Heifer Development: Nutrition, Health and Reproduction

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Introduction

Replacement heifer development is a critically important area for veterinarians to offer production medicine advice to their beef-producing clients. Productivity for beef cattle herds has been shown to increase when a high percentage of heifers become pregnant early in the first breeding season.[55] A producer's heifer development program should result in most heifers in the replacement pool reaching puberty at least 42 days prior to the start of breeding because the conception rate to first service is lower on the pubertal estrus compared to the third estrus.[14,80] Many producers put additional pressure on heifers to reach puberty at a young age by breeding them 3 to 4 weeks earlier than the mature cow herd. The stress of calving is greater on heifers than older cows, and more likely accompanied by calving difficulty. Thus, breeding replacement heifers essentially one heat cycle earlier than the mature cows allows the producer to concentrate on the heifers at calving. In addition, the length of time from calving to the resumption of cycling is longer in heifers than in cows.[98] Therefore, calving heifers earlier than mature cows gives the heifers the extra time they need to return to estrus and be cycling at the start of the subsequent breeding season.

In order for heifers to reach puberty by 12 to 13 months of age they must receive adequate nutritional intake to signal the body that the "luxury" of reproduction is attainable. Once puberty is attained, nutrition must be at a level that allows the heifer to continue cycling, ovulate a viable oocyte, and establish pregnancy. Nutritional demands of heifers during pregnancy exceed that of mature cows because the heifer is partitioning nutrients for her own growth as well as fetal growth and development. This increased demand for nutrients continues through early lactation, when the beef female has her highest nutritional requirements. Deficiency of energy or protein for extended periods in any production phase during the first two and one-half years of life will impact negatively on fetal development, calf viability, milk production and/or rebreeding for the next pregnancy.

Ration Formulation

Social interaction within beef herds dictates a lower status to smaller, younger animals such as replacement heifers. If harvested forage or supplements are fed to groups that contain both mature cows and replacement heifers, the intake of heifers is negatively affected by dominance aggression displayed by mature cows. Because of this social constraint, heifers must be fed separate from the mature cows in order to obtain necessary nutrients.

Before determining supplement needs, analyzing harvested forages for energy and protein content is recommended. Different cuttings of hay, and hay from different fields, should be evaluated separately so the nutritional value of each forage is known. Beginning with forage analysis and then working with heifer requirements through different phases of development, one can formulate appropriate rations. Once the rations are being fed, follow-up to determine body condition scores and weight gain is necessary to ensure that target weights are being met, and to allow adjustments in recommendations.

Weaning to breeding

The 1996 NRC estimations of Mcal and metabolizable protein (MP)requirements for heifers from weaning through early pregnancy should be used as a guideline in formulating rations for developing heifers, but adjustments may be needed to achieve the desired gains. Factors such as amount of activity required for grazing,[68] environmental temperature,[76] breed[34,36,74] and compensatory gain[17,31] may decrease or increase the actual animal requirements when compared to the NRC estimates. Using NRC estimates plus any adjustments, one can calculate requirements to meet a desired "target weight" at a specific time during development. If the target weight is not met, adjustments can be made so that the desired weight at the start of the breeding season is achieved.

The target weight concept[27,116] is based on the fact that *Bos taurus* breed heifers such as Angus, Hereford, Charolais, or Limousin are expected to reach puberty at about 60% of mature weight. Dual-purpose breed heifers such as Braunvieh, Gelbvieh, or Red Poll tend to reach puberty at about 55% of mature weight. *Bos indicus* heifers, most commonly Brahma or Brahma-cross, are older and heavier at puberty than the other beef breeds, at about 65% of mature weight.[50,51,52,92,106] One can determine the target weight for heifers by knowing the average mature weight of the cow herd, or by knowing the frame score and predicting mature weight (Table 1).[33] Once the target weight is known and the number of days until the start of the breeding season (or until a mid-development ration change) is determined, the rate of gain needed is a simple calculation:

(Target wt.- Present wt.) ÷ number of days = lbs/day

Meeting the target weight, but not grossly exceeding it, is important for heifer fertility and production. Developing heifers on a high plane of nutrition (both energy and protein) from weaning to breeding results in earlier puberty,[73,115] improved udder development,[8] and increased conception rates[77,96] compared with a low plane. Short and Bellows[96] showed that pregnancy rates after a 60-day breeding season in heifers fed to gain 0.6 lb/day from weaning to breeding were 50%. Rates averaged 86% in heifers fed to gain 1 lb/day, while pregnancy rates in heifers fed to gain 1.5 lb/day were 87%. This difference in pregnancy rate is probably at least partially due to differences in pituitary function of heifers fed a low-energy versus a high-energy diet. Day *et al* (1986)[20] found that heifers developed on a low-energy diet failed to exhibit an increase in luteinizing hormone (LH) pulse frequency at a time when heifers developed on an adequate diet exhibited increased LH pulse frequency and attained puberty.

Adequate gains during the weaning-to-breeding phase are also necessary for proper udder development and future milking ability. For heifers fed to gain 1.1 lb/day,[54] 1.3 lb/day,[30] or 1.4 lb/day[12] postweaning, an advantage was seen in milk production compared to slower-gaining controls.

