Evaluation of peripubertal replacement breeding animals in beef herds

by

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Abstract

The selection of young replacement animals can have a significant impact on beef herd reproductive performance. Replacement heifers can be utilized to improve reproductive performance by replacing mature animals that failed to meet the production with young, cycling heifers that can have the potential of improving the reproductive momentum of a herd. The use of yearling bulls in natural breeding herds has the advantage of shortening the generational interval of the herd and has the potential of reducing the cost per cow exposed as additions to the bull battery. This thesis involves two studies that investigated methods used for the selection of peripubertal replacement animals in beef herds. The first study evaluated the ability of the novel Ready-Intermediate-Problem (RIP) replacement heifer evaluation matrix to classify heifers into groups that allow producers to select for replacements that meet production goals.

Beef heifers (n=341) were classified according to the RIP matrix guidelines and then exposed to AI breeding, bull breeding, or a combination of both as per the management plans for each participating herd. Following breeding season the heifers were evaluated to determine pregnancy status, pregnancy status to single AI exposure, days bred, and the number of 21 day cycles needed during breeding season to become pregnant. After breeding season, 298 (87%) of the heifers were pregnant, 204 (68%) of which became pregnant in the first 21 days of the breeding season. Probability of overall pregnancy and pregnancy after single AI exposure was not significantly associated with RIP classification. There was a significant interaction in RIP classification by 21 day cycle.

The second study was a retrospective study using BSE result data to determine the proportion of yearling beef bulls that are classified as satisfactory potential breeders when reevaluated after failing their initial breeding soundness evaluation (BSE) and to identify any

predictive factors at initial BSE for satisfactory performance at revaluation. The study included 2,805 beef bulls between 11 and 14 months of age at first BSE evaluated at KABSU from 2006 to 2014. Generalized linear mixed models were created to assess potential associations among breed, age, and interaction between breed and age and passing the initial evaluation and identify predictive factors for risk of passing BSE after initial failure. The majority (93%) of the study bulls passed one of up to three BSEs. There was a significant interaction between age and breed of bull at initial BSE.

Identification of suitable peripubertal replacement animals that will improve herd reproductive performance remains a challenge for producers. There are several factors that can affect replacement animals' ability to perform according to expectations at the beginning of the breeding season. Classification of heifers into categories that can predict performance during breeding season with reasonable confidence can assist producers in identifying heifers that complement the reproductive performance goals of the herd. Utilizing BSE to identify bulls that have adequate semen quality as well as other traits important for breeding soundness is similarly important in reducing the risks of using young bulls for breeding.

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Chapter 1 - Thesis Introduction

The selection of young replacement animals can have a significant impact on beef herd reproductive performance. Replacement heifers can be utilized to improve reproductive performance by replacing mature animals that are not pregnant, not productive, or failed to meet the production goals and timeline of the producer with young, cycling heifers that can have the potential of improving the reproductive momentum of a herd. The use of yearling bulls in natural breeding herds has the advantage of shortening the generational interval for the genetic improvement of the herd and has the potential of reducing the cost per cow exposed compared to the purchase of older bulls as additions to the bull battery.[1,2] Selection of the appropriate replacement animals is paramount to be able to take advantage of these possible benefits of utilizing young replacements.

Well managed replacement heifer programs are essential to good reproductive efficiency in beef herds. The goal of a replacement heifer program is to bring new, productive animals into the herd that will take the place of non-productive or otherwise less-desirable cows. Beef producers are challenged with the risk of inconsistent yearling heifer reproductive efficiency that can negatively affect herd performance. Developing replacement heifers requires the allocation of scarce resources; therefore, using criteria to accurately evaluate reproductive potential of incoming breeding females is important.

Early recognition of heifers that are likely to have sub-optimal reproductive performance will improve the efficiency of replacement heifer management. Heifers that are not likely to become pregnant early in the breeding season are not desirable as replacements. In addition, heifers that have an increased risk of dystocia due to small size or abnormal pelvic shape are also at risk of sub-optimal reproductive performance. Ideally, heifer evaluation should contribute both to the identification of heifers that will negatively affect the herd reproductive efficiency as well as heifers that will perform superiorly due to their physiologic readiness for pregnancy at the beginning of the breeding season and physical conformation that is not associated with increased risk of dystocia. There are several methods that have been described which attempt to identify the population of heifers that should not be used in heifer replacement programs as well as the heifers that should be superior additions in a heifer replacement program.[3-14] However, lack of repeatability, inconvenience, and complexity may limit the widespread use and interpretation of some methods of evaluation.

A study in this thesis (Chapter 3) evaluated a novel, management-driven matrix that combines the evaluation of body condition, percent mature body weight, reproductive tract score, and pelvic area together to describe the well-being and readiness for breeding of heifers evaluated. The Ready-Intermediate-Problem system is a matrix designed as an efficient monitoring step to help veterinarians and producers manage and reduce yearling heifer reproductive inefficiency and thus improve herd reproductive performance. The system uses BCS, percent mature body weight, reproductive organ traits, pelvic area and pelvic shape to classify potential replacement heifers into one of three classifications that will predict their ability to add to herd reproductive performance by becoming pregnant early in breeding season, having a decreased risk of calving difficulty if bred to an appropriate bull, and having a short intercalving interval.

The final classification will be useful for augmenting current management decisions. The heifers that are classified as “Ready” (R) are deemed suitable for immediate enrollment in AI programs. The heifers classified as “Intermediate” (I) are suitable replacement heifers but may not be suitable for enrollment in an AI program and depending on the management goals of the producer, may be better suited to a pasture breeding system. The heifers classified as “Problem” (P) are not at high risk for not being suitable replacement heifers.

As part of this thesis the RIP system’s ability to be an accurate and repeatable tool to classify heifers into groups that will allow producers to select for replacements that will meet production goals was evaluated. Heifers classified using the RIP system should express different reproductive efficiency outcomes based on their classifications. The outcomes measured were pregnancy to AI breeding, pregnancy in the first 21 days of breeding season, pregnancy by 21 day cycle, and overall pregnancy percentage. It was hypothesized that Ready and Intermediate classified heifers would outperform Problem classified heifers for all outcomes; Ready heifers would be superior to Intermediate and Problem heifers in AI program performance; and more Ready classified heifers would become pregnant in the first 21 day cycle than the Intermediate and Problem heifers.

Appropriate bull selection is also an important component of herd improvement through introducing desired genetics and enhancing herd reproductive performance. Both the ability of a bull to transfer desired genetics and to support optimum herd reproductive performance are dependent on the fertility of the bull. Many herds have started to use bulls younger than 18 to 24 months of age in an effort to shorten generation interval, reduce risk of transmission of venereal disease to cows, and reduce cost per cow exposed. The use of younger bulls can result in decreased herd reproductive performance if the bulls are not sufficiently sexually mature. Young bulls are hypothesized to be less efficient due to inexperience, unknown or decreased libido, and potentially less than desirable semen quantity and quality due to immaturity.[15-23] Performing (BSE) before sale or use of young bulls is a useful way to identify bulls that have adequate semen quality as well as other traits important for breeding soundness. Ideally the BSE of yearling bull cohorts should be scheduled when it would allow for the identification of bulls that may express the trait of delayed attainment of puberty, while at the same time a reasonable percentage of the candidate bulls are likely to pass the BSE. Ideal BSE scheduling can be a challenge because the BSE date and sale date are fixed but the bulls are born over a range of dates and the age at which a bull is able to pass a BSE is highly variable between individuals. In this thesis (Chapter 4), yearling bull was defined as a beef bull between the ages of 11 and 14 months at the time of initial BSE.

The primary objective of the retrospective study detailed in this thesis (Chapter 4) was to determine the proportion of yearling bulls not classified as satisfactory potential breeders during their initial BSE which were later classified as satisfactory in follow up evaluations. The study then sought to determine if age or breed play a role in the likelihood to fail the initial BSE and to create guidelines for the minimum age for Angus, Simmental, and Charolais bulls in the study population to be evaluated for breeding soundness with the expectation of sufficient sexual maturity to pass a BSE. A secondary objective was to identify significant factors that could predict future risk of passing the BSE after failing the initial evaluation.

Chapter 2 - Review of Literature

Replacement heifer management

Replacement heifer management is an important part of maintaining a beef herd with good reproductive efficiency. The goal of a replacement heifer program is to bring new, productive animals into the herd that will take the place of older, non-productive cows. Beef producers are constantly challenged with inconsistent yearling heifer reproductive efficiency that can negatively affect their herd's performance. Developing replacement heifers can be expensive; therefore, using criteria to evaluate the reproductive potential of incoming breeding females is important. Early recognition of heifers that will perform sub-optimally as replacement heifers can prevent the use of heifers that will adversely affect a beef producer. Undesirable heifers are would slow herd momentum because they are not physiologically prepared to become pregnant at the beginning at the heifer breeding season. Producers also need to identify heifers that have an increased risk of dystocia due to small size or abnormal pelvic shape. Ideally, producers should have a tool that will enable them to not only remove these heifers that will negatively affect the herd reproductive efficiency but should allow them to select for heifers that will perform superiorly due to their maturity, physiologic readiness for pregnancy at the beginning of the breeding season, and physical conformation that is not associated with increased risk of pregnancy. There are several methods that have been individually developed which attempt to identify the population of heifers that should not be used in heifer replacement programs as well as the heifers that should be superior additions in a heifer replacement program. However, the variability and complexity of these different systems complicates their widespread use and interpretation.

