Reproductive evaluations and clinical interventions in beef herds

Ramanathan K. Kasimanickam,[a] Vanmathy R. Kasimanickam,[a] John P. Kastelic,[b] William D. Whittier[c]
[a]Veterinary Clinical Sciences, College of Veterinary Medicine, Washington State University, Pullman, WA; [b]Production Animal Health, Faculty of Veterinary Medicine, University of Calgary,Calgary, AB, Canada; [c]Large Animal Clinical Sciences, VA-MD Regional College of Veterinary Medicine,Virginia Tech, Blacksburg, VA

Abstract

Cow-calf and purebred beef producers need to operate at high efficiency to have profitable, sustainable operations. Although beef cattle veterinarians are ideally positioned to support this, producers are often initially reluctant to purchase the broad range of services that can be provided. Therefore, practitioners must demonstrate a sound knowledge of principal factors affecting beef cow herd productivity and their ability to translate that knowledge into effective herd investigative strategies and planned intervention programs. The goal of this review is to provide guidance for practitioners wishing to embrace this opportunity.

Introduction

The single most important parameter in measuring production efficiency of a beef cow herd is maximum output of marketable pounds of beef produced per cow exposed in a year. Consequently, there is a clear need for effective reproductive management to achieve production potential. Reproductive herd health programs should focus primarily on: control of infectious and noninfectious diseases of the reproductive tract; bull fertility or synchronization and detection of estrus (or synchronization of ovulation), or breeding technique, semen quality and handling; and endocrine imbalances. Given the importance of dietary energy and its effects on reproduction, fertility examinations should include nutrition monitoring and body condition scoring (BCS). Although bovine veterinarians have critical roles in reproductive management of dairy operations, making them well positioned to assume the same role in beef herds, few beef herd farmers actively seek veterinary input regarding this aspect of herd management.[1] One of the main reasons is that few farms have data in a readily useable format (e.g., Excel, CowCalf5). In that regard, up to 17.7% of beef cow-calf operations had no records, whereas 78.6% kept records by hand.[1] Consequently, this is an opportunity for beef cattle practitioners to offer record keeping services to beef producers (on a fee-for-service basis). Although data essential to basic fertility analysis and benchmarking are not complex (Table 1), without recording and analyzing these data, it is difficult to identify deficits and recommend changes to improve performance.

Given the low input and high output nature of beef production, there is a great need for beef farmers to closely examine their production system, with the objective of optimizing reproductive efficiency. Key skills for a practitioner to provide appropriate service is the ability to demonstrate an understanding of reproduction in the beef herd, investigate herd-level reproductive performance, establish goals, and recommend changes needed to achieve those goals. Therefore, a thorough understanding of factors that determine reproductive performance in beef herds is required, along with an effective investigative strategy.

Determinants of reproductive performance

The principal measure of output for a beef cow herd is weight of calf weaned per cow exposed or breeding. At the most basic level, this is determined by number of cows that conceived and the rate at which that happens. For an individual cow to achieve maximum reproductive efficiency, a calf must be produced every 12 months. The gestation length for commonly used terminal sire breeds is approximately 285 days, leaving only 80 days for uterine involution, resumption of ovarian cyclicity and conception. This restricts the breeding season to only nine weeks. However, extending the breeding season can conceal both poor conception rates and prolonged anestrus. Even though this increases number of calves born, they are younger and therefore lighter weight at weaning or sale.

Four weeks postcalving is widely accepted as the average interval from calving to complete uterine involution in suckled beef cows.[2] However, resumption of ovarian cyclicity in beef cattle is more complex. Suckling has an inhibitory effect on the hypothalamic-pituitary axis and prolongs postpartum anestrus compared to milked cows. Postpartum anestrus in suckled beef cows (29 to 67 days) is longer than in milked dairy cows (15 to 21 days).[3-5] Duration of postpartum anestrus after calving influences cows' opportunities to get re-bred.[6] Cows 50 days after calving and in moderate body condition had an increase from 45% cycling with no treatment to 79% cycling with treatment (calf removal coupled with nutritional flushing). However, anestrus is prolonged if there is a combination of low body condition and inadequate energy intake. Although suckling prolongs postpartum anestrus, removing calves from cows for 48 h at the beginning of the breeding season, coupled with a nutritional flushing program, significantly improved pregnancy rates. Calves experienced almost no ill effects when given access to feed and water during the 48-hour interval.

It should be noted that even young cows, when given the opportunity, will achieve calving intervals < 365 days and repeat this for the next breeding season. Consequently, despite obvious constraints, the physiology of beef cows is not an inherent barrier to achieving the requisite level of reproductive performance in a nine-week breeding season. In a 63-day breeding season with a 70% conception rate, a 98% pregnancy rate could theoretically be achieved if all cows were cycling at the onset of the season. It should be noted that under US management, only 30% of mature cows are cycling at 40 days postpartum, although up to 95% are cycling by 90 days postpartum.[6] Cows with a good BCS that calve in the first month of the calving season are highly likely to be cycling by the onset of bull exposure and thus have three or more chances of having a fertile estrus during the breeding period. In contrast, thin cows, even if they calve in first four weeks of the calving season, are unlikely to start cycling until after they are exposed to bulls. Furthermore, thin cows that calve late in the calving period may only start cycling in the last few weeks of the mating period and are at increased risk of failing to conceive. However, if the average cow does not begin cycling until 45 days into the breeding season, a maximum pregnancy rate of only 81% would be expected. Clearly, early calving is especially important, as it influences both resumption of ovarian cyclicity and probability of conception.