Overfeeding heifers before breeding has also been demonstrated to have detrimental effects on pregnancy rates.[30,35,96] Heifers that gained 1 to 1.5 lb/day had higher (P<.01) pregnancy rates during a 45-day breeding season than did heifers with gains above or below this range.[110] Body condition scores in the same group of 1,863 heifers showed the same result, with improving first-service conception rates as body condition increased up to a score of 6, and then declining in fat heifers.[110] Other reports have indicated that gains above 2 lb/day had a negative impact on heifer fertility.[62,109] In addition, excessive supplemental feeding of beef heifers before puberty has been shown to reduce lifetime calf weaning weights[61] due to impaired milk production.[40] This impaired milk production appears to occur in heifers that exceed energy intake needed for optimal postweaning gain and subsequently deposit fat in the udder.

Although hitting the target weight at the start of the breeding season is important for fertility and future productivity, weight gains do not need to be consistent throughout the weaning-to-breeding period. Smith *et al* (1995)[101] and Lynch *et al*[57] compared groups of heifers managed differently but who reached the same target weight and body condition score pre-breeding. Half of the heifers were fed to gain 1.3 lb/day[101] or 1.2 lb/day[57] throughout the weaning-to-breeding period. The other half were fed at a low rate of gain for 105 days (0.55 lb/day; Smith *et al*[101]) (0.12 lb/day; Lynch *et al*[57]) and then fed for higher gains the last 54 days before breeding (2.5 lb/day; Smith *et al*[101]) (3.5 lb/day; Lynch *et al*[57]). The heifers fed at a low rate of gain–followed by a period of rapid gain–had the same age and weight at puberty; the same first-service pregnancy rates; and the same pregnancy rates to a 45-day breeding season as the control heifers managed for a steady rate of gain; in the respective studies.

To assure that target weights and body condition scores are being met, a sub-group of the heifers should be weighed and scored for body condition at reasonable intervals (such as monthly) to confirm that desired gains

Table 1. Expected mature weights and target weights for heifers to reach puberty for cattle of different frame sizes.

Frame score	Expected mature wt (lb)[a]	55% of mature wt (lb)	60% of mature wt (lb)	65% of mature wt (lb)
2	953	524	572	619
3	1027	565	616	668
4	1100	605	660	715
5	1173	645	704	762
6	1247	686	748	811
7	1320	726	792	858

[a]Mature weights are from Fox[8]

are being reached. If gains are not near target levels, the ration should be adjusted.

Breeding through mid-gestation

Overfeeding protein during the breeding season and early gestation, particularly if inadequate energy is supplied to the rumen, may be associated with a decline in fertility.[15,29] The mechanism for this decline may be a decrease in uterine pH during the luteal phase in cattle fed high levels of degradable protein.[29] The combination of highly digestible protein and low energy concentrations on an as-fed basis in early growth cool-season grasses may explain the lower-than-expected fertility seen in females placed on such pastures near the time of breeding.

The "target-weight" concept can be continued for planning the nutritional requirements through pregnancy. A heifer should weigh 80% to 85% of her mature weight at the time of calving as a 2-year-old. By the following calculation, one finds that heifers need to gain between 1.3 and 1.5 lb/per day depending on mature weight. Heifers that will mature at heavier weights will need to have a higher daily gain.

target weight at parturition =
85% of mature weight
weight of pregnancy = 2X calf birth weight
wt. gain during pregnancy =
(target wt. at parturition + wt. of pregnancy)
- wt. at breeding
daily gain during pregnancy =
weight gain during pregnancy ÷ 283.

For a heifer with a mature weight of 1100 lb having a 75-lb calf, the equation would be:

[(935 + 150)- 660] ÷ 283 =
1.5 lb/day daily gain during pregnancy.

Energy and protein requirements (NRC estimates) for growing heifers during mid-gestation should be used to formulate rations that allow heifers to maintain body condition and progress toward target calving weight. As long as the environmental temperature remains above the critical point, and the level of pathogen exposure, mud, or other stressors remains low, the nutrient requirements for this period during heifer development can often be met with fairly low-cost forages. For example, requirements for an 885-lb heifer (body condition score = 6, with a mature weight of around 1,100 lb) on day 130 of gestation are about 9.9 Mcal/day and 476 grams of metabolizable protein. We can expect her to consume 2.0% to 2.5% of her body weight on a dry matter basis of an average quality brome hay (NEm=1.18 Mcal/kg; NEg=0.61 Mcal/kg; MP=7.34%). Consuming 17 lb (DM basis) of this hay will leave a deficit of .97 Mcal NEg and is adequate for protein. One and one-half pounds of corn (as fed) will supply the needed energy.

However, the wind chill is below the critical temperature (Table 2), energy requirements increase about 1% for each 1°F drop in wind chill. Protein requirements are not appreciably increased due to temperatures below the critical point. For example, if the same 885-lb mid-gestation heifer is subjected to several October days of rain and 40°F temperature, her NE requirement increases by 19% to 11.7 Mcal/day during the period of inclement weather. Because of the importance of environmental temperature, the expected environmental conditions for a locality should be considered when planning rations and purchasing supplements.

Table 2. Estimated critical temperatures for cattle.

Coat description	Critical temperature
Summer coat	59°F
Fall coat	45°F
Winter coat	32°F
Heavy winter coat	18°F
Wet coat	59°F

Economic considerations may favor limited weight gain or even weight loss during mid-gestation in mature beef cows. But because of higher nutrient demands of heifers, little or no decrease in body condition should occur during the first pregnancy.

Last 60 days of gestation

The nutritional demands of pregnancy increase as gestation progresses. These demands occur not only due to fetal growth, but also due to uterine/placental growth and metabolism involved with the fetal/maternal interaction and exchange of nutrients and waste.