Heifer onset of puberty

Puberty in heifers is reached when the heifer expresses estrous behavior and is able to ovulate a fertile oocyte. The three main drivers of pubertal onset in heifers are age, breed, and body weight. Age and body weight can be viewed as a threshold whereas, heifers over the minimum threshold are more likely to cycle, but the percent cycling does not linearly improve as days of age or body weight increases above the threshold. Breed influences the weight and age thresholds.[24] Heifers are expected to reach puberty at 55-60% of their mature body weight in *Bos taurus* breeds and 65% of their mature body weight in *Bos indicus* breeds.[25-27] Meeting the target weight can be important for heifer fertility and production.[28] Heifers exhibit significantly higher conception rates on their third estrus compared to their pubertal estrus.[27,29] Ideally heifers will reach puberty one to three months prior to breeding to ensure that they are cycling and have a high potential fertility. Nutritional management has significant impact on the age at which heifers reach puberty.[30] If evaluation of heifers for suitability as replacements is done less than 6 weeks before breeding then there is no time remaining to adjust nutrition so that small heifers have a chance to reach ideal potential fertility before exposure and the heifers need to be 55-65% of their mature body weight at the time of evaluation.

Body Condition Scoring (BCS)

Body condition score (BCS) is also an important tool for those managing replacement heifers. This visual body condition evaluation system uses numerical classifications 1 through 9 to categorize the condition of cows from emaciated (classification 1) to good (classification 6) to obese (classification 9).[31] BCS pre-calving has been correlated with peripartum interval, services per conception, calving interval, milk production, calf weaning weight, calving difficulty, and calf survival.[32] Heifer first-service conception rates improve as body condition score increases up to classification 6.[28]

Pelvic measurement

Pelvic area measurement has been used for over four decades as a way to identify heifers with an increased risk of dystocia due to a small or misshaped pelvis.[33-35] Pelvic area is obtained by using a pelvimeter via transrectal palpation to obtain measurements in the birth canal of the vertical distance between the backbone and the floor of the pelvis at midsacrum and the horizontal distance between the shafts of the ilia perpendicular to the vertical measurement. These two measurements are then multiplied to get the pelvic area.[36] The correlation between yearling and two year old pelvic areas is 0.70.[34] Yearling pelvic area measurement can be used to predict size of the pelvis at parturition and can be useful to identify heifers that should be culled for not meeting a minimum standard or having a misshapen pelvis.[5,24] Using pelvic area alone for selection of replacement heifers does not significantly decrease the incidence of dystocia and is a poor predictor of calving difficulty.[37,38] Pelvic area measurement should be used in concert with other information designed to evaluate heifers for suitability as replacement heifers.

Reproductive tract scoring

The conventional reproductive tract scoring (RTS) system is a 5 category classification system developed in the early 1990s at CSU as a tool for producers to use to make replacement heifer decisions. The system estimates pubertal status and can be used to evaluate heifer development and time breeding synchronization programs. This is accomplished by transrectal palpation and evaluation of the uterine horns, ovaries, and ovarian structures. A 5 point scoring system is used to describe these findings. Heifers with a tract score of 1, 2, or 3 are considered prepubertal heifers while heifers with a score of 4 or 5 are considered pubertal.[3] The RTS system was validated in 2003 as a repeatable and accurate tool to evaluate pubertal status in beef heifers.[39] However, due to the subjective nature of the RTS system, risk of misclassifying pubertal heifers as prepubertal can be high for evaluators that lack experience which can limit the ability to predict performance for heifers that have RTS classifications other than 1, especially if no other data are collected to aide in management decisions.[39] The RTS system only provides data on one aspect of heifer puberty and subsequent reproductive performance. In 2016, Holm published a study that showed using pelvic area measurement with RTS evaluation was more prognostic for poorly performing heifers than RTS alone.[11] The system, when used properly, has the potential ability to identify suboptimal heifers that should be culled prior to the breeding season. In 2009, Holm compared RTS score to other indicators of reproductive performance (body weight, age, BCS, and Kleiber ratio) to evaluate the system's potential use as a predictor of lifetime production of cows. The RTS system compared well with the other traits when the heifers were followed through their second breeding season.[12] In 2014, Holm published the results of a 7 year study designed to determine the ability of the RTS evaluation to predict long term reproductive performance in beef heifers. The study showed three levels of performance based on RTS classification. The heifers classified RTS 1 or 2 (prepubertal) were more likely to be in anestrus for the first 24 days of the breeding season independent of pre-breeding BW, age or BCS than those classified as RTS 4 or 5 (pubertal). They were also more likely to fail to become pregnant even after adjusting for the anestrus period, and had an increased risk of early reproductive failure compared to those classified as RTS 4 or 5. The heifers that were classified RTS 3 (peripubertal) did not perform significantly better or worse than the other RTS classifications of heifers overall. The RTS 3 heifers tended to have a higher incidence of 24 day anestrus during the breeding season than those classified as RTS 4 or 5 but also tended to calve earlier than those classified as RTS 1 or 2. The herd in the study had a strict culling policy based on reproductive failure and there were no differences in calving rates and days to calving between RTS categories in those that remained in the herd. The effect of RTS classification on long term reproductive performance was determined mostly by the outcome of the first breeding season with the second season having some effect as well. The study concluded that RTS was an appropriate tool for replacement heifer management if used to exclude heifers that are likely to or fail to become pregnant or calve late in the calving season.[9] Gutierrez evaluated the reproductive efficiency of heifers based on RTS score and showed that heifers with a higher RTS score were able to become pregnant earlier in the breeding season compared with heifers with a lower RTS score.[40]

Reproductive performance of heifers

Several researchers have shown that heifers calving early during their first breeding season will calve early during subsequent breeding seasons as well and will have increased lifetime production.[13,25,41-43] Cushman showed that heifers that are able to get pregnant early in the breeding season had better reproductive performance over six parturitions than those that got pregnant later in their first breeding season due to increased longevity in the herd compared to heifers that calved in the second 21 day period or later. The same study found that calving period as a heifer also significantly influenced the unadjusted weaning body weight of their first 6 calves.[43] A study by Funston and colleagues demonstrated that replacement beef heifers that were born in the first 21 days of the calving season had a higher likelihood of cycling at the beginning of the breeding season and that pregnancy rate decreased from 96% to 86% and 78% for the first to the second and third 21 day period of the spring calving season respectively.[44]

MacGregor et al. concluded that in restricted breeding season systems calving date is a suitable alternative to the more biased calving interval as a measure of beef cow reproductive performance.[41] Selecting cows to remain in the herd solely based on short calving interval can result in indirect selection for heifers with later pubertal onset and can penalize the cows that calve earliest in restricted breeding season systems. The use of calving date as a measure of breeding cow reproductive performance will encourage selection of cows that will calve early and have a sufficient post-partum anestrus period so they have increased risk of continually becoming pregnant early in the breeding season. Lesmeister et al. reported that heifers that conceive early demonstrate greater reproductive efficiency and tend to remain in early calving groups throughout their productive lives resulting in a higher average annual lifetime calf production.[25] Lesmeister et al. also reported that the repeatability of calving date was 0.105 which is higher than that of calving interval.[25] Therefore selection of heifers with ideal calving date performance will increase the likelihood that the performance will continue in the herd.

Yearling bulls

The use of young bulls for breeding has both benefits and risks. The use of yearling bulls shortens the generational interval and can result in more genetic improvement in the herd per year compared to the use of older bulls and also has the economic benefit of reducing bull cost per pregnancy.[1,45] This benefit is offset by fact that they are inexperienced and unproven, which can have variable and hard to predict consequences on herd reproductive performance.[45] Variability and poor reproductive performance by yearling bulls may be due partly to inadequacy in mating ability, however, semen quality and quantity are more important factors.[2,15,16]

Spermatogenesis

Understanding testicular development and spermatogenesis in bulls is important when managing yearling bulls and evaluating the prognosis of bulls with problematic spermiograms. Work by Evans and colleagues showed that between three and five months of age, follicle stimulating hormone (FSH) rises and initiates several physiologic processes that result in a surge in testis size.[46] A simultaneous rise in luteinizing hormone (LH) causes increased testosterone production.[46,47] Levels of FSH and LH then remain low between five and eight months of age until the onset of puberty. The greater the initial rise in LH at three to five months of age, the earlier the onset of puberty (and the larger the testis will be at a year of age).[46] There is evidence that calves that will mature later and have smaller testes at maturity have lower amounts of LH during the initial rise in LH and FSH secretion.[46] In studies of Holstein bulls, semen characteristics increased through 77 to 88 weeks of age and total volume and number of sperm in a week increased from 89 to 104 weeks of age.[48] Similar work by Curtis and Amann that detailed testicular development in Holstein bulls showed that anatomic development to enable spermatogenesis was completed by about 8 months of age at a testis weight ≥ 80 g (107-127 g) in holsteins.[49] The establishment of spermatogenesis in Holsteins was progressive over a period of four months and was associated with a greater than 4 fold increase in testis weight.[49] The transition from prepubertal to pubertal testes before the onset of puberty occurs between 4 and 6 months.[49] Testis sperm numbers in bulls are highly significantly correlated (0.62-0.97) with testis weight.[50,51] The incidence of sperm abnormalities decreased in a population of Angus bulls as scrotal circumference increased from 11 to 14 months.[52] At 14 months of age, bulls with SC ≤ 32 cm had more histologic testicular lesions and poorer seminal characteristics than bulls with SC > 32 cm.[52]