Key management areas

For a beef herd to reach its reproductive potential, critical issues include:

Management of heifers
Nutritional management of cows
Prevention of dystocia
Management and assessment of bull fertility

Management of heifers

Heifers that have not reached mature bodyweight must be fed for growth as well as maintenance and pregnancy. The target breeding weight is 65% of mature weight at a body condition score of 5. These cattle should reach 85% of their mature weight at the start of the following breeding season. Recent research suggests that development of beef heifers to approximately 55-60% of mature body weight at breeding may provide economic benefit in comparison to the previously recommended 65% of mature weight, if post-breeding nutrition is good.[7-9] Although, there is new evidence that 55% mature weight is adequate, it should be adopted with the caution. Even though it is attractive from the perspective of reduced feed and costs, the following issues have not been addressed:

- economics of feeding pregnant heifers to gain from 65 to 85% versus 55 to 85%
- consequence of fetal programming in adult life for offspring born to heifers with 65 versus 55% BW at breeding
- lifetime productivity differences between heifers at 65 and 55% mature BW at breeding.

Feeding to gain mature weight can be difficult to achieve, as heifers and two-year old females that have calved are very susceptible to poor-quality rations and competition if rations are restricted. On average, the first estrus after the first calving is 20 days later than in mature cows. After the second calving, effects are similar, but the delay is less pronounced. One way to manage this is to breed heifers 30 days before cows. It should be noted that if replacement heifers are raised on farm, insufficient numbers may have reached target weight at that time. In order to overcome this, it was suggested to expose 20% more heifers to bulls and conduct pregnancy diagnosis soon enough to accurately stage pregnancies.

Alternatively, synchronization of estrus or ovulation and use of artificial insemination (AI) in heifers 30 days prior to the start of the cow's breeding season is recommended. With a well-managed synchronization program, >50% should become pregnant. Consequently, they will calve early and have a longer interval to recover. A good program should employ heifer selection based on body weight, reproductive tract development and pelvic area.[10]

Producing replacement heifers within a commercial beef cow herd cannot be achieved in all situations. Unfortunately, there is a conflict between growth characteristics of the terminal generation and maternal characteristics necessary for optimal heifer replacements. To prevent genetics of the cow herd from becoming progressively more dominated by those of the terminal sire breeds, a crisscross mating system has been recommended.[11,12] The essential element is that bulls from two breeds with complementary characteristics are used. Female offspring from one breed are then mated to bulls of the other breed. Consequently, such herds have groups of cows that must be managed separately at breeding, which can be difficult in herds with <150 cows. Consequently, smaller herds may have to purchase breeding replacements and forego biosecurity advantages offered by a closed herd.

When purchasing replacement heifers, it is important to ensure that they are purchased at an optimal time and bodyweight that will allow them to reach the target bodyweight of 55 to 65% of mature weight at the onset of the mating season. Irrespective of which heifer program is followed, it is vital that both virgin and first-calf heifers receive preferential nutritional management to ensure they continue to grow and achieve the target body condition score at calving. Older cows in poor body condition can be included in this group for feeding.

Nutritional management of cows

Feed accounts for the largest percentage of input costs in both cow-calf and stocker operations.[13] Nutritional needs of beef cattle differ by age, weight, production stage and performance. Physiological and environmental stressors may also impact nutritional requirements. It is imperative to understand beef cattle nutrient requirements for designing an effective and efficient grazing and supplementation program. Comprehensive beef cattle nutrient requirements and ration formulation are available.[14-17]

A cow requires energy for eating, moving, fetal development, milk production, temperature maintenance, reproduction, etc. In addition, first- and second-calf cows require additional energy for growth until they mature. Factors that influence energy requirements are: body weight, rate of gain, lactation, and fetal development. Lactation represents the greatest need for additional energy beyond that needed for maintenance. On average, a lactating beef cow requires nearly 50% more net energy than she does when nonlactating.

First-calf heifers represent a special challenge to maintain successful reproductive performance. Their postpartum energy requirements exceed those of mature cows, because energy is needed for growth, in addition to body maintenance and lactation. Inadequate energy during the last third of gestation and from calving to rebreeding can prolong anestrus (on average, they take longer than mature cows to resume cyclicity). In addition to demands that all beef cows have, these heifers are continuing to grow, but they have less body capacity and therefore consume less energy when fed high-roughage rations. Consequently, without special management considerations, an excessive number of these heifers are likely to be culled for reproductive inefficiency when they fail to conceive during a controlled breeding season.

Body size affects energy requirements; as expected, large cows require more energy than small cows. For example, a 1,300 lb nonlactating pregnant cow in the middle third of pregnancy requires 32% more net energy than a 900 lb cow at the same stage of production.