Heifers calving in BCS of 4, 5, or 6 had calves with progressively heavier birth weights, but dystocia score was not influenced by BCS at calving.[104] Heifers with greater weight gains prepartum had calves with heavier actual and 205-d adjusted weaning weights than did heifers with moderate weight gains.[104] Greater BCS at calving resulted in more heifers in estrus and more heifers pregnant by 40 to 60 d of the subsequent breeding season.[104] Thin females should be fed levels during the last third of pregnancy to achieve a targeted body condition score of ≥ 6 at calving, whereas those in moderate-high to high body condition at 90 d prepartum should be fed levels to maintain body reserves.

When body weight or condition loss occurred during the middle third of pregnancy, increased nutrient intake one to three months before calving substantially improved pregnancy rate compared to cows that continued to lose weight.[95] However, cows that maintained weight throughout the last half of pregnancy had higher pregnancy rates than those that lost weight and had to gain it back later, even though pre-calving BCS were similar between the two groups.[95]

Although there is disagreement over the effect of level of nutrition and body condition score changes after calving in cows and heifers that calve in good condition, most research clearly demonstrates that body condition at calving is a dominating factor in postpartum fertility. Higher body condition scores or greater levels of supplemental energy during late gestation improved the percentage of cows showing estrus by 60 days after calving and subsequent pregnancy rates.[1,95] Heifers that calve in poor body condition have lighter birthweight calves,[104] a longer postpartum interval to return to estrus, and lower pregnancy rates during the following breeding season.[95,104]

First 80 days of lactation

During the first 80 to 100 days following parturition, the heifer must continue to grow at about 0.5 lb per day, support lactation for a suckling calf, resume estrous cyclicity, and conceive for her second pregnancy. The maintenance requirement for lactating heifers averages about 20% higher than non-lactating heifers, but maintenance requirements are greatly affected by milk production potential. In beef cattle, peak lactation occurs at approximately 60 days postpartum and maximum yield has been reported to range from 9 to 30 lb/day.[68]

It is clear that energy and protein requirements post-calving greatly exceed that of mid-gestation heifers and even late-gestation heifers. These higher demands make it difficult to add body condition to heifers once they begin lactation. Because post-calving condition score and energy balance control ovulation,[120] and condition scores of 6 or greater are required for high conception rates in heifers,[21] both body condition at calving and level of nutrition postpartum are critical control points affecting pregnancy rates.

Marston *et al*[59] illustrate the importance of adequate body condition at calving in that postpartum supplementation of energy or protein after calving had little effect on subsequent pregnancy rate. The period of time between calving and rebreeding is fairly short–only 82 days to maintain a 365-day calving interval–and during this time the cow has her highest nutritional demand due to lactation. Because of these factors, weight gain or body condition increase is difficult in the early postpartum cow. Marston and Lusby[58] also show that in grazing cattle, it is difficult to increase the intake of energy once protein requirements are met. For cows grazing forage or consuming poor- to average-quality hay that is deficient in protein, supplementing protein to the diet will increase dry matter digestibility, intake, and subsequently energy intake. But after protein deficiencies are corrected, additional protein or energy merely replaces forage, rather than supplementing it. These findings do not decrease the importance of postpartum nutrition; they only illustrate the constraints placed on the postpartum period nutritionally if body condition is not adequate at calving.

By recognizing the importance of body condition at calving, one should not assume that if condition is adequate or good at calving that postpartum nutrition is less critical. Wiltbank *et al*[117] found that regardless of prepartum energy regimens, more cows that were fed greater amounts of energy diet after calving became pregnant than cows fed a reduced energy diet postpartum. Dunn *et al*[26] showed that although the pre-calving energy level exerted a strong influence on the early postpartum anestrous period, pregnancy rates at 120 d post calving were directly related to post-calving energy levels. Prepartum nutrition does, to some extent, influence early post calving ovarian function, but data from Rakestraw *et al*[86] as well as the results of Wiltbank *et al*[117] and Dunn *et al*[26] support the concept that good body condition at calving does not guarantee optimal rebreeding unless nutrition during early lactation is adequate.

Puberty

Puberty in the beef heifer is reached when she is able to express estrous behavior and ovulate a fertile oocyte. The maturing of the neuroendocrine system that induces the maturation and ovulation of the first oocyte as well as the hormonal changes that induce the first expression of behavioral estrus are the result of a gradual increase in gonadotropic activity (luteinizing hormone; LH, and follicle stimulating hormone; FSH). This increased gonadotropic activity is due to a decreased negative feedback of estradiol on the hypothalamic secretion of gonadotropin-releasing hormone (GnRH).[32,72] The gradually increased secretion of LH initiates ovarian production of steroid hormones and gametes, resulting in follicle maturation and ovulation. The first ovulation is usually not accompanied by external indications of estrus. It is generally believed that a certain amount of progesterone is needed during a period preceding estrus in order to induce estrus behavior and for the following cycle to be of normal length.[24] Once the heifer has gone through a cycle with corpora luteal (CL) development or has been exposed to sufficient progesterone levels from other endogenous sources, the following cycles are normal.[38]

The onset of puberty is primarily influenced by age and weight within breed.[70,73,115] Other factors can also have some influence on the onset of puberty and include exposure to bulls,[79,90] time of year,[93] and exposure to progestogens.[37,97,103] Planning the nutrition program so that heifers reach a target weight is used to ensure that a large percentage of heifers within breed types have reached the body weight that coincides with the onset of puberty. However, weight is not the only controlling factor, as a minimum age requirement must also be reached in order for heifers to reach puberty.[69] The age at puberty can be decreased by selecting for breeds with a younger age at puberty, selecting within a breed for younger age at puberty, or crossbreeding with another breed that has a similar or younger age at puberty.[99]

Some studies have indicated that exposing prepubertal heifers to bulls[79,90] or bull urine[42] decreased the age at puberty. However, other studies have contradicted those results.[6,88] The proposed mechanism of action of bull exposure involves stimulation of the hypothalamic-pituitary axis so that LH and/or FSH secretion is increased,[78] as has been shown in mice[9] and ewes.[60,81] Exposure of prepubertal heifers to mature cows[70] or cycling heifers[89] did not decrease the age or weight at puberty.