In a study that included 9 common beef breeds, the correlation coefficient between scrotal circumference at 1 year of age and paired testis weight and scrotal circumference at 2 years of age were 0.76 and 0.65, respectively.[53] At 1 year of age the paired testis weight that corresponds to a scrotal circumference of 33.5 cm in beef bulls is approximately 500 grams and increases linearly at 37-40 g/cm, although breed differences exist.[53] Based on these findings, Coulter and Keller concluded that scrotal circumference at 1 year of age of beef bulls can be used to aid in the selection of herd sires that would have above average testicular size and so would increase the probability of impregnating more females when under heavy breeding pressure.[53] Barth reported that testicular growth in well-fed beef bulls is almost linear between 7 and 12 months of age with a decline in growth after 12 months of age.[54] Scrotal circumference measurements at weaning may not be useful for bull selection, but measurements at 240 days of age may be useful for selecting Simmental, Charolais, Limousin, Saler, Hereford or Angus bulls with more the 80% likelihood of meeting the minimal SC at one year of age.[54] By 24 months of age, the testes of beef bulls will be approximately 90% of mature size.[55]

Bull onset of puberty

Identifying the probable onset of puberty in a cohort of beef bulls is important in the management of young bulls intended for use as herd sires. Onset of puberty has been defined as the first time ejaculate has at least 50 million sperm with at least 10% having progressive motility.[47,56,57] Bulls going through puberty have high numbers of a variety of sperm abnormalities including proximal droplets.[58] Lunstra has shown that completion of puberty, when the testes are fully functional and semen quality is consistent with adult levels (>60% motility and >70% morphologically normal), occurs 3-4 months after onset of puberty in beef bulls.[58] Onset of puberty in beef bulls occurs between 8 and 12 months of age.[56,57] Motility of sperm increases in the twelve weeks after puberty.[48]

Chase and colleagues looked at the effect of breed on growth and reproductive development and identified significant breed-by-age interactions in yearling beef bulls for body, testicular, skeletal, and pelvic growth traits.[59] Chase's study concluded that the breeds of bulls in the study population had different patterns of body, testicular, skeletal, and pelvic growth between 8 and 20 months of age.[59] Research on the reproductive development of yearling beef bulls cannot be applied across breeds without caution.

Variability in the onset of puberty in beef bulls, both among and within breeds, makes estimation of pubertal onset and completion in a cohort of young beef bulls difficult. The documented range of onset of puberty in Angus bulls in one study was 291-299 days of age. The same study reported the range of pubertal onset in Hereford bulls as

317-335 days. The range of pubertal onset in Hereford and Angus crosses in the same study was 287-308 days of age.[58] A similar study looking at the onset of puberty in bulls offered a high nutrient diet reported that Angus bulls attained puberty at 273-364 days of age and Herefords at 273-364 days of age.[57] The documented range of onset of puberty in charolais bulls is much wider at 231-371 days.[60]

Barth advocates selection of bulls for early puberty to increase the probability their usefulness as breeding bulls by 14-16 months of age.[2] Bulls that are not yet mature exhibit low sperm motility and a high percentage of abnormal spermatozoa.[61] The percentage of normal sperm heads, tails, and acrosomes increases as the number of proximal droplets reduces and coincides with an increase in sperm concentration during the first 3 to 4 months after the onset of puberty.[58] In Arteaga's study of 11 to 15 month old beef bulls only 20% of the bulls were considered mature at 11 months and 60% were considered mature at 15 months. Over all ages, 42% had mature spermiograms and 57% had $\geq$ 70% morphologically normal semen. In another study in Sweden, semen samples were collected postmortem from 142 beef bulls that were 11 to 13 months old and evaluated to establish the proportion of the bulls with mature spermiograms. The criteria in this study for the classification of mature spermiograms was <15% abnormal heads and <15% proximal droplets. Approximately 47% of the bulls in this study were considered mature using the defined criteria.[62]

Bulls with larger scrotal circumference measurements have an earlier onset of puberty and have satisfactory spermiograms earlier that bulls with smaller testicles.[56] A study by Lunstra and colleagues showed that scrotal circumference may be more appropriate than age or weight as an indicator of onset of puberty, regardless of breed.

The study included 31 bulls of various breeds including Angus, Angus-Hereford crosses, Brown Swiss, Hereford, Hereford-Angus crosses, and Red Poll. The mean age of puberty was 295, 296, 264, 326, 300, and 283 days respectively. Age at the onset of puberty varied by 62 days among breeds and 88 days among bulls. There were significant breed differences in age and body weight at onset of puberty, but breeds did not differ in scrotal circumference at onset of puberty. Scrotal circumference at onset of puberty averaged 27.9 ± 0.2 cm with a range of 25.9-30.1 cm.[56] Smith found that Santa Gertrudis bulls in Texas with SC less than 30 cm were correlated with a low percentage of mated pregnant females.[63]

Brito and colleagues investigated the association between average daily gain and body weight with age at onset of puberty, age when semen has satisfactory quality, scrotal circumference, paired-testes volume and weight, and several other parameters of spermatogenesis in a population of Angus and Angus x Charolais.[17] No significant association was found between average daily gain from 6 months to 16 months and any of the end points of interest. Brito and colleagues concluded that growth weight from weaning to sexual maturity did not affect sexual development and reproductive function in these bulls.[17] Body weight at various ages was negatively correlated with age at onset of puberty and age at satisfactory semen quality in both breed groups of bulls. Body weight was also positively correlated with paired-testes weight in both bull breed groups. The onset of puberty ranged from 280 to 339 days in this population of bulls. The semen quality improved with age and the interval from the onset of puberty and the study's definition of maturity (satisfactory semen quality) was approximately 7 weeks (maturity at 315-399 days). Age, weight, scrotal circumference, and paired-testes weight were all good predictors of pubertal and mature status with sensitivity of 71.6% and specificity of 92.4%. Improved nutrition and rate of gain might be beneficial as greater body weight was associated with reduced age at puberty and maturity and larger scrotal circumference at 16 months of age, but the nutrition must be offered before 6 months of age.[17]

Breeding soundness evaluation

Hopkins and Spitzer co-authored a review article in 1997 that discussed the 1993 revised Society for Theriogenology (SFT) breeding soundness evaluation (BSE) system. The BSE provides a systematic format for predicting potential fertility in natural mating situations and identifying problems that could potentially limit bull fertility.[64] The intent of the SFT BSE is to classify bulls as either satisfactory potential breeders or unsatisfactory for breeding using established baselines. The system is most effective in identifying low-fertility or sterile bulls but does not identify the bulls that may be the most fertile or most capable of high and efficient rates of calf output.[19,64] The BSE is still a quick and economical procedure to use for screening and selecting bulls before sale or breeding.[19] Limitations of the BSE include the fact that results are most valid at the time of examination, and the BSE does not attempt to accurately predict fertility.[19]

Components of a complete BSE include physical examination, reproductive examination, scrotal circumference indexed for age, and collection and examination of semen for estimation of sperm motility and classification of morphology based on differential counts of normal and abnormal sperm..[19,64,65] To be classified as “satisfactory potential breeders” bulls must pass the general physical and detailed reproductive exam and equal or exceed the minimal thresholds for scrotal circumference, semen motility, and semen morphology.[19,64,65] There are three categories recommended by the Society for

Theriogenology for classification of bulls after a complete BSE. Bulls are classified as satisfactory potential breeders if they meet or exceed the minimum requirements for scrotal circumference, sperm motility, and sperm morphology, and have no evident genetic, infectious, or structural defects that could compromise breeding or fertility. Bulls that fail to meet one or more threshold and are unlikely to improve are classified as unsatisfactory potential breeders. The “unsatisfactory potential breeder” category is intended for bulls that have genetic faults or physical defects that would compromise breeding or fertility as well. The decision deferred category is reserved for bulls that do not meet the requirements of either previously described category and might benefit from a reevaluation. Bulls with immature spermiograms and substandard semen profiles that might be capable of improvement are properly classified in this category. Bulls that do not provide satisfactory ejaculate for evaluation or extend to allow for examination of the penis or prepuce and bulls with treatable physical exam abnormalities also belong in the decision deferred category.[19]

To fulfill the physical exam requirement of the BSE, bulls should be observed at a distance for overall appearance, attitude, condition, and gait before being restrained in a chute. Once restrained, the bull’s identification should be verified and the eyes, limbs, and feet examined as well as any physical abnormalities such as limb or joint swellings, abnormal head or body carriage, hematomas, seromas, abscesses, warts, or injuries. The eyes should be examined specifically for evidence of vision deficits, squamous cell carcinomas, corneal damage, or lymphoma. The feet should be examined specifically for evidence of abnormal hoof wear, pain, subsolar pathology, screw claw, or interdigital fibromas. The limbs should be examined specifically for evidence of hock joint injuries, physitis, stifle swelling, or any other joint or limb injury.[64,65]

The reproductive exam and scrotal circumference measurement can be done at the same time. The testes, epididymis, and scrotal neck should be visually evaluated and palpated for abnormalities. The testicles within the scrotum should be symmetrical, freely moving, and free of any hard or overly soft areas. Then the scrotal circumference measurements can be obtained. The prepuce and penis should also be evaluated and palpated for abnormalities. Transrectal palpation is then utilized to evaluate the pelvic area, the urethralis muscles to the seminal vesicles, then the ampullae at the fornix of the seminal vesicles, and then the inguinal rings, pelvic lymph nodes, and iliac lymph nodes on each side. The kidney and any viscera within reach should also be palpated if possible. Stimulation may be initiated then by massaging the ampullae and seminal vesicles. This massage is intended to stimulate the candidate bull and also check for an abnormal painful response. The urethalis muscle and prostate are then massaged as the hand progresses back to the anus. Manual massage can be utilized to obtain a semen sample or the electro-ejaculator can be utilized at this point to facilitate penile extension and ejaculation. At the end of the examination the examiner should feel confident that the bull has no signs consistent with hernia, lymphoma, cryptorchidism, scrotal abnormality or injury, testicular abnormality or injury, inguinal hernia, kidney pain or abnormality, adhesions, seminal vesiculitis, or prostate abscess. Before the reproductive examination can be considered complete, the internal prepuce and penis must be examined and palpated for lacerations, scars, abscesses, hematomas, tumors, persistent frenulum, hair ring, and warts. Not all scars may interfere with penile extension or coitus but they should still be noted. Persistent frenulums can be corrected when identified and may not prevent a bull from being classified as a satisfactory potential breeder but the finding should still be noted at the time of BSE.[65]

Scrotal circumference measurement is done by gently holding both testes together at the bottom of the scrotum by applying distal pressure with one hand at the neck of the scrotum. The measuring should be done at the widest point with a metal measuring tape designed for scrotal circumference measurement. Care should be taken to not spread the testes apart and to apply sufficient pressure with the measuring tape so that the top surface of the tape is even with the skin but not indenting into the skin.[65] It is good practice to measure at least twice to make sure that the measurements are similar, before recording the measurement. Scrotal circumference measurements indexed for age and in some cases specific to breed standards have been published.[2,52-54,63,66,67] If the bull has physical or reproductive exam abnormalities that will result in an unsatisfactory classification or his scrotal circumference does not meet the minimum requirement, there is no need to continue the evaluation.