A net energy deficit delays return to ovarian cyclicity; this can be either due to a failure to match nutritional input to production requirements and/or poor quality diet. For beef cows, the critical measure of nutritional adequacy is body condition score at calving. A system of scoring cows for body condition based on examination of the spine, short ribs and appearance of the tail head area has been developed (Table 2). Cows calving below target body condition score for the production system often have a delayed return to cyclicity, which is difficult to overcome with dietary manipulation immediately before or after calving or during the breeding season. In the US, the target condition score for beef cows at calving is 5, on a scale of 1 (emaciated) to 9 (obese). At breeding, they should be in moderate to good condition (5 to 7 BCS). Influence of body condition on estrus expression, and AI and breeding season pregnancy rates are shown (Figure 1).

Prevention of dystocia

High rates of dystocia will delay conception and an increase percentage of cows not pregnant at the end of a restricted breeding season. Dystocia also has an adverse effect on calf survival. The benchmark for dystocia in a beef farm is ≤ 3%; therefore, reducing the incidence of this condition is vital. Rates of dystocia are highest in beef heifers and thereafter decline with age, indicating the importance of fetal-maternal disproportion.[18,19] A heifer selection program based on bodyweight and pelvimetry (pelvic area measurement) will be beneficial, but is not a complete solution.[20] Paternal influence on dystocia can be managed by careful bull selection based on expected progeny difference (EPD). The EPD is a prediction of how future progeny of each animal are expected to perform relative to progeny of other animals in the database, expressed in units of measure for a trait (plus or minus). For example, to reduce dystocia, bulls with a negative EPD for gestation length and a positive EPD for calving ease should be selected. Gestation length EPD predicts difference in gestation length (in days) for progeny of a bull. Bulls with lower gestation length EPDs are expected to sire calves that are born earlier. In that regard, shorter gestation lengths are associated with slight decreases in birth weights and improvements in calving ease. Breeds that report EPDs for both calving ease and gestation length generally include effects of gestation length in calving ease EPD. Calving ease EPD is reported as deviations in percentage of unassisted births. In the above example, if Bulls A (0) and B (+5) were mated to the same set of heifers, we would expect heifers bred to Bull B to have 5% more unassisted births. In other words, we would expect fewer calving problems when Bull B was mated to heifers. By using AI in the heifer program, more extreme bulls can be selected for the greatest effect. This principle should also be applied, albeit to a lesser degree, when selecting bulls for cows. It should be noted that selection of sires should focus on other economically important traits other than calving ease in order to maintain a balance.

Management and assessment of bull fertility

The minimum standard used to define a bull as fertile is the one that is expected to get 90% of 50 normal cycling disease-free females pregnant within nine weeks and 60% of these should be pregnant within the first three weeks after the onset of bull exposure. The emphasis is on the minimum standard and many bulls achieve the same or a better result with more cows. This is in contrast to the longstanding advice that one bull should be mated with 25 cows.[21] The reason for this difference in approach can be related to the often-quoted figure that one in five bulls is subfertile.[22] Therefore, by recommending a group size well below the potential of a fertile bull, a subfertile bull has more chance of being accommodated. However, with subfertility being so prevalent, it is likely that at least several bulls and, in some cases, most or all bulls will be subfertile in many bull batteries. Rotation of bulls every three weeks between breeding groups is commonly practiced, but further obscures effects of subfertile bulls on herd productivity. However, this inefficiency can be reduced by conducting breeding soundness examinations on the bull battery each year prior to the breeding season, removing infertile bulls and perhaps exposing subfertile bulls to fewer cows.

Semen evaluation is a critical part of the breeding soundness examination. However, facilities on most farms are not suitable for using an artificial vagina to collect semen. Fortunately, electroejaculation has been refined and is now well tolerated by most bulls. Semen evaluation using electroejaculation along with a clinical examination can usually be completed within eight to ten minutes per bull. Although it is not commonly done, assessment of libido and service action on restrained, estrous cows, provides further information regarding breeding potential. Consequently, it is suggested that bulls that have not been tested for libido and serving capacity should be restricted to 25 cows, whereas bulls that meet standards can be exposed to up to 50 cows.[23] Notwithstanding, even bulls that have met standards before the breeding season can become lame or have reduced fertility during the breeding season. Observation of the breeding activity of bulls is therefore important. For herds with an established nine-week breeding season, >80% of cows should be bred in the first three weeks and no more than 40% in the second three weeks. Observations not consistent with these standards should prompt re-evaluation of bull fertility and appropriate corrective action.

Indices of reproductive performance

Production indices are essential to properly assess reproductive performance in beef herds. The single most important denominator is the number of females that are bred; thereafter, the number of cows not pregnant at pregnancy diagnosis, abort, or produce a stillborn calf, or give birth to a live calf, can be compared to this denominator. Analyses should be subdivided into separate groups for heifers, first calvers, and mature cows. Thereafter, the second denominator is the number of breeding females that calve. Again this also can be subdivided by parity. Number of females that produce a stillborn calf, suffer from dystocia or have a calf that dies within 48 hours can be divide by this denominator.