Although considered a non-seasonal animal, season does have some effects on bovine reproductive performance. Heifers born in the fall reach puberty at a younger age than heifers born in the spring.[93] This difference may be due to photoperiod differences during the maturation of the neuroendocrine system. Work in ovariectomized cows[107] and intact and castrated bulls[108] indicates that mean concentration of circulating LH or amplitude of LH pulses are increased at the spring equinox, compared to the fall equinox. Concentrations of LH from blood samples taken from prepubertal heifers between 6 and 7 months of age were higher in the spring (fall-born heifers) than in the fall (spring-born heifers).[93] If heifers are kept in environmental chambers and exposed to spring followed by summer temperatures and photoperiods from 6 to 12 months of age, no difference in age at puberty exists between spring-born and fall-born heifers, supplying evidence that photoperiod differences during the second 6 months of life influences the age at puberty.[93]

Progestogens

Progesterone and synthetic progestogens induce puberty in heifers, and management systems that capitalize on this result have been developed. Short *et al*[97] showed that more prepubertal heifers (8.5 m old and 249 kg or 548 lb) given a progesterone implant for 6 d plus an injection of estradiol-17β 24 h after implant removal showed estrus and ovulated within 4 d than heifers treated with estradiol-17β alone. Gonzalez-Padilla *et al*[38] also used progesterone or norgestomet (a synthetic progestogen) in conjunction with estradiol valerate to induce estrus in prepuberal beef heifers in a series of experiments. Synchro-Mate B®[a] was, until recently, a commercially available estrous synchronization product that utilizes a 9-day, 6 mg norgestomet implant coupled with an injection of 3 mg norgestomet plus 5 mg estradiol valerate at the time of implant insertion. Gonzales-Padilla *et al*[38] were able to induce estrus in approximately 93% of heifers treated with either the standard Synchro-Mate B treatment or daily i.m. injections of 20 mg progesterone for 4 d plus 2 mg estradiol-17β 2 d after the last progesterone injection. Pregnancy rates ranged from 43% to 73%.

Another commercially available synthetic progestogen is melengestrol acetate (MGA®[b]). Work has also demonstrated the ability of MGA to induce puberty in heifers, especially heifers near the age and weight requirements for spontaneous induction of puberty. Conception rate at first service for heifers that attained puberty while being treated with MGA administered orally for 14 days, followed by Prostaglandin $F_{2\alpha}$ given as an i.m. injection 17 days after the final day of MGA feeding, was not different from that of control heifers that attained puberty during the same period.[93]

Ionophores

Ionophores were originally cleared for use to improve the feed efficiency of feedlot cattle on high-concentrate diets[87] and to improve pasture cattle gains.[75,82] Now ionophores are cleared for use in replacement heifers. Inclusion of ionophores in heifer diets has been shown to increase the number of heifers that had reached puberty by the start of the breeding season,[65] decrease the age at puberty,[64,85,105] decrease the weight at puberty,[85] increase the corpora luteal weight, and increase the amount of progesterone produced.[11] The decrease in age at puberty was independent of improved average daily gain and increased body weight. Moseley *et al*[64] speculate that changes in ruminal fermentation patterns to favor proprionic acid production produce an endocrine response which influences the mechanisms regulating puberty.

Growth Implants

Implanting suckling calves with anabolic growth promotants is a highly profitable practice used by cow-calf operators to increase weaning weights of calves intended for slaughter. Research on the effect of implants on percentage cycling and conception rates of heifers which are later saved for replacements has been somewhat inconsistent, with results ranging from negative[45,91,100] to positive.[113] When nutritional levels are adequate to sustain the anabolic effects on weight gain, implants have been reported to have no negative effects.[23,47] Negative results were most likely to occur when implants were placed at birth, or when heifers were implanted with anabolic agents three times between birth and puberty.[45,91,100]

However, a recent paper revealed possible negative effects of a progesterone and estradiol implant that is approved for use in heifers intended to be retained as heifers.[3] Bartol *et al* implanted some heifers according to label directions at 45 days of age. Other heifers in the experiment were implanted at birth, at 21 days of age, or remained as un-implanted controls. All the implanted heifers had reduced uterine weight, decreased myometrial area, decreased endometrial area, and reduced endometrial gland density compared to the control heifers. The effects were greatest in heifers implanted at birth.

Numerous studies have shown that heifers implanted with anabolic growth promotants at 2 to 3 months of age have a larger pelvic area as yearlings than controls without implants.[16,39,47,53,91,100,113] This increase ranged from 10 to 29 cm^2. A few studies have followed the heifers to calving at 2 years of age to determine whether the larger pelvic areas were maintained.[39,47,91,100,113] These studies showed that much of the advantage for implanted heifers seen as yearlings was lost by the time they were ready to calve: the advantage was only 3 to 9 cm^2 compared to controls with no implants.