Semen should be collected into a warm, dry, sterile collection device. The volume, density, and gross characteristics of the ejaculate do not appear to be directly related to fertility and evaluation of these is not required by SFT but this information may be useful to record.[19] A drop of semen should be transferred onto a pre-warmed slide and evaluated for gross and individual motility under a microscope as soon as possible to reduce the effects of cold shock and possible urine contamination. A warm microscope stage and slide coverslip can also be used to maximize possible motility estimation.[19,65] Spermatozoa concentration assessment is not a necessary part of the bovine BSE because

SC measurement is considered a better estimate of sperm production in range-type bulls.[19] Gross motility is a function of sperm concentration and individual motility and is estimated by looking at degree of swirling in an undiluted sample at 100 times magnification. The gross motility is then classified into one of four categories (very good, good, fair, poor) depending on degree of swirling from rapid swirl to sporadic oscillation. Individual progressive motility is done by estimating the percent of active, progressively motile cells at 400x magnification. The individual motility is then classified into one of four categories depending on the percentage estimate. Greater than 70% is very good while less than 30% is poor.[19,65] Bulls with unsatisfactory motility should be collected an additional time to insure that collection technique was not a factor. Bulls must have a minimum of 30% progressive motility or fair gross motility to meet the SFT threshold for a satisfactory potential breeder.[19,64,65]

Differential counts of morphologically normal and abnormal sperm cells are done by examining fixed or stained semen preparations using phase microscopy or bright-field microscopy respectively. At least 100 spermatozoa should be observed in different fields. Use of eosin-nigrosin stain to evaluate sperm under oil immersion (1000-1200X) using bright-field microscopy is common. To be classified as a satisfactory potential breeder a bull should have at least 70% morphologically normal sperm, regardless of the types of abnormalities seen.[19,64,65]

There are several categorization systems for sperm abnormalities. SFT uses the primary and secondary abnormality classification system to further classify abnormal spermatozoa. Blom established the primary and secondary abnormality system. Abnormalities attributed to problems during spermatogenesis are considered primary.

These abnormalities include head and midpiece abnormalities, as well as proximal droplets, strongly coiled tails, double heads or midpieces, and abnormal acrosomes. Abnormalities that occur subsequent to sperm release are considered secondary. These abnormalities include loose normal heads, loose folded acrosomes, abaxial tails, simple bent tails, and distal droplets. Determining the number of abnormalities that fall into each category during the BSE can be useful for determining prognoses or monitoring progress in problem bulls.[19,65] Listing the most abundant abnormalities in bulls with <70% morphologically normal spermatozoa can help assess improvement and prognosis when compared to morphology at reevaluation.[65] It takes a total of 60 days for a spermatogonium to evolve into a spermatozoa, and another 9-14 days for it to transverse the extragonadal duct system and appear in the ejaculate so a good policy is to schedule retests for 6-8 weeks later. Then it is possible to differentiate between temporary and more permanent problems.[19] This might not be possible depending on the timetable for proposed sale or use of the bull.

The inclusion of libido/serving capacity testing as well as special testing for the identification of specific disease entities (e.g., campylobacteriosis, trichomoniasis) are not part of the routine BSE but may be indicated in some situations.[19] Due to increased awareness and current regulations for intra- and interstate movement of bulls, trichomoniasis testing of bulls that are deemed satisfactory potential breeders is becoming more common.

Satisfactory breeding soundness evaluation in yearling bulls

Producers wishing to use yearling bulls for breeding should select bulls with early birth dates that demonstrate good sex drive and normal mating ability. Scrotal circumference measurements should be above average and semen evaluation must be done to ensure that the pubertal development period has passed and normal spermatozoa are being produced.[2] In 2013 Barth reported that studies at the Western College of Veterinary Medicine indicate that approximately 45% of physically sound beef bulls produce satisfactory semen quality at 12 months of age. Similarly, approximately 75% of physically sound beef bulls will have satisfactory semen quality at 14 months of age. Barth reports that most bulls (81-100%) will have satisfactory semen quality and be considered mature by 16 months of age.[2] Similarly Arteaga reported approximately 33% of Canadian beef bulls will have satisfactory semen quality at 12 months of age. This increases to 60% and 90% at 14 and 15 months of age respectively.[18]

A study of 11-13 month old beef bulls (Charolais, Hereford, Simmental) in Sweden evaluated the proportion of bulls with mature spermiograms at a time when they are commonly used for breeding. After clinical examination, scrotal circumference measurement, and morphologic examination of postmortem cauda epididymal contents, 48% of the bulls examined met the study definition for mature spermiogram (<15% abnormal heads and <15% proximal droplets).[21] The percent of morphologic defects decreased with increased age in the study bulls.[62]

A retrospective study that evaluated data from BSE results over 12 years in North Carolina found that BSE of 12 to 15 month old bulls provided valuable information for selecting bulls for breeding.[68] This study included 1,952 bulls from 4 different breeds; Angus, Charolais, Hereford, and Simmental. In the study more Simmental bulls were classified as satisfactory breeders than any of the other breeds. Charolais was the breed with the fewest bulls classified as satisfactory. Breed effect on BSE classification was not significant (*P*=0.052) Primary morphologic semen abnormalities were the most important factor in determining BSE classification. Age at BSE affected the score (*P*<0.01) with a gradual increase in BSE scores by month of age, but did not have a significant effect on final BSE classification using the older SFT BSE guidelines. When the data was converted to “pass” or “fail” (unsatisfactory + questionable), age had a significant effect on classification.

A retrospective evaluation of 3,648 single SFT93 BSE results in yearling beef bulls found that 76.2% of yearling bulls were classified as satisfactory.[69] Of the bulls that were unsatisfactory, most failed due to inadequate scrotal circumference; followed by inadequate semen morphology, unsatisfactory semen motility, physical abnormalities, and a combination of inadequate semen motility and morphology.[69] The *Bos indicus* influenced bulls were classified as satisfactory at a significantly lower rate than the *Bos taurus* influenced breeds. Satisfactory classification percentage was also positively correlated to age (range 10 mo-19 mo).[69]

A prospective study by Chenoweth, Chase, and colleagues showed that breed and age influenced semen motility and morphology in yearling beef bulls.[61] Qualitative semen traits assessed in the study improved with age, particularly from 12 to 18 months. The study concluded that the most efficacious use of BSE was in *Bos taurus* bulls 15 months or older and *Bos indicus* bulls older than 18 months of age.[61]

The finding of proximal droplets in the semen of young bulls is often considered a sign of bull immaturity.[15] Studies in yearling bulls have shown that proximal droplets as the most prevalent defect; tail, acrosome, head defects, and detached heads were found in less than 8.5% of the sperm.[18,70] In Arteaga’s study of 11 to 15 month old Canadian beef bulls, proximal droplets were the main defect contributing to classification of immature.[18] The percentage of morphologically normal sperm increased with the increase in the age of the bull from 11 to 15 months.[18,26,70] It would be risky to assume that young bulls that fail to produce satisfactory semen at evaluation will be satisfactory if they are given more time to mature. While this may be true for some bulls, especially the youngest in a cohort of young bulls being evaluated for breeding, not all bulls will meet the requirements for classification as a satisfactory potential breeder when mature.