Describing distribution of cows calving in relation to the breeding season is not as straightforward as it would seem. The start of the calving season starts, on average, 285 days after the bulls are exposed to cows (average gestation length for beef breeds). However, there is a natural variation in gestation length of ~10 days, even for cows mated to the same bull; therefore, all cows calving before the expected date are included in the first period. The second period commences 21 days later (which is the mean length of the estrous period) and the third 42 days later. This methodology inflates the number of cows estimated to be conceiving in the first three weeks, but providing it is consistently applied, meaningful data can still be generated.

Targets for reproductive performance

The benchmark figure for reproductive performance in beef cow herds in North American production system is 95 cows pregnant per 100 cows mated. To achieve this, it is clear that every factor must be well managed. Benchmark figures are outlined in Table 3.[24,25]

Investigative strategy

Investigating infertility in the beef herd can appear daunting. Compared to dairy cattle, there is often no or poor records and, in most cases, the breeding season is over before the problem is recognized. A common response is to screen for infectious disease or assess trace element status (typically by collecting liver or blood samples in a subgroup of females and males) or evaluate breeding potential of bulls. However, an approach focused on these aspects is likely to yield little useful information, and may result in inappropriate advice.

The preferred approach is to carry out a full herd reproductive evaluation in a systematic manner to minimize missing important factors. The key to resolving many fertility problems lies in details of the previous calving season; therefore, this should be the starting point for any investigation. Basic information required for an investigation includes calving dates from the previous calving season and pregnancy diagnosis data from the previous breeding season (for each breeding group). Most producers record this information. Collection of data in an appropriate format should be delegated to the producer, but can be facilitated by providing appropriate tables.

Information required for each separate breeding group is:

Pregnancy rate per cow exposed (based on pregnancy data)
Length of current breeding season (i.e., one under investigation)
Length of previous calving season

Length of previous breeding season (bull entry to bull exit)
Calving distribution (by date) of previous season
Number of calvings for each 3-week period of previous season
Number of assisted calvings in previous season
Age distribution of herd
Number of bulls used, their ages, and EPD if available

Nonpregnant cow investigation

The distribution of nonpregnant cows should be compared to that of pregnant cows on the basis of age, degree of dystocia (current and previous calving), body condition[26,27] and temperament.[28,29] A breed comparison should also be done to establish whether the herd is comprised of more than one breed of cows. This is readily achieved if tables are kept simple and distributions are expressed as a percentage. In Excel, a pivot table may be used to explore this (https://www.youtube.com/watch?v=Vx-Fuw46VbY). Where doubt remains over the significance of any observed difference, a Chi-square test (http://vassarstats.net/tab2x2.html) should be used.

Nonpregnant cows are frequently over-represented by the following:

Young or old
Cows that calved towards the end of the calving season
Cows assisted at calving
Cows with poor body condition
Cows with an excitable temperament

A comprehensive program review should be performed when there are too many young cows in the nonpregnant group; information regarding their body weight, reproductive tract scores,[30] pelvic measurements, and vaccination and breeding programs should be evaluated. However, if bovine virus diarrhea (BVD) or venereal diseases (trichomoniasis and/or campylobacteriosis) is endemic in a herd, heifers and first-calvers are also predominantly affected. Trace mineral status of sub groups of females and males (liver or blood samples) should also be investigated.[31] (It is suggested 10 to 15% of herd or animal populations should be sampled for screening. For accurate sample size calculations refer to Reference[32] and http://epitools.ausvet.com.au/content.php?page=SurveyToolbox). Excessive numbers of old cows indicate that the replacement strategy should be reviewed. Over-representation of cows that calved late in the season points either to a failure to achieve the target body condition score at calving[26,27] or to provide an adequate plane of nutrition after calving. If none of the above apply, then the following should be suspected: bull infertility, recent introduction of BVD or venereal diseases to a naive herd, or involvement of toxins.

Bull battery evaluation

A bull battery evaluation is simply an assessment of the cow to bull ratio in the breeding groups by age of bulls. Health and previous fertility record of bulls is also relevant. At this initial stage, a clinical examination of all breeding bulls should be done to ensure that they are not lame and have normal external genitalia. History of testing for and/or vaccination against venereal diseases should be included.

Biosecurity

Protecting cattle from infectious disease is generally cost-effective. Biosecurity involves management practices that prevent diseases from infecting a herd. Beef operation biosecurity centers around preventing introduction of disease into the operation and developing adequate herd immunity. A biosecurity inspection focuses on animals added to a herd (whether bulls are purchased, rented or shared) and whether animals are grazed on community pastures.[24] Farm boundaries are also important considerations, as heifers or bulls commonly break into or out of premises.[27] On farms that use reproductive technologies such as AI and embryo transfer, sources of semen/embryos should also be recorded. Records of vehicle and personnel entry should be maintained.[33]

For successful biosecurity measures, beef producers should be advised to:

- Properly identify cattle and maintain accurate and complete records.
- Monitor cattle for adverse health symptoms or behavior.
- Test and remove animals that harbor certain diseases (e.g. Johne's, trichomoniasis or BVD). If these animals are not removed, they can shed these pathogens and infect other animals.
- Minimize contact with wildlife that may harbor disease.
- Disinfect/sterilize reusable equipment.
- Develop a carcass disposal plan.
- Minimize fecal and urine contamination of feed and water sources.
- Control pest populations and limit access to feeds.
- Create an emergency contact list of community resource people.