Implants from two companies are approved for use in suckling heifers that are to be retained as replacements, but I do not recommend implanting calves that can be identified at a young age as likely replacements. There are no benefits to implanting replacement heifers since producers do not benefit economically from maximum growth. Instead, economic benefits from replacement heifers occur due to early onset of puberty, high rates of fertility, and a long productive life in the cowherd.

Anthelmintic Treatment

Internal parasites can have a negative impact on virtually all production characteristics of beef cattle, including gains from weaning through the first pregnancy.[48,114,118] The presence of internal parasites affects nutrient utilization and possibly alters metabolism in infected animals. Minimizing the negative impact of internal parasites with the use of broad-spectrum anthelmintics that are able to kill inhibited stages of *Ostertagia ostertagi* improves the efficiency of gain for replacement heifers. Improved gain increases body weight and hence the number of heifers cycling at the beginning of the breeding season.[48,85] But it is interesting to note that improvements in reproductive response in replacement heifers treated with anthelmintics may not be solely due to reaching target weights faster than non-treated heifers. It is noteworthy that Larson *et al*[48] found the correlations between weight gain, or prebreeding heifer weight, and puberty in ivermectin-treated heifers approached zero, indicating that the gain response does not fully explain the earlier onset of puberty. Purvis and Whittier[85] also showed that decreased age and weight at puberty in ivermectin-treated heifers, compared to controls, was not due to improved average daily gains. Therefore, other pathways affecting onset of puberty, besides weight gain, are being stimulated due to treatment with ivermectin and possibly other anthelmintics. These pathways are probably related to parasite burden in the growing animal.

Evaluation of Reproductive Soundnesss of Yearling Heifers

Reproductive tract scores

Age at puberty can be determined fairly closely in a laboratory setting by measuring blood progesterone levels from samples taken every 10 days (or more frequently). Of course, this method is impractical for production herds, and another method of determining onset of puberty was needed. The reproductive tract scoring (RTS) system was developed to subjectively classify pubertal status using size of the uterus and ovaries estimated by palpation per rectum.[2] The system assigns a score to each heifer using a 5-point scale where a score of 1 is considered an immature tract and a score of 5 is considered a cycling tract (Table 3).

Heifers with infantile reproductive tracts that are not near the time of puberty when palpated are designated RTS 1. These heifers have small, flaccid tracts and small ovaries with no significant structures. Heifers may be assigned an RTS of 1 because: 1) they are simply too young to fit into the breeding season being planned, 2) they are too light to reach their target weight and are not able to express their genetic potential for reaching puberty, 3) they were implanted with a growth-promotant near the time of birth. Heifers assigned an RTS of 2 have slightly larger uterine diameter, but tone is still lacking and the ovaries have very small follicles. Heifers described as having an RTS of 3 have some uterine tone and larger uterine diameter than heifers with more immature scores. These heifers are subjectively evaluated as being within 6 weeks of cycling. Heifers assigned a score of 4 or 5 are considered cycling, as indicated by good uterine tone, size, and easily palpable ovarian structures. RTS 4 is assigned to heifers that, although large follicles are present, do not have a palpable corpus luteum (CL) because they are in their pubertal cycle or are in a stage of the estrous cycle where a CL is absent. Heifers with an RTS of 5 are similar in uterine and ovarian size, tone, and structure when palpated per rectum as compared to RTS 4 heifers, except that a CL is present.

RTS scores can predict reproductive performance of yearling heifers, especially for pregnancy rates to synchronized breeding and pregnancy rates at the end of the breeding season. Heifers with more mature reproductive tracts had higher pregnancy rates and calved earlier.[76]

Heifers should be evaluated for tract score about six to eight weeks prior to the breeding season. If deficiencies are found, management changes instituted this

Table 3. Reproductive tract scores[110]

Reproductive Tract Score (RTS)	Uterine Horn Size / Tone	Approximate Ovarian Size Length (mm)	Height (mm)	Width (mm)	Ovarian Structures
1	<20 mm diameter No tone (immature)	15	10	8	No palpable follicles
2	20-25 mm diameter No tone	18	12	10	8 mm follicles
3	25-30 mm diameter Slight tone	22	15	10	8-10 mm follicles
4	30 mm diameter Good tone	30	16	12	>10 mm follicles CL possible
5	>30 mm diameter Good tone	>32	20	15	>10 mm follicles CL present

far ahead of the breeding season can result in an increased number of heifers reaching puberty by the start of the breeding season. If the heifers are evaluated too far ahead of the breeding season (> 8 weeks), they are likely to be young and to have tract scores lower than what is a true reflection of their potential to reach puberty before the breeding season.

A reasonable goal is to have at least 80% of replacement heifers cycling before the start of the breeding season. A group is considered to be properly developed to reach this goal if at least 60% of the heifers are scored RTS 4 or 5 and most of the remainder of the heifers are RTS 3 when evaluated six to eight weeks before breeding. Because melengestrol acetate (MGA) will induce puberty in some heifers that are near puberty (RTS 3), a lower percentage (50%) of heifers with RTS 4 or 5, when evaluated six to eight weeks prior to breeding, is adequate to meet the 80% goal at breeding if using MGA. In order to reach the goal of at least 80% of heifers in a replacement pool cycling at the start of the breeding season, nutrition must remain adequate for continued growth from the time of RTS evaluation until breeding.

If a low percentage of heifers are cycling at the time of RTS evaluation and many of the heifers are scored as 2, management changes must be instituted immediately. These changes may include: 1) increasing the plane of nutrition so that increased weight gain will allow the heifers to reach target weight by the start of the breeding season, 2) increasing the plane of nutrition and delaying the start of the breeding season by several weeks, 3) holding the heifers over to breed six months later to calve in the fall (for spring-calving herds), 4) marketing the heifers for feeder cattle and finding another source of replacements.