A study reported by Barth et al. showed that a surprising number of 13-14 month old decision deferred bulls did not improve when reevaluated at 15-16 months of age. The study looked at the BSE results of 524 bulls at a government bull rearing station from 2008-2011. Approximately 66.6% of the bulls were Angus and 33.3% of the bulls were Charolais. The bulls were tested in April when they were 13-14 months of age. The author expected approximately 15% of the physically normal mature bulls to have unsatisfactory semen quality. On initial evaluation 85 bulls (16.2%) had no physical abnormalities but poor semen quality and were classified as decision deferred. The 26 bulls (5.0%) with unsatisfactory spermiograms and physical exam abnormalities were culled. The majority (n=71) of the decision deferred bulls were retested in June when they were 15-16 months of age. It was hypothesized that over 80% of the bulls would have satisfactory semen quality after being given time to mature. However, only 25 bulls (35%) of the decision deferred bulls had satisfactory semen quality at reevaluation.[71]

A recent study investigating the association between breed, age group (11-13 mo, 13.5-18 mo, 19-26 mo, and > 26mo), and scrotal circumference, and their interaction on the percentage of beef bulls in Alberta with satisfactory sperm morphology did not find significant association between mean percentage of sperm abnormalities, total abnormal and normal sperm, age, and scrotal circumference of the beef bulls.[72] As age increased, the percentage of bulls classified as satisfactory also increased from 79% at 11-13 months to 87% at >26 months.[72] The overall prevalence of morphological abnormal sperm in beef bulls was approximately 20% with distal midpiece reflex the most prevalent abnormality.[72] In the study population, 17% of the bulls were classified as unsatisfactory due to abnormal sperm morphology, highlighting the importance of morphologic examination of sperm.[72] Cow pregnancy rates after 120 day breeding season can be statistically higher in cows exposed to bulls with 70-80% or more normal sperm when compared to cows exposed to bulls with <70% morphologically normal sperm.[73]

Chenoweth encourages producers to utilize the BSE in young bulls as close to sale or use as possible, allowing adequate time for either retesting or replacement before breeding. It is common practice to schedule the initial BSE within one month of sale or introduction to the breeding herd. Young bulls should be pubertal for BSE classification.[19] A guide that would provide information on the expected proportion of yearling bulls of various breeds that can be expected to be sexually mature at various ages would be useful for those that are selling yearling bulls for breeding. The information can be used to select bulls and schedule breeding soundness evaluations for when the majority of the bull are sufficiently mature for efficient classification and selection. While this approach would decrease the number of BSE needed to classify young bulls as satisfactory or unsatisfactory potential breeders, delaying initial BSE will result in the inability to identify bulls within a cohort that naturally mature earlier.

Minimal changes were seen in the quality of semen obtained from mature Holstein bulls when compared to the semen quality of those same bulls as yearlings.[74] The only significant differences seen with maturation were an increase in the volume of ejaculate and the number of sperm per ejaculate.[74] A similar study that compared frozen semen samples form Holstein bulls at 14 months of age against samples from the same bulls at 4 years of age showed that the earlier samples had greater proportions of proximal cytoplasmic droplets and the more mature samples had greater proportions of intact acrosomes. Semen normal morphology, primary defects, and tertiary defects did not differ significantly between the two sampling time points. The final results of the study suggested that the semen quality of yearling Holstein bulls was related to semen quality later in life.[75]

Bull fertility

The primary mission of a natural-breeding bull is to efficiently impregnate all available females as early in the breeding period as possible. Cows are naturally bred in most beef herds and herd sire selection has an important impact on overall reproductive efficiency.[76] Breeding bulls must have good eyesight and musculoskeletal conformation as well as the necessary reproductive anatomy and sex drive to produce and deliver sufficient numbers of fertile spermatozoa.[19] Even with BSE classification as a satisfactory potential breeder, bull reproductive performance can be affected by libido and mating ability. Environmental conditions and physiological stress during the breeding season can have negative effects on bull testicular function, sperm production, and physical ability to breed, especially in yearling bulls.[20] In multisire mating groups, social relationships and interactions can also influence sexual behavior and overall reproductive performance.[19]

In 1990 Perry, Chenoweth, and colleagues outlined three factors that exert the greatest influence upon reproductive performance: semen characteristics, sex drive/mating ability, and social interactions between animals in the breeding pasture.[77] Only the first factor (semen characteristics) are evaluated by BSE. The omission of the other two factors could contribute to the variability observed in the relationship between BSE classification and subsequent bull fertility.[78,79] There are several publications that agree that no single trait is an accurate predictor of bull fertility, but rather that several variables are influential.[77,80,81] These variables do not always act in harmony.

To address this source of variability, some have attempted to construct a fertility index that would encompass numerous traits and would predict reproductive performance with greater accuracy. To create fertility indices for beef bulls, Perry and colleagues used a step-wise regression procedure to select the most suitable combinations of traits that were highly correlated with pregnancy rates in single-sire mating groups. They concluded the most important traits incorporated into the fertility indices included peripheral LH levels following GnRH stimulation, testicular volume, libido, and bodyweight with age and dominance value also being represented.[77] The fertility indices derived were predictive of pregnancy rates with one correlation of 0.45 and all other correlations ranging from 0.66 to 0.89. Interestingly, in this cohort of bulls the tests carried out 2 weeks before and after breeding did not result in regression equations that were strongly correlated with pregnancy rates. BSE score and all assessments of semen quality were not included in the regression equations. However, the author points out that bull to female ratio ("mating load") and breeding group composition (single- vs. multiple-sire) could affect which fertility traits have greatest impact. More intensive mating systems might result in an increase in the importance of seminal and other characteristics.[77]

In 2002, Holroyd and colleagues conducted an intensive study of bull fertility in multiple-sire breeding groups in Australia and developed multiple regression models that related pre-mating measures of physical, seminal, and behavioral traits to calf output by breed group. Measures of semen quality based on spermatozoa morphology were important contributors to calf output in the Santa Gertrudis and Brahman models where percent normal spermatozoa was positively related to calf output. The study findings also supported the practice of focusing on spermatozoa morphology rather than spermatozoa motility during semen evaluation prior to use in multiple-sire groups. While no one single trait could be used to predict calf output, sperm morphology was important in all models. The authors suggested that it may be difficult to identify the extremely fertile, "super bulls", but a systematic physical and reproductive examination will identify a large number of bulls that will be poor contributors to calf output.[81]

There are other variables that could be detrimental to bull fertility such as disease, age, injury, weather, and nutritional status. Barth did a retrospective study that reviewed BSE records from 2110 beef bulls to determine the prevalence and importance of factors affecting BSE classification. The time of year had an affect that the author attributed to cold stress, short photoperiod, and reduced feed quality. Semen quality was lowest in the fall and winter and highest in the spring and summer. Poor or excessive body condition, scrotal circumference below the recommended minimum, lameness, and severe scrotal frostbite all reduced the probability of a satisfactory breeding soundness classification in beef bulls in Saskatchewan.[82]

A study looking at the association between practitioner BSE results and pregnancy outcomes in western Canada found that cows exposed to bulls with SC < 34 cm were likely to become pregnant and had a longer median interval from first bull exposure to calving.[83] No other link was identified between reproductive outcomes and the semen characteristics measured for BSE, sperm morphology, sperm motility, or BSE classification. Only 6.9% of the bulls used for breeding were classified as unsatisfactory by BSE prior to breeding and many of the bulls were used in multi-sire pastures, which affected the ability of the study to determine usefulness of BSE classification to predict pregnancy status.[83]

Fertility of yearling bulls versus mature bulls

Farid and colleagues investigated bull fertility in 62 single sire breeding herds over a 10 year period.[84] Each bull was used as a yearling and then again as a two year old in 60 day summer breeding seasons. Bulls were not evaluated for libido or semen characteristics, nor was note of examination of their reproductive organs at the time of selection, apart from a routine inspection for general physical soundness. The average pregnancy rate of cows mated to yearling bulls was similar to that for 2 year old bulls. While there was a trend toward earlier breeding for the two year old bulls, the authors reported that the repeatability estimates of the measures of bull fertility were low and concluded the reproductive performance of a two year old bull cannot be accurately predicted from his performance as a yearling.[84]

Makarechian and colleagues investigated the relationships between beef bull natural service fertility and the components of BSE, age, preweaning average daily gain (ADG), yearling weight, and libido scores in two groups of beef bulls.[45] The first group was made up of 15 yearling bulls that were rotated in groups of 5 every week during the six week breeding season on 124 cows. The second group was made up of 1 three year old bull and 4 two year old bulls that were exposed to 126 cows for six weeks straight.[45] The progeny of the bulls were then identified using blood typing. There was a larger calf crop in the group covered by the older bulls than the yearling bulls but the difference was not significant. Variation in fertility between the individual older bulls was significantly large. The three year old bull sired 41% of the calves in the mature bull group. The differences in fertility of the two year old bulls was not significant. In each of the first and second set of yearling bulls there was a bull that did not produce any progeny and a bull that sired 44% of the calves. There were significant differences in fertility and the average date of progeny birth for the three groups of yearling bulls. The third set of yearling bulls sired 49.4% of all the calves in the younger bull group. The correlation coefficients of bull fertility and the traits used before the breeding season to predict performance were small and inconsistent for the older and yearling bulls.[45]

In 1987 Makarechian and colleagues published a follow-up study of yearling bull fertility in multiple sire pasture breeding operations.[85] Twelve yearling bulls were split evenly into four groups and exposed to approximately 70 cows for each group for 60 days. The progeny were identified via blood typing.[85] Fertility of individual bulls within the breeding groups was significantly different. In each breeding group there was one bull that sired at least 50% of the calves. There was a positive association between the fertility and age of bulls among the breeding groups.[85] The youngest bull in each breeding group had the lowest fertility. Age of bull and percent normal spermatozoa were the only traits that which were significantly related to bull fertility. Scrotal circumference, sperm volume, preweaning average daily gain, weaning weight and daily gain in the period between yearling and breeding showed positive but insignificant correlation with bull fertility.[85] The measures of libido did not show any association with fertility in this study.[85]

A final study comparing the performance of yearling bulls to those of 2 year old bulls during pasture breeding over 3 breeding seasons was reported by Makarechian and colleagues in 1993. Pregnancy and calving rates were used as measures of bull fertility. Neither age nor breed of bull had a significant effect on the outcomes studied.[79] There was a tendency for the 2 year old bulls that had breeding experience as yearlings to have higher calving rates than the yearling bulls.[79]

Chapter 3 - Determining potential pregnancy status differences based on a new method of yearling heifer prebreeding examination

Abstract

The study objective was to evaluate the Ready-Intermediate-Problem (RIP) replacement heifer evaluation matrix's ability to classify heifers into groups with differing reproductive outcomes. Beef heifers (n=341) from six Kansas herds were classified according to RIP matrix guidelines and then exposed to AI breeding, bull breeding, or a combination of both as per the management plans for each participating herd. Following the breeding season the heifers were evaluated to determine pregnancy status, AI pregnancy status, days bred, and the number of 21 day cycles needed during breeding season to become pregnant. After the breeding season, 298 (87%) of the heifers were pregnant, 204 (68%) of which became pregnant in the first 21 days of the breeding season. There was a significant interaction (P = 0.01) in RIP classification by 21 day cycle. Ready classified heifers had a significantly greater risk of becoming pregnant after a single AI exposure (P=0.03) and in the first 21-day cycle (P=0.02) compared to Problem classified heifers, and significantly less risk of being non-pregnant at the end of the breeding season ($P<0.01$) compared to Problem classified heifers. The RIP matrix can be useful for classifying heifers prior to the onset of the breeding season. Further research is needed to evaluate the matrix in other settings and populations of U.S. beef heifers as well as at different intervals between evaluation and the start of breeding season.