Health and nutrition status assessment

A health and nutrition investigation covers vaccination history and any diagnostic testing during the previous two years. The ration in the past year should also be considered, particularly with regard to pattern of feeding and the adequacy of energy and protein provision. Securing a good history of nutritional provision can be a major challenge. However, analysis of the ongoing nutrition in an operation can often elucidate routine management errors that negatively affect reproductive performance. Deficiencies of energy and protein have major effects on reproductive outcomes.[34] Energy nutrition has been documented to influence beef cow pregnancy rates in two ways. Long-term energy balance is the major determinant of body condition score which has been extensively researched and exerts a major influence on return to cyclicity postpartum.[35]

A report on the nutritional outcomes of medium sized (1,175 pounds) cows that were fed rations (hay) with three different nutritional characteristics showed different energy and protein balances during breeding times (60 and 90 days after calving).[36] Table 4 show cows fed rations with 50 % TDN and 7.9 % crude protein are in both negative energy and protein balance during this critical time; cows fed rations with 60 % TDN and 7.8 % crude protein rations are about neutral for energy and protein; cows fed rations with a 70 % TDN and 9.1 % crude protein ration are in positive protein and energy balances.

Energy and protein values of feeds, especially forages, can only be accurately known if feed analysis is conducted. There is much more variation in the nutrient values of forages than concentrates so using book values will result in large errors in estimating forage quality. Correct procedures for feed sampling and storage prior to analysis are crucial. For hay sampling, bale corers and sampling a random group of bales must be used in order to get a true estimate of the nutritional value of forages.

Trace element supplementation should be examined in the light of the history of trace element problems in the herd or area. Trace element supplementation is a complex subject and evaluation should include copper, zinc, manganese, iodine, cobalt, and selenium. Furthermore, minerals interact with each other, antagonistically or synergistically (directly, or indirectly via other elements such as minerals or hormones) and such interactions should be anticipated during supplementation.[37]

Assessment of reproductive technologies used in beef herds

Artificial insemination

Although AI is much more widely used in the dairy industry compared to the beef industry, its use in beef cattle has increased in recent years. Historically, detection of estrus was done to determine when to inseminate. Commercially available prostaglandins create a means to induce luteolysis, provided cattle are cycling and at the appropriate stage of the estrous cycle. A major challenge with prostaglandins alone for synchronization is that the interval from treatment to estrus/ovulation is variable.[38-40] However, there are current protocols that control ovarian follicular development and luteal function, resulting in reasonably synchronous ovulation in a high percentage of cattle, with acceptable fertility (often 50 to

60%) to fixed-time insemination.[41-43] With ongoing improvements in reliable characterization of genetic merit in beef cattle, AI facilitates introduction of specific genetics (e.g. calving ease sire for heifers, good maternal characteristics for generating future brood cows, and specific feedlot performance and carcass characteristics for production of feeder cattle). Many current progesterone-based synchronization protocols for fixed-time AI will achieve a satisfactory pregnancy rate in pre-pubertal heifers and anestrus postpartum cows that are close to spontaneous ovulation. In addition to commercial frozen semen, cattle can be inseminated with fresh semen,[44] including semen collected from one or more herd sires, or semen can be collected on-farm and frozen. In that regard, minimal specialized equipment is needed to successfully collect, extend and freeze bull semen and achieve good fertility. In case of reduced success of AI program, estrous and synchronization programs, semen handling and insemination techniques, body condition and temperament of cattle should be evaluated. As mentioned earlier, the investigation should also include screening for reproductive diseases and evaluating mineral status of the cattle.

Sexed semen

The technology to produce gender-selected semen has improved dramatically, facilitating large shifts in gender ratios.[45] Gender-selected semen is much more widely used in the dairy industry, but gender-selected beef semen is becoming more widely available, and producers are starting to use this technology. The broadest use for gender-selected semen in cow-calf production is to produce maternal lines to be mated to terminal lines (using X- and Y-sorted sperm, respectively). Furthermore, with artificial insemination and bull selection, a producer could create a marketing advantage by generating uniform market steers with specific characteristics. Seed-stock applications include using Y-sorted semen for bull production and X-sorted semen for replacement heifer production or enhancing female lines.

Currently, the only practical, proven method for producing gender-selected semen is flow cytometry to exploit the small difference in DNA content between X and Y chromosomes.[46] Despite substantial development and refinement, sperm sorting remains relatively slow and inefficient. Therefore, insemination of a suboptimal number of ~2 million gender-selected sperm is commonly used as a compromise between cost and acceptable conception rate.[47] In addition, the sorting procedure inflicts damage to sperm, especially to the DNA.[46,48,49] As a consequence of both a suboptimal dose and damage to sperm, conception rate with frozen gender-selected semen is typically 70 to 80% of that from conventional semen at the typical dose rate.[45,46] Furthermore, due to the uncompensable nature of sperm damage, the reduction in conception rate cannot be fully overcome by increasing insemination dose.[50,51] Unfortunately, reduced fertility with frozen gender-selected semen in seasonal production systems is directly at odds with cows needing to conceive within a short interval. Improvements in fertility would make gender selected sperm more appealing. Freezing and thawing damage sperm, with more profound effects on gender-selected sperm.[52,53] In dairy cattle, the fertility of liquid (never frozen) gender-selected semen was >94% that of conventional semen, a two-fold efficiency gain relative to frozen, gender-selected semen.[54] Seasonal beef production systems with short breeding periods would enable the benefits offered by liquid gender-selected semen to be efficiently exploited. However, it should be noted that success in terms of pregnancy and sex ratio varies depending upon breeding management (Table 5).