Pelvic Area Measurement

Use of pelvic measurement at one year of age as a tool to decrease the incidence of dystocia has been described extensively since the early 1980s.[22,41,71] Veterinarians have used pelvic-area measurements of yearlings because the major cause of dystocia is a disproportionately large calf compared to the heifer's pelvic area. Since the correlation between yearling and 2-year-old pelvic areas is 0.70,[71] measuring a heifer's pelvic area as a yearling is beneficial for predicting pelvic size at the time of parturition. Pelvic area is moderately to highly heritable (.44 to .61),[5,41,63] so after a few years of measuring replacement heifers and bulls used to produce replacements, producers can increase average pelvic size of the herd.

Critics of using pelvic area measurements to decrease dystocia point out that pelvic area is also positively correlated to mature cow size and calf birth weight.[49,84] If producers place selection pressure on heifers for pelvic area by selecting for increasingly larger pelvic area, calf birth weight will also increase and the rate of dystocia is not likely to decrease.[4] A number of researchers have shown that selection based on pelvic area alone did not significantly reduce the incidence of dystocia in groups of heifers.[66,111,112]

Rather than using pelvic area measurement to select for maximum pelvic size, this tool should be used to set a minimum pelvic size as a culling criterion (such as 150 cm^2 at one year of age) without assigning preference for heifers that exceed the minimum. In addition, including mature weight as a selection criterion, heifers with a genetic predisposition for small pelvic area are culled without increasing mature size.

Using weight, RTS, and pelvic area to describe the reproductive soundness of heifers

An effective way to evaluate the reproductive soundness of yearling heifers in a ranch setting is by using yearling weights, RTS, and pelvic area measurements together to describe the maturity and reproductive soundness of the heifer group. These three criteria are closely correlated in that, within a set of heifers with similar genetic makeup, one should expect higher tract scores in heifers that have heavier yearling weights, and these heifers should also have greater pelvic areas than lighter-weight heifers.

Because we expect yearling weight, RTS and pelvic area to be related, one should make note of heifers, or groups of heifers, where that relationship is not strong. Heifers that have reached their target weight and have a high RTS, but have small pelvic areas, may be genetically predisposed to a small pelvis. This genetic input may have come from the male or female side. Another example of heifers failing to perform as expected is in cases where heifers are implanted with a growth promotant near the time of birth. Often these heifers have adequate yearling weights and pelvic areas, but RTS scores indicate tract immaturity.

The fact that pelvic area tends to increase more rapidly near the time of puberty than during the prepubertal period[10] is useful knowledge when examining pelvic area data. For example, a heifer that has an RTS of 5 and is adequate yearling weight, but has a small pelvis, has a high probability of having a small pelvis at the time of calving as a two-year-old. Whereas, a heifer with the same pelvic area who has an RTS of 2 and has not reached her target weight, may very well have an adequate pelvis at calving if management changes are made so that she reaches puberty and becomes pregnant.

Biosecurity for Heifer Replacements

Biosecurity is the attempt to keep such infectious agents as bacteria, virus, fungi and parasites away from a herd. One aspect of biosecurity is a vaccination program that improves the immunity of cattle against the infectious agents they may contact. Not all diseases of cattle have commercial vaccines available, and no vaccine is completely effective at preventing disease. Therefore, other aspects of disease prevention and biosecurity are at least as important as a vaccination program. A vaccination program should be tailored for specific risk factors and then rigorously applied to the herd.

Vaccination Protocol

Commercial vaccines are not available for all pregnancy-wasting infectious agents. Other diseases have vaccines manufactured for their control, but the vaccines are not adequately efficacious, or are not a primary concern for a particular area or herd. For most beef herds, the potential list of diseases in a vaccination program would include: brucellosis, infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD), vibriosis (campylobacteriosis), and leptospirosis. Other diseases for which vaccines are available include *Hemophilus somnus* and trichomoniasis. When selecting diseases to include in a vaccination program, it is wasteful and unjustified to vaccinate with every available antigen. The antigens selected should be limited to those for which there is an effective vaccine that will produce protective immunity and for which the herd will possibly be exposed. This decision is largely based on the classification of the herd as a closed, modified-open or open herd.[102]

As brucellosis is a zoonotic disease, its control in animals is especially important to the human population. *Brucella abortis* strain RB51 vaccine is a live bacterial product and confers long-term, cell-mediated protection in healthy animals vaccinated properly. For many areas of the country brucellosis has been eradicated, and in those areas many herds are no longer utilizing Official Calfhood Vaccination. Whether to continue with a brucellosis vaccination program should be determined only after considering interstate movement, risk of exposure and legal responsibility.

Commercially available vaccines exist for IBR and BVD, which are two viral pregnancy-wasting diseases. To decrease the risk of pregnancy wastage from these viral diseases, non-pregnant heifers should be given modified live vaccines two or more times, from weaning to 6 weeks before breeding. Although modified live IBR/BVD vaccines do not require a booster to induce a protective response, it is recommended that vaccinations be repeated two or more times because one does not know when maternal antibody interference with active immunization wanes, or if nutritional or host factors interfering with immunization are present. Multiple vaccinations allow the maximum number of heifers to develop active immunity to the vaccination. An open herd with a high level of risk may benefit from having higher levels of circulating IgG subsequent to annual IBR/BVD booster immunizations.