Introduction

Replacement heifer management is an important contributor and constraint to reproductive efficiency of beef herds. The goal of a replacement heifer program is to bring new, productive animals into the herd that will take the place of non-productive or otherwise less-desirable cows. Beef producers are challenged with the risk of inconsistent yearling heifer reproductive efficiency that can negatively affect herd performance. Developing replacement heifers requires the allocation of scarce resources; therefore, using criteria to accurately evaluate reproductive potential of incoming breeding females is important. Early recognition of heifers that are likely to have sub-optimal reproductive performance improves the efficiency of replacement heifer management. Heifers that are not likely to become pregnant early in the breeding season are not desirable as replacements. In addition, heifers that have an increased risk of dystocia due to a pelvis of small size or abnormal shape are also at risk of sub-optimal reproductive performance. Ideally, heifer evaluation should contribute both to the identification of heifers that will negatively affect the herd reproductive efficiency as well as heifers that will perform superiorly due to their physiologic readiness for pregnancy at the beginning of the breeding season and physical conformation that is not associated with increased risk of pregnancy. There are several methods that have been described which attempt to identify the population of heifers that should not be used in heifer replacement programs as well as the heifers that should be superior additions in a heifer replacement program.[3-14] However, lack of repeatability, inconvenience, and complexity may limit the widespread use and interpretation of some methods of evaluation.

Puberty is reached when a heifer can express estrous behavior, ovulate a fertile oocyte, and have a corpus luteum with a normal life span. The three main drivers of pubertal onset in heifers are age, body weight, and breed. Age and body weight can be viewed as thresholds where a minimum is necessary, but individual heifer fertility does not increase in a linear fashion with additional age and weight, while breed influences the weight and age thresholds.[24] Fifty percent or more of *Bos taurus* heifers are expected to reach puberty by the time they reach 55 to 60% of the expected mature body weight based on the body weights of their dams while cohorts of *Bos indicus* heifers require a higher threshold of 65% of their expected mature body weight to achieve 50% cycling.[25-27] Meeting a desired target weight is important to manage age at puberty and breeding season success.[28,30] Fertility of mating at the estrus associated with the onset of puberty is reported to be less than the fertility of mating at the third estrus.[27,29] Therefore, it is often desirable for heifers to reach puberty one to two months prior to the start of breeding to ensure greater reproductive success early in their first breeding season.

Body condition score (BCS) can also be used as a tool for evaluating and managing replacement heifers. A commonly utilized scoring system uses classifications 1 through 9 to categorize the condition of cows from emaciated (classification 1) to good (classification 6) to obese (classification 9).[31] BCS at various stages of breeding cow production has been correlated with peripartum interval, services per conception, calving interval, milk production, calf weaning weight, calving difficulty, and calf survival.[32] Heifer first-service conception risk improves as BCS increases up to classification 6.[28] Calving interval is also shorter for cows that calve in higher body condition classification, making BCS an important monitoring tool at breeding and calving.[86]

Pelvic area measurement has been used for over four decades as a way to identify heifers with an increased risk of dystocia due to a small or misshaped pelvis.[33-35] Pelvic area is estimated by using a pelvimeter placed in the rectum to obtain the vertical distance between the backbone and the floor of the pelvis at midsacrum and the horizontal distance between the shafts of the ilia perpendicular to the vertical measurement. These two measurements are then multiplied to estimate the pelvic area.[36] The correlation between yearling and two year old pelvic areas is 0.70 therefore yearling pelvic area measurement can be used to predict size of the pelvis at parturition and can be useful to identify heifers that should be culled for not meeting a minimum standard or having a misshapen pelvis.[5,24] However, selection for large yearling pelvic area does not significantly decrease the incidence of dystocia and is a poor predictor of calving difficulty in primiparous cows.[37,38] Pelvic area measurement should be used in concert with other information designed to evaluate heifers for suitability as replacement heifers.

The conventional reproductive tract scoring (RTS) system was developed in the early 1990s at Colorado State University as a tool to assist replacement heifer selection decisions.[1] The system estimates pubertal status and can be used to evaluate heifer development at a group-level and the likelihood of a targeted percentage of the replacement cohort becoming pregnant following estrous synchronization and AI. Reproductive tract scoring is accomplished by transrectal palpation and evaluation of the uterine horns, ovaries, and ovarian structures. A 5-point scoring system is used to describe these findings. Heifers with a tract score of 1, 2, or 3 are considered prepubertal while heifers with a score of 4 or 5 are considered pubertal.[3] The RTS system was validated in 2003 as a repeatable and accurate tool to evaluate pubertal status in beef heifers.[39] Although, due to the subjective nature of the RTS system, risk of misclassifying pubertal heifers as prepubertal can be high for evaluators that lack experience which can limit the ability to predict performance for heifers that have RTS classifications other than 1, especially if no other data is collected to aide in management decisions.[39]

In 2016 Holm published a study that showed using pelvic area measurement with RTS evaluation was more prognostic for poorly performing heifers than RTS alone.[11] In 2009 Holm compared RTS score to other indicators of reproductive performance (body weight, age, BCS, and Kleiber ratio) to evaluate the system's potential use as a predictor of lifetime production of the cows. The RTS system compared well with the other evaluated traits when the heifers were followed through their second breeding season.[12] In 2014 Holm published the results of a 7 year study of a single 292 head Bovelder beef cow herd in South Africa designed to determine the ability of the RTS evaluation to predict long term reproductive performance in beef heifers. Reproductive failure in this study was defined as a negative pregnancy diagnosis after the AI breeding season. Cows and heifers not pregnant to AI were removed from the herd. The study showed three levels of performance based on RTS classification. The heifers classified RTS 1 or 2 (prepubertal) were more likely to be in anestrus for the first 24 days of the breeding season independent of pre-breeding BW, age or BCS than those classified as RTS 4 or 5 (pubertal). They were also more likely to fail to become pregnant even after adjusting for the anestrus period, and had an increased risk of reproductive failure and removal from the herd at a young age compared to those classified as RTS 4 or 5. The heifers that were classified RTS 3 (peripubertal) did not perform significantly better or worse than the other RTS classifications of heifers. The RTS 3 heifers tended to have a higher incidence of 24 day anestrus during the breeding season than those classified as RTS 4 or 5 but also tended to calve earlier than those classified as RTS 1 or 2. The herd in the study had a strict culling policy based on reproductive failure and there were no difference in calving risk and days to calving after the second pregnancy between RTS categories in those that remained in the herd. The effect of RTS classification on long term reproductive performance was determined mostly by the outcome of the first breeding season with the second season having some effect as well. The study concluded that RTS was an appropriate tool for replacement heifer management if used to exclude heifers that are likely to fail to become pregnant or to calve late in the calving season.[9] Gutierrez evaluated the reproductive efficiency of heifers based on RTS score and showed that heifers with a higher RTS score were able to become pregnant earlier in the breeding season compared with heifers with a lower RTS score.[40] Several researchers have shown that heifers that calve early during their first breeding season will calve early during subsequent breeding seasons and will have increased lifetime production.[13,25,41-43] Cushman et al. showed that heifers that became pregnant early in the breeding season had better reproductive performance over six parturitions than those that became pregnant later in their first breeding season due to increased longevity in the herd and increased weight weaned.[43]

The Ready-Intermediate-Problem (RIP) system is a novel, management-driven matrix that combines the evaluation of body condition, percent mature body weight, reproductive tract score, and pelvic area together to describe the well-being and readiness of potential replacement heifers for breeding. The matrix was designed as an efficient monitoring step to help veterinarians and producers manage and reduce yearling heifer reproductive inefficiency and thus improve herd reproductive performance. The system stratifies potential replacement heifers into one of three classifications that will predict their ability to positively impact herd reproductive performance by becoming pregnant early in breeding season and having a decreased risk of calving difficulty if bred to an appropriate bull.

The heifers classified as “Ready” (R) are deemed suitable for immediate enrollment in AI programs. The heifers classified as “Intermediate” (I) are suitable replacement heifers but may not be suitable for enrollment in an AI program and depending on the management goals of the producer, may be better suited to a pasture breeding system. The heifers classified as “Problem” (P) are at high risk for failing to become pregnant or to become pregnant late in the breeding season.