Embryo technologies and application of genomics

Embryo transfer involves harvesting one or more embryos from a donor female and transferring them to recipient females. The primary reason most cattle producers utilize embryo transfer is to enhance genetic improvement in their herds. By collecting embryos from genetically elite females and transferring the harvested embryos into females of lesser genetic merit, it is possible to produce more calves from genetically superior females and fewer calves from genetically less valuable females. The result is an increase in the rate of genetic improvement. Transfer of embryos harvested from genetically elite donor females also enables those genetically elite females to produce more calves in a single year than they would produce in their normal reproductive lifetime.

Currently, embryo recovery and transfer are done nonsurgically.[55] Improvements in protocols for superovulation of donors and synchronization of recipients have made this technology economical, and increased efficiency and availablity.[56] Furthermore, advances in embryo freezing have facilitated global distribution of frozen embryos and the ability to implant them under field conditions. One limitation of embryo transfer is that the interval between successive superovulation and embryo collections is a minimum of ~ four to eight weeks.[56] However, with ultrasonographic imaging and transvaginal aspiration of ovarian follicles (ovum pick up; OPU), oocytes can be retrieved every few days (in cycling, nonpregnant cattle, but even from pre-pubertal heifers and cows prior to mid-pregnancy) and fertilized in vitro, enabling production of large numbers of embryos in a short interval.[57] This technology has great potential. A number of private companies and some embryo transfer firms have added this procedure to their list of commercially available services. The thrust for using these procedures in beef cattle include producing hundreds of offspring from a single genetically superior female, producing embryos from prepubertal or pregnant females, producing offspring from clinically infertile females, and ultimately obtaining more productive livestock at a lower cost.

Advances in genomics have led to identification of genes or markers associated with genes that influence traits. In association with classical genetic selection, genomics can be used to promote genetic improvement in cattle. Female reproductive technologies could be readily combined with genomic selection in beef cattle breeding programs.[58] Depending on goals of the beef operation, application of these technologies may differ. With genomics technology, breeding females could be categorized as top 20%, middle 50% and bottom 30%, with these groups designated for embryo production, breeding (AI or natural service) and embryo recipients, respectively. In general, the genomic application should be focused on improving production parameters that are economically important. Further the application should focus on improving reproductive performance, minimizing reproductive losses, and disease resistance.

Investigation of success of embryo transfer

There are numerous factors influence the success of embryo transfer. Even though several factors are beyond the control of the practitioner, the most important factor affecting the success is management of donors and recipients. Breed, age, nutritional status, and reproductive history of donors and recipients, superovulation treatment of donors and synchronization treatment of recipients, hormones and drugs used, timing of insemination, method of collection and transfer, stress and biosecurity are some factors that influence the success. Individual variation among females in response to superovulation remains the largest and least understood variable. Some females consistently produce large numbers of embryos in response to superovulation, while other female cohort perform poorly. Superovulation success is related to parity, virgin heifers and cows > eight years of age produce fewer embryos. Elevated temperature-humidity index are detrimental to superovualtion success. Thin cows produced fewer transferable embryos compared to cows with moderate to good body conditions. Cows in poor metabolic status (abnormal non-esterified fatty acid or blood urea nitrogen concentrations) had fewer transferable embryos. Increased pregnancy losses associated with in vitro produced (IVP) embryos, increased risk of omphalophlebitis/arteritis in IVP calves, and the wide range of birth weights (some excessively large) of IVP calves should also be evaluated. A practitioner could make a meaningful contribution to improve success by providing advice on donor and recipient selection and better management options.

Focused investigation

Focused investigation is warranted in poor reproductive performance of a beef operation. This may include one or more of the following:

Bull breeding soundness examination (for all bulls);

Screening for infectious disease (e.g., venereal diseases, BVD, infectious bovine rhinotracheitis, *Leptospira borgpetersenii serovar hardjo type hardjo-bovis*);

Review of nutritional management (e.g. ration and trace mineral evaluation and analysis, feeding groups and current body condition).

Determination of potential exposure to toxins

Report

Once the investigation is complete, it should be possible to identify a specific problem or at least narrow down the investigation to allow a more focused review. Finally, based on findings, a report for producers is prepared, including suggestions for changes in management. It should be noted that the report should include economic advantages of the management plan, as this is a key element that will convince the producer to implement changes detailed in the report.