Leptospirosis is a zoonotic bacterial disease that causes pregnancy wastage primarily in the last trimester of gestation. Leptospiral organisms cause latent infection in the kidneys of host animals and the organisms are excreted in urine for a variable time, depending on serovar and age of the host. Leptospires survive in wet environments for up to 30 days. Infection of susceptible cattle occurs through mucous membranes and abraded or water-softened skin, or by sexual contact. *Leptospira interrogans* has over 180 serovars grouped into 19 serogroups. Each serovar is adapted to a particular maintenance host, although they can cause disease in any mammalian species. In the United States, serovar *hardjo* type hardjo-bovis has a "maintenance-host" relationship with cattle. A maintenance-host relationship is characterized by high susceptibility to infection, endemic transmission within the host species, relatively low pathogenicity of the serovar for its host, a tendency to cause chronic rather than acute disease, and a low efficacy of vaccination for prevention of infection.[83] Infertility may follow localization of leptospires in the uterus and oviduct of maintenance-host *hardjo* carriers. Vaccination against *hardjo* infection in cattle does not appear to prevent kidney establishment, urinary shedding, or fetal infection after conjunctival infection with type hardjo-bovis.[7]

By contrast, an "incidental-host" relationship is characterized by relatively low susceptibility to infection but high pathogenicity for the host, with a tendency to cause acute, severe disease; sporadic transmission within the incidental-host species, and acquisition of infection from other species; and good efficacy of vaccination in preventing infection.[83] Serovar *pomona (kennewicki)* is a common incidental pathogen of cattle, and the maintenance host is swine. Leptospira strains maintained by non-domestic animals such as skunks, raccoons, opossums, foxes, beavers, mice, deer and others can infect cattle herds that are exposed to environmental contamination, such as urine-contaminated waterholes.

An incomplete vaccination program directed against leptospiral organisms may be more detrimental than the lack of a vaccination program. Because of the maintenance-host adaptation of the serovar *hardjo* to cattle, vaccination acts to disrupt the enzootic cycle, thereby preventing natural immunization. And because of the relatively low immunogenicity of *hardjo* vaccine, vaccination programs, once initiated, must be continuous to ensure that "holes" in the herd's protection do not develop between vaccinations.[28] The reintroduction of *hardjo* into a herd where vaccination has been discontinued or poorly applied might result in particularly severe outbreaks of clinical disease.

If risk of exposure to leptospirosis warrants an attempt to establish immunity against the organism, primary immunization of heifers should consist of two or three vaccinations given at month intervals pre-breeding, and another booster in mid-gestation of the first pregnancy. Bacterins produce immunity of fairly short duration (at most, a few months) for controlling clinical disease. The length of protection in the genital tract against abortion may be even shorter than for clinical disease. Because of these limitations, annual (preferably in mid-gestation) or twice annual boosters should be given. Methods other than vaccinations for reducing risk of exposure to leptospirosis should also be implemented. These would include having a closed herd, and fencing cattle away from water sources that can be contaminated by other herds, swine, or non-domestic animals.[83]

Campylobacter fetus ss *venerealis* is an infertility-inducing venereal disease causing early embryonic mortality. After transmission to susceptible females, the organism can be found initially in the vagina, cervix, uterus, and oviducts. Infection of the uterus and oviducts persists for up to 2 months, but thereafter it is progressively eliminated and by the end of the third month is usually confined to the cervix and vagina.[25] Management factors that minimize risk include artificial insemination with semen from non-infected bulls; utilizing bulls less than 3 years of age, as they tend to be difficult to infect when exposed to the organism; treating or culling infected females; and initiating an immunization program.

Campylobacter fetus ss *venerealis* is an unusual bacterial pathogen whose infection is limited to the genital tract and results in only local immunity. Systemic immune response, as indicated by antibodies against *C. fetus* in serum, is not helpful in diagnosing vibriosis because titers do not change before or after infection.[19] Both local humoral and local cellular immune responses are involved in clearing the organism from the uterus and oviducts following a natural infection. Once the organism is cleared from the uterus and oviducts, the female regains fertility. Immunoglobulin G is the primary Ig class active in the uterus following infection, whereas IgA predominates in the vagina. Immunoglobulin G acts to immobilize and opsonize *C. fetus,* allowing intracellular killing by neutrophils and macrophages present on the endometrium. In contrast, IgA produced in the vagina immobilizes the bacteria, preventing uterine infection, but does not opsonize and likely blocks the opsonizing effect of IgG. Thus, it prevents complete clearance of organisms from the vagina. After eliminating the uterine infection, convalescent females are resistant to further *C. fetus* colonization of the uterus, but colonization of the vagina often occurs and may persist for 6 to 24 months.[19] This apparent immunity to disease, combined with a vaginal carrier state, may be an adaptation that keeps protective antibody levels high by providing constant antigenic stimulation.[19]

Protection of a herd from *C. fetus*-induced disease by parenteral vaccination apparently violates the assumption that to create a protective immune response, the induced response should be of the same character as the natural infection. In natural infection, local humoral and cell-mediated responses clear the organism and then confer protective immunity for 2 to 4 years. In contrast, parenteral vaccination induces a systemic humoral response consisting primarily of IgG_1 and IgG_2. However, this route has proven to be effective in preventing the clinical infertility syndrome and, in fact, systemic vaccination can be used to cure, as well as prevent, infection in both males[18] and females.[94,119] Because the IgG produced in response to parenteral vaccination is found in both uterine and vaginal secretions, the systemic immunity induced by the bacterin is successful in clearing both the uterine and the vaginal (carrier state) infection.[119] This vaccine-induced clearance of the carrier state is contrary to the usual dogma on vaccine use.