The optimum timing of a reproductive soundness examination will depend on the nutrition, breeding, and marketing plans for specific herds. Producers who want to ensure that a high percentage of heifers are cycling before the start of breeding and who are not interested in exerting selection pressure to identify heifers that reach puberty at a lower body weight are likely to desire that the evaluation be done early enough to not only identify the percent of heifers that are cycling, but to increase that percentage if necessary by the start of breeding. Evaluating heifers six weeks prior to the breeding season provides time to correct low body weight and corresponds to optimal timing of pre-breeding vaccination, but will provide less certainty about the percentage of heifers that will be cycling when the breeding season starts. In contrast, producers who want to develop heifers at a lower daily rate of body weight gain between weaning and breeding in order to identify heifers that reach puberty at a lower body weight realize that a relatively high percentage of the replacement cohort will not be cycling at the start of breeding and may desire that the evaluation be done at the same time as the decision about whether or not to initiate a synchronization protocol for each individual heifer. Evaluating heifers immediately prior to synchronization or just before bull turn-out provides very accurate information about the percentage of cycling heifers, but affords no opportunity to make adjustments that may increase that number. Confirming that a high percentage of replacement heifers are cycling prior to the start of the breeding season as well as identifying and removing freemartins, very immature heifers, and pregnant heifers will increase the success of an estrous synchronization and artificial insemination (AI) program.

The RIP system was designed as a monitoring tool to help veterinarians and producers manage and reduce reproductive inefficiency, but has yet to be evaluated in a research setting. The objective of this study was to evaluate the RIP system's ability to classify heifers into groups that will express different reproductive efficiency outcomes. The outcomes measured were pregnancy to AI breeding, pregnancy in the first 21 days of breeding season, pregnancy by 21 day cycle, and overall pregnancy percentage. It was hypothesized that Ready and Intermediate classified heifers would outperform Problem classified heifers for all outcomes and that Ready heifers would be superior to Intermediate and Problem heifers in AI program performance. And, more Ready classified heifers would become pregnant in the first 21 day cycle than the Intermediate and Problem heifers.

Materials and Methods

Animals

The Kansas State University Institutional Animal Care and Use Committee approved the research design and use of heifers in this study (IACUC 3444). This study included 341 yearling heifers from six beef commercial and seedstock producers. The heifers were managed according the replacement heifer development programs of their individual source ranches. In order to qualify for inclusion in the study, the participating producers had to agree to be blinded to the data gathered during the study and to manage all of the heifers within each producers' cohort the same during the study. Data gathered from the producers before evaluation included each heifer's date of birth, individual ID, date of weaning, weaning weight, post-weaning nutrition, and the average mature body weight of the herd. The AI dates, synchronization protocol, and bull exposure dates were also gathered during the study if applicable. Pregnancy determination was performed after the end of each breeding season.

Description of RIP heifer prebreeding evaluation matrix

Table 1 presents the cutoffs utilized in the Ready-Intermediate-Problem (RIP) classification matrix for BCS classification, body weight as a percent of estimated mature body weight, reproductive tract evaluation, pelvic area, and pelvic shape. R or I classification requires that the heifer meets each of the criteria described. If a heifer meets any of the criteria described in the P category, criteria for P classification will have been met. Specific pelvic area cutoffs can be adjusted depending on the genetics and goals of the producer's heifer development program.

Table 1 - Ready-Intermediate-Problem Classification Matrix

Score	BCS		Weight		Reproductive Tract		Pelvic Area		Pelvic Shape
R (Ready)	≥5	&	55-65% of mature wt.	&	Cycling: CL present and/or >10 mm follicles with good uterine tone	&	>130 sq. cm. or herd-specific cut-off	&	Normal
I (Intermediate)	≥5	&	50-60% of mature wt.	&	Not-cycling, but palpable ovarian structures and slight to good uterine tone	&	>130 sq. cm.	&	Normal
P (Problem)	<5	or	<50% of mature wt.	or	Immature uterus with no palpable follicles or follicles <8 mm, freemartin, or pregnant	or	<130 sq. cm. or herd-specific cut-off	or	Abnormal

Evaluation of heifers

The heifers in the study were evaluated and classified according to the RIP matrix two to four weeks prior to the start of the respective herd's heifer breeding season. The heifers were evaluated and classified into the appropriate RIP category after all information utilized in the matrix was gathered for each heifer. Visual determination of BCS was performed by the same assigned BCS observer for every heifer. Measurement of weight was performed by the producer and compared to the estimated mature body weight of each herd. Reproductive tract scoring via transrectal palpation was performed by the same experienced veterinarian using the RIP criteria. The 5-category RTS classification described by Anderson et. al. (1991) was also determined and recorded for comparison.[1] Determination of pelvic shape and pevimetry measures (horizontal distance, vertical distance, and area in centimeters) were done transrectally by the same experienced veterinarian for all heifers. The producer was blinded to the RTS classification, pelvic measurements, and RIP classification. The heifers were then exposed to AI breeding, bull breeding, or a combination of both as per the management plans for each participating herd. The data gathered both before and at the RIP evaluation were used to calculate age at weaning, age at RIP classification, and average weight gained post-weaning and percent mature body weight as compared to average mature body weight reported in each herd. After the breeding season of each herd, the heifers were evaluated to determine pregnancy status, AI pregnancy status, and days bred as determined by transrectal uterine palpation. The pregnancy evaluation was done by the same veterinarian that performed the RIP evaluation. If the heifer was determined to be not pregnant via transrectal uterine palpation or any abnormality was palpated, transrectal ultrasonography was utilized to verify the findings. The days bred data obtained at the pregnancy determination was used to calculate the number of 21 day cycles the heifers needed to become pregnant.

Statistical Analysis

To test the effect of RIP classification on risk of pregnancy to a single AI exposure, a multivariable analysis with the independent variable being the R, I, and P classifications and the covariant being herd was used. A generalized linear mixed model was developed to evaluate overall pregnancy risk by RIP classification. Due to the hierarchical structure of the data, a random effect for herd was included. A separate generalized linear mixed model was used to evaluate the effect of RIP classification on the risk of pregnancy by 21 day cycle. A random effect of herd was included and a P value of less than 0.05 was considered significant. Pairwise comparisons were used to compare pregnancy risk within 21 day cycles by RIP classification with a P value of less

0.05 considered significant. All analyses were performed with an open source statistical computing and graphics program.[a]

Results

Prebreeding heifer classification

At prebreeding classification 252 heifers were classified as Ready (R), 48 were classified as Intermediate (I), and 41 were classified as Problem (P). After the 341 heifers were classified, they were exposed; 297 to AI followed by natural bull exposure and 44 to natural bull exposure only. Of the 297 heifers that had a single AI exposure followed by exposure to a pasture bull, 217 were classified as R, 43 as I, and 37 as P.

Pregnancy status after breeding season

After the producer-determined breeding season (range 45-60 days), 298 (87%) of the heifers were pregnant. Of the heifers that were pregnant at the end of the breeding season, 204 (68%) became pregnant in the first 21 days of the breeding season. Of the remaining heifers, 56 heifers (19%) became pregnant in their second cycle, 23 (8%) in their third, and 15 (5%) in their fourth.

RIP classification matrix

Risk of pregnancy after single AI exposure was not significantly associated with RIP classification ($P = 0.14$). The risk of pregnancy overall was not significantly associated with RIP classification ($P = 0.21$). There was a significant interaction ($P = 0.01$; Figure 1) between RIP classification and risk of pregnancy by 21 day cycle. Ready classified heifers had a significantly greater risk ($P = 0.02$; Figure 2) of pregnancy in the

[a] RStudio Team (2016). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA

first 21 day cycle and significantly less risk of being non-pregnant at the end of the breeding season (P<0.01; Figure 2) compared to Problem classified heifers.

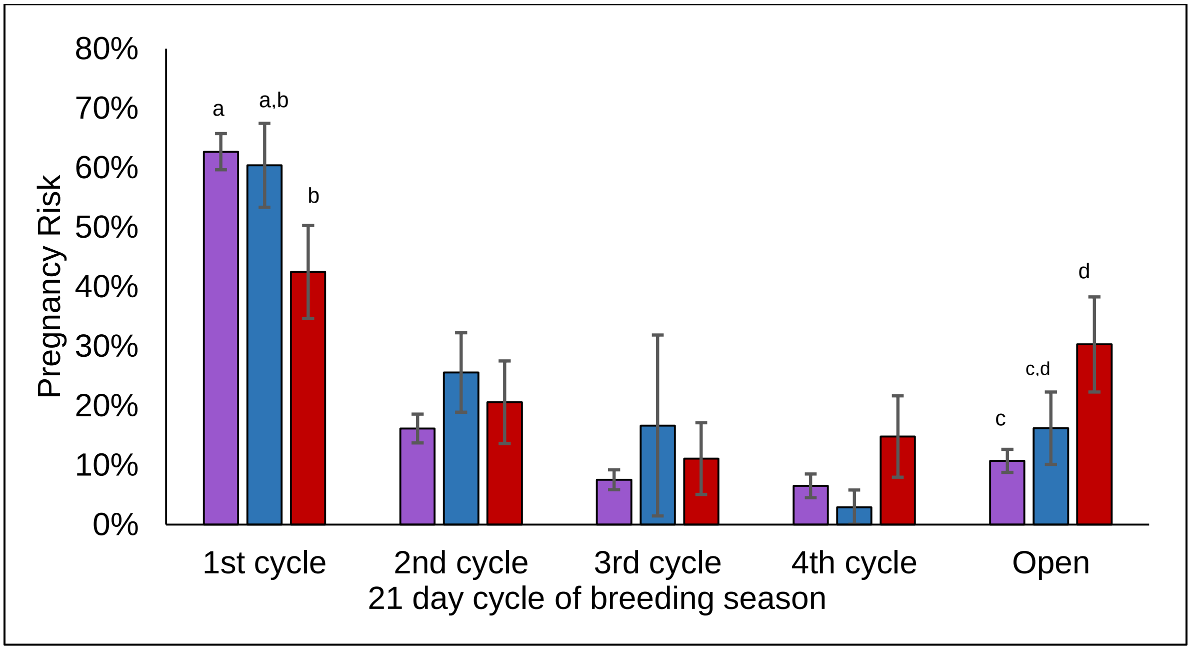

Figure 1 - Pregnancy Risk by RIP Classification and 21 Day Cycle

There is a significant interaction (P=0.01) in RIP classification by 21 day cycle. The purple bars are the heifers classified as Ready (R). The blue bars are the heifers classified as Intermediate (I). The red bars are the heifers classified as Problems (P). In the first cycle, the (R) heifers had a significantly greater risk (P = 0.02) of pregnancy that the (P) heifers. In the heifers open at the end of the breeding season, (R) heifers had a significantly less risk (P < 0.01) of pregnancy than (P) heifers. [abcd]Bars with different superscripts are significantly different (*P*< 0.05).