Key actions for success

Continued success is vital for long term viability of a beef operation. In order for continued success it is important that required outcomes are achieved. Key action for success includes:

- Evaluate current performance of your client's herd
- Set clear and achievable goals and objectives for your clients
- Explore alternative strategies, evaluate benefits, feasibility and risks, prioritize and recommend the best options
- Implement the new strategy, maintain accurate records and regularly re-evaluate performance with expected targets

Future directions

It is predicted that world's population will reach 9.1 billion, 34% more than today and 70% of the world's population will be urban compared to 49% today.[59,60] In order to feed this larger, more urban and affluent population, food production must increase by 70%. Meat production will need to rise by >200 million tons to reach 470 million tons.[59,60]

In comparison to the past 50 years, the rate at which pressures are building up on natural resources such as land, water, and biodiversity, will be increased during the next 50 years.[61] Furthermore, much of the natural resource base already in use worldwide shows worrying signs of degradation. The surge in livestock production that took place over the last 40 years resulted largely from an increase in the overall number of animals being raised. It is hard to envisage meeting projected demand using the same level of natural resources currently available. Regardless, increases in production will need to come from improvements in efficiency of livestock systems in converting natural resources into food and reducing waste. Veterinary input will be essential to develop systems and knowledge that will continuously improve production.

The beef industry is a moving target. Cattle owners have to balance their focus on management, genomics and biosecurity. Farm animal genomics is of interest currently because of the usefulness derived from understanding how genomics and proteomics function in various organisms. Genetic improvement in cattle populations mainly involves selection of males and females that, when mated, are expected to produce progeny that perform better than the average of the current generation. Applications such as increased livestock productivity is one of several reasons that farm animal genome activity is thriving. Given current genomic advancement, perhaps the top 10% of cattle today would only be the average in the next 10 to 20 years. Consequently, it is critical to have knowledge of genomic applications and how targeted selection could improve economically important traits.

The future of agriculture and the ability of the world food system to ensure food security for a growing world population are closely tied to improved stewardship of natural resources. Major changes and investments are needed in all regions to cope with rising scarcity and degradation of land, water and biodiversity and with added pressures resulting from climate change and energy demands. The encouraging signs are: the beef industry today uses significantly less water and land than 30 years ago to produce each pound of beef; the industry has also reduced its carbon footprint by 16.3% for every 10^9 kg of beef produced.[62] In addition, since 1992, the U.S. beef cow and overall beef cattle inventories have continually dropped an average of 1 to 1.25% annually,[63] meaning more pounds of beef produced with fewer numbers of cattle, due to advances in pharmaceuticals, reproductive management, genetics and nutrition. Clearly, comprehensive knowledge on reduced use of resources and reducing carbon footprint of the beef operation without affecting production is important.

Conclusions

The approach described above can be used to provide routine services for reproductive management of the beef herd. Data are collected and analyzed at pregnancy diagnosis and compared to set targets, with nutritional management and body condition scores concurrently reviewed. The bull battery should be examined at least one month prior to the start of the breeding season. Appropriate monitoring and intervention will help herds achieve performance targets.

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Table 1. Beef performance records

Birth	Weaning	Yearling	Health	*Reproductive*
Birth Weight *Birth date* *Sex* *Parentage* *Calving Ease* Color Markings Horned/Polled	*Weaning Weight* *Weaning date* *Hip Height or Frame* Environmental Management Code: - Contemporary Group - Creep Feeding - *Embryo Transfer*	*Yearling Weight* *Yearling Date* *Hip Height or Frame* *Pelvic Area* *Scrotal Circumference* *Reproductive Tract Score/Age at Puberty* Ultrasound (carcass)	*Vaccination dates* *Vaccine codes* *Health examination* Treatments Temperament *Preconditioning* Procedures Early weaning *Castrated* – Bunk trained – Dehorned	*Breeding dates* *Breeding Soundness Exams* *Pregnancy Rate* *Body Condition Score* *Temperament* *Cow age*

Parameters contributing to reproductive evaluation are in italics. To produce a comprehensive report, it is important to collect all required information.

Table 2. Characteristics of body condition scores

Score	**Category**	**Characteristics**
1,2	Thin	Spine and short ribs are sharp to the touch and can be distinguished visually.
3,4	Borderline	Processes of the spine can be identified individually by touch. They feel rounded--not sharp and spaces between processes are less pronounced.
5	Moderate	Processes can be felt with slight pressure and ends feel rounded. Spaces between processes can be distinguished only with firm pressure. Areas on either side of tail head are filled.
6,7	Good	Ends of the processes can be felt only with firm pressure. Spaces between processes cannot be distinguished at all. Abundant fat cover around tail head, with some patchiness.
8,9	Obese	Bone structure cannot be felt at all. Tail head is buried in fat.