To induce an immune response to vibriosis, heifers should be vaccinated 2 or 3 times at one-month intervals after they are 6 mo of age for the primary immunization. Annual boosters should be given 30 days prior to each breeding season if risk of exposure is present. Because of the curative ability of the vaccination, all bulls brought into a herd should be vaccinated a minimum of twice, at monthly intervals, with the last vaccination 30 days prior to the breeding season. If risk of exposure to carrier males or females is present, annual vaccinations should be used to booster immunity.

Hemophilus somnus can cause vulvitis, vaginitis, male and female infertility and, rarely, sporadic abortion. Transmission for the abortion syndrome is uncertain, but is most likely ingestion. Data showing the ability of vaccination to protect against abortion is lacking,[56] although the development of a systemic IgG_2 antibody response may provide local immunological protection in the uterus.[13] Like all bacterins, protection from clinical disease is short-lived at best; therefore, a minimum of two primary vaccinations given at month intervals and at least annual boosters would be needed to provide even theoretical protection in those herds where the disease has been demonstrated.

Trichomonas foetus infection is a protozoal venereal disease. Transmission occurs during coitus. In cows, the parasite is confined to the reproductive tract. Trichomonades produce cytotoxic factors that damage host tissue, cause inflammation of the uterus, and invade placental and fetal tissue, resulting in early embryonic death. After a variable period of infertility following the initial exposure, cows are usually able to clear the infection, although persistently infected females have been reported. On subsequent exposure to infected bulls, cows appear to be less susceptible to infection.

In bulls, trichomoniasis is asymptomatic. The organisms are located on the surfaces of the penis and penile sheath, where they cause little damage. Bulls less than four years of age appear to recover spontaneously or to be refractory to infection.[44] Control of trichomoniasis outbreaks involves management practices including use of artificial insemination, use of bulls less than 4 years of age only, culling females that do not conceive in a short breeding season and continued surveillance of the herd by culturing bulls and culling carriers.

Vaccination programs for females exposed to *Trichomonas*-infected bulls would appear to be beneficial in controlling outbreaks. The program should include 2 vaccinations, 4 weeks apart for primary vaccination and annual boosters thereafter. Researchers have shown that, although an immunization program did not prevent *Trichomonas fetus* infection, it did decrease the duration and incidence of infection.[46]

Preventing the introduction of trichomoniasis into a herd in endemic areas includes eliminating common pastures and examination of smegma samples from replacement bulls three times, at weekly intervals, before the start of the breeding season. Smegma samples may be placed in sterile saline and examined directly under the microscope for *Trichomonas* organisms, or placed in Diamond's medium for culturing.

Isolation

Because most infectious agents cannot live very long outside or off an animal, and most don't travel great distances through the air, a method to keep other animals and people away from a herd nearly accomplishes the goal of keeping infectious agents away. Keeping a closed herd is one method of biosecurity. A closed herd is one where no cattle enter the farm and no cattle on the farm have contact with cattle from other farms. A herd is not closed if cattle share a fence with cattle from a different farm; bulls, replacement heifers, replacement cows or stocker cattle are purchased; cattle return to the herd after being at a performance evaluation (i.e. bull test station) or show; bulls are borrowed or loaned; or cattle are transported in a vehicle that transports other cattle. Using this definition, it is difficult (and maybe not desirable from a production standpoint) to have a completely closed herd. However, utilizing as many closed-herd-protocols as possible will minimize exposure to infectious agents.

In open herds, replacement females and bulls should only be purchased from herds with a known, effective vaccination and disease-testing and diagnosis program. Avoid purchasing animals from unknown sources or that have been mixed with other cattle prior to sale. Also, additions to the herd should be isolated from the resident herd for at least one month prior to introduction to the herd. Isolated cattle should not share feeders, waterers, or air space (distance depends on wind velocity and direction). During the isolation period, the additions should be tested for and vaccinated against transmissible diseases.

Equipment and animals other than cattle can carry infectious diseases. Rodents, birds, cats, and dogs should all be limited in their exposure to your cattle. Rodents and birds are primarily a problem when cattle are confined, and professional exterminators may be needed to devise an effective control plan. Salmonellosis, crypotosporidiosis and other diseases can be passed by dogs and cats. Therefore, keeping pet animals away from cattle is an important aspect of biosecurity.

Humans can carry infectious diseases in their respiratory, urinary, or digestive tracts, as well as on skin or clothing. Therefore, limit access to the herd and ensure that visitors wear clean boots and coveralls if they have recently visited other cattle operations. Have trucks that deliver animals and feed, or that pick up animals (alive or dead) remain away from the herd and away from normal traffic areas.

During the quarantine period, animals should be screened to identify those persistently infected with BVD using an immunohistochemistry (immunoperoxidase) test on a skin biopsy sample, or by polymerase chain reaction, virus isolation or enzyme-linked immunosorbent assay (ELISA) of serum or blood. Work with your diagnostic laboratory to accurately interpret the tests. Some herds may also screen for Johne's and bovine leukemia virus (BLV).

Conclusion

Nutritional development that ensures heifers will reach target weights is necessary in order to have a high percentage of heifers pubertal prior to the start of the breeding season. Proper nutritional development, as well as utilization of the commercially available ionophores, anthelmintics and progestogen-containing estrous synchronization systems (MGA) will ensure that a high percentage of heifers are pubertal and available for breeding at the start of the breeding season. A herd biosecurity program that includes stringent vaccination and quarantine protocols for replacements will minimize the risk of pregnancy-wasting diseases.

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