 18 to 24 days before a timed AI protocol was initiated. In 2012–2013, ovulation was induced in approximately 80% of heifers before the breeding season and this proportion did not differ between the Nelore and crossbreed heifers. Two consecutive estrous synchronization protocols, separated by approximately 35 days, were then used in conjunction with timed AI (initial timed AI and resynchronization and AI of non-pregnant heifers); no natural service was used. Pregnancy rates after two rounds of AI were approximately 60% in Nelore and 80% in Nelore x Angus heifers. Pregnancy rate achieved in 2012–2013 for Nelore heifers was similar to that achieved with Nelore heifers in the previous two years. These results are similar to those that are often achieved with Nelore heifers that calve for the first time at three or four years of age under traditional management. The results in Nelore x Angus were confirmed in 2013 – 2014 with an approximate pregnancy rate after two AI of 77%. Pregnancy rates in the Nelore x Angus heifers in this program are similar to those we often attain with Angus crossbreed heifers in Ohio.

A second major question with this program was the ability Nelore-influenced cattle to rebreed as primiparous cows. Pregnancy rates after two AI for primiparous cows that calved at two years of age in 2013-2014 were 58% for Nelore and 88% for Nelore x Angus females. In each of these groups, nutritional supplementation was provided for 3 months after calving as this was during the dry season in Brazil. These preliminary findings indicate that a majority of Nelore and Nelore x Angus heifers can successfully calve at two years of age and rebreed as primiparous cows provided that they receive sufficient nutritional management and an aggressive hormonal approach in conjunction with timed AI. Evaluation of the economic benefit of using an approach of this nature in heifers that calve later than 2 years of age in southern regions of the USA is warranted.

Conclusions

Age at puberty in beef heifers influences economic efficiency of beef production through influences on both age at first calving (2 vs. 2.5+ years of age) and the time of conception of heifers in their initial breeding season. The seasonal nature of beef production and the advantages to production efficiency of a breeding season of restricted duration exacerbate the resultant loss in efficiency if puberty does not occur at the appropriate age. Current practices for the desired age at first conception vary by climate and the predominant breeds that best suit regional production practices. An overarching factor that influences age at puberty in heifers is the nutritional management that occurs during the development of the heifer. Highly effective hormonal technologies exist to aid in induction of puberty in well managed heifers of an appropriate age. Age at first ovulation and pregnancy in heifers can be substantially influenced through implementation of nutritional and/or hormonal manipulation strategies. The appropriate level of intervention with these strategies, as well as age at first breeding, that yields optimal economic and reproductive efficiency is not consistent between regions, production systems, breed, etc. Application of knowledge and technologies and assessment of impacts on efficiency are necessary to determine the optimal approach in a given situation.

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SESSION NOTES