Table 3. Benchmarks for beef herd reproductive performance

Parameter	Numerator	Denominator	Target (%)
Cyclicity rate*	Cycling cows	Total cows	>85
AI pregnancy rate	Cows pregnant to AI	Total cows inseminated	>50
Breeding season pregnancy rate	Cows pregnant during breeding season	Total cows exposed	>90
Abortion rate	Gestational losses	Total females pregnant	<2
Early calving rate	Cows calving in 1st 21-day period	Total cows calving	>65
Stillbirth rate	Perinatal loses	Total females calving	<2
Weaning rate	Weaned calves	Total females pregnant/calved	>85
Replacement rate	Replacement heifers	Total females pregnant	15

*At beginning of breeding season
References[22,23]

Table 4. Energy and protein balance for cows at typical rebreeding times (days 60 and 90 days after calving)

Ration	TDN % (DM)	Crude Protein % (DM)	Energy 60 d after calving (Mcal/d)	Energy 90 d after calving (Mcal/d)	Protein 60 d after calving (MP g/d)	Protein 90 d after calving (MP g/d)
A	50	7.9	-4.59	-3.31	-216	-136
B	60	7.8	0.47	1.69	-38	35
C	70	9.1	6.48	7.65	187	256

Reference [36]

Table 5. Sex-ratio following artificial insemination‡ at an observed estrus or at a fixed time using conventional or sexed (female) semen in beef heifers

Parameters	Estrus-AI		Fixed time AI	
	Conventional semen	Sexed semen	Conventional semen	Sexed semen
Number of heifers	100	100	100	100
Estrus detection rate (%)§	85	85	100	100
Conception rate (%)†	60	48	-	-
AI pregnancy rate	51	43	60	48
Sex-ratio from AI (Female: male)⌖	26:25	39:4	30:30	43:5
Remaining open heifers pregnant to clean-up bull❄	43	51	34	46
Sex-ratio from clean-up bull breeding	21:22	25:26	17:17	23:23
Total female: male calves (AI + clean-up bull breeding)	47:47	64:30	47:47	66:38

AI- artificial insemination;

Assumptions: ‡Beef cattle are artificially inseminated once and reminder of open cows are bred by clean-up bulls; §Estrus detection rate estrus-AI is 85% and for FTAI is 100%; †20% reduction in fertility for sexed semen; Note: Progesterone based estrus synchronization used for estrus AI. ⌖Sex ratio for conventional semen is 1:1 and for sexed semen is 9:1;❄Breeding season pregnancy rate is 94%.

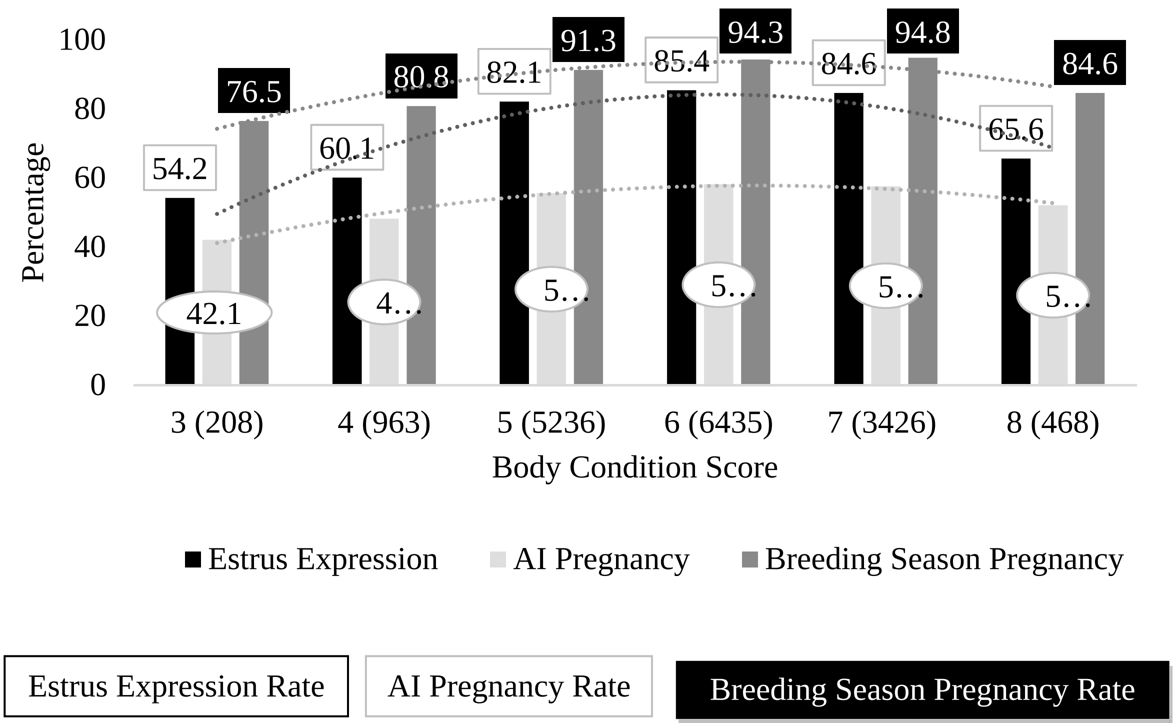

Figure 1. Influence of body condition score on estrus expression, AI pregnancy and breeding season pregnancy rates
Body condition score 1- emaciated; 9- obese;
'n' is given in parentheses;
Reference (22), updated data figure.
Dotted lines represent associations between body condition score and estrus expression, AI pregnancy and breeding season pregnancy (R^2=0.86, 0.97 and 0.89, respectively).