Discussion

This study found that heifers classified as Ready were more likely to become pregnant during the first 21 days of breeding, and less likely to be non-pregnant at the end of the breeding season compared to Problem heifers, with Intermediate-classified heifers being numerically intermediate. The importance of replacement heifers becoming pregnant early in the breeding season has been supported by a study by Lesmeister et al. who reported that heifers that conceive early demonstrate greater reproductive efficiency and tend to remain in early calving groups throughout their productive lives resulting in a higher average annual lifetime calf production.[25] Similarly, Cushman et al. found that heifers that calved in the first 21 days of the calving season had increased longevity in the herd compared to heifers that calved in the second 21 day period or later.[33] The same study found that calving period as a heifer also significantly influenced the unadjusted weaning body weight of their first 6 calves.[43]

Conclusions and Implications for Future Research

This is the first report describing the use of the RIP matrix. The RIP matrix can possibly be useful for classifying heifers in preparation of the breeding season. Ready classified heifers were more likely to become pregnant in the first 21-day cycle, and were less likely to be non-pregnant at the end of the breeding season compared to Problem classified heifers.

Further research is needed to evaluate the matrix in a commercial setting and in populations of heifers more representative of the U.S. beef heifer herd as a whole as well as at different intervals between evaluation and the start of breeding season. Specific studies of interest would be the performance of the matrix in large populations of heifers that were commingled from several sources with unknown age and genetic information; field studies of the matrix's ability to decrease first calf heifer dystocia rates; evaluation of the peripartum anestrus period, calving interval, and second calf calving date for second calf heifers that were classified before the first breeding season; and 6 to 9 year performance of heifers that were classified before the first breeding season.

Chapter 4 - Factors associated with passing subsequent Breeding Soundness Evaluations after failing an initial evaluation in yearling bulls

Objective – To determine the proportion of yearling beef bulls that are classified as satisfactory potential breeders when reevaluated after failing their initial breeding soundness evaluation (BSE) and to identify any predictive factors at initial BSE for satisfactory performance at revaluation.

Design – Retrospective data analysis

Animals – 2,805 beef bulls between 11 and 14 months of age at first BSE evaluated at Kansas Artificial Breeding Service Unit from 2006 to 2014

Procedures - For each bull, data on age, breed, and BSE parameters were analyzed. A binary variable was created to identify bulls that did or did not meet Society for Theriogenology standards as satisfactory potential breeders at the initial BSE and up to two reevaluations. A generalized linear mixed model was created to assess potential associations among breed, age, and interaction between breed and age and passing the initial evaluation. A second generalized linear mixed model was used to identify predictive factors for risk of passing BSE after initial failure. The predictors assessed were breed, age (month), scrotal circumference per day of age, and percentage of morphologically normal spermatozoa.

Results – 1,921 of 2,064 (93%) yearling bulls passed one of up to three BSEs. There was a significant interaction between age and breed of bull at initial BSE. No significant predictors for passing later evaluations after failing initial evaluation were identified.

Conclusions and Clinical Relevance - No significant predictors for risk of passing subsequent evaluations could be identified in yearling bulls that fail initial BSE.

Introduction

The primary function of a beef bull is to propagate desired genetics by successful initiation of pregnancy of heifers or cows as early in the breeding season as possible. Appropriate bull selection is an important component of herd improvement through introducing desired genetics and enhancing herd reproductive performance. Both the ability of a bull to transfer desired genetics and to support optimum herd reproductive performance are dependent on the fertility of the bull. The desire to improve beef herds through selection of superior genetics has resulted in the use of bulls younger than 18 to 24 months of age. The use of younger bulls has the benefit of shortening the generation interval but can result in decreased herd reproductive performance if the bulls are not sufficiently sexually mature. Young bulls are hypothesized to be less efficient due to inexperience, unknown or decreased libido, and potentially less than desirable semen quantity and quality due to immaturity.[15-23]

Performing (BSE) before sale or use of young bulls is a useful way to identify bulls that have adequate semen quality as well as other traits important for breeding soundness. Age at puberty has a significant effect on semen motility and morphology of yearling bulls.[18,58,61,70,87] Ideally the BSE of yearling bull cohorts should be scheduled when it would allow for the identification of bulls that may express the trait of delayed attainment of puberty, while at the same time a reasonable percentage of the candidate bulls are likely to pass the BSE. Ideal BSE scheduling can be a challenge because the BSE date and sale date are fixed but the bulls are born over a range of dates and the age at which a bull is able to pass a BSE is highly variable between individuals. It would be useful to know at what age a significant proportion of young bulls would be able to pass a BSE so that time and resources are not allocated to evaluations during a time when the results do not reflect performance during the breeding season that follows the sale. Development a minimal age guideline would theoretically reduce the number of reevaluations needed to estimate a young bull’s semen quality prior to its first breeding season.

This study sought to determine the proportion of yearling bulls capable of passing a second or third BSE after failing the initial BSE. The effect of the study population age and breed on the likelihood of failing the initial BSE was also evaluated with the goal of developing guidelines for the minimum age for Angus, Simmental, and Charolais bulls to be evaluated for breeding soundness with the expectation of sufficient sexual maturity to pass a BSE. The final objective of the study was to identify significant factors that could be used to predict likelihood of passing a second or third BSE after failing the initial evaluation.

Materials and Methods

KABSU data set

Retrospective BSE data for individual yearling bulls evaluated at the Kansas Artificial Breeding Service Unit (KABSU) by a single experienced technician under the direct supervision of a licensed veterinarian from 6 different ranches were obtained. The KASBU licensed veterinary technician graduated from a two year associate degree program and has 31 years of experience, including training under numerous veterinarians in the evaluation of bull semen and attendance at National Association of Animal

Breeders bovine semen workshops. During the BSE the technician grades the semen and reports all findings to the supervising veterinarian and the supervising veterinarian examines the bulls and reevaluates all semen samples that do not meet SFT minimum guidelines for satisfactory classification. The supervising veterinarian classifies all bulls as satisfactory, deferred, or unsatisfactory. The data was collected during the years 2006 to 2014 but not all source ranches provided data each year. The study population consisted of bulls presented for routine initial evaluation prior to yearling bull sales from seedstock ranches willing to have recheck evaluations done at KABSU on bulls that failed the first BSE. For this study, yearling bull was defined as a beef bull between the ages of 11 and 14 months at the time of initial BSE.

Society for Theriogenology (SFT) 1993 guidelines[88] were utilized to classify bulls as satisfactory potential breeders, unsatisfactory potential breeders, or decision-deferred bulls based on physical exam, scrotal circumference, or spermiogram motility and morphology. If no semen sample was obtained or there was no penile extension after three attempts, the bull was classified as decision-deferred if he was not classified as unsatisfactory based on physical exam, reproductive exam, or scrotal circumference.

Data extracted for each bull included source ranch, test date, date of birth, breed, physical exam abnormalities, scrotal circumference, and spermiogram results including percent progressively motile spermatozoa and percent morphologically normal and abnormal spermatozoa for the initial BSE and up to 2 recheck evaluations. BSE results were converted into binary results by classifying them as pass or fail. For the purpose of this study, classification as a satisfactory potential breeder was considered passing the evaluation and classification as an unsatisfactory potential breeder or a decision-deferred bull was considered failure to pass the BSE.

Data Management

The original data set included 2,805 bulls and 3,252 evaluations. Data for bulls 15 months and older[18] (n = 36), younger than 11 months (n = 35), and from breeds with less than 20 bulls (n = 12) were removed prior to analysis. Bulls missing date of birth, breed, or scrotal circumference data (n=658) were also removed prior to analysis. The final data set included 2,342 evaluation results from 2,064 bulls. Physical exam findings, scrotal circumference, motility, and morphology as individual components of each bull's BSE were similarly converted to pass/fail binary results based on the 1993 SFT BSE requirements (Table 2). Failure in any category resulted in an overall failure classification.

Table 2 – BSE result pass or fail cutoffs

BSE Parameter	Pass	Fail
Physical Exam (soundness, vision, health)	NAF	Ab
Reproductive System Exam	NAF	Ab
Scrotal Circumference	≥ 30 cm	< 30 cm
Extension	Yes	No
Semen Sample	Yes	No
Motility	≥ 30% PM	< 30% PM
Morphology	≥ 70 % MNS	< 70% MNS

NAF-No abnormality found; Ab-Abnormality identified; PM-Progressively motile; MNS-Morphologically normal spermatozoa

Bulls were classified into one of four breed categories (Angus, Charolais, Simmental, and Angus-Simmental cross) based on information collected at the initial evaluation. Bulls classified as Angus-Simmental crosses were 50% Angus genetics and 50% Simmental genetics. There was only one source ranch for Charolais bulls. The other ranches contributed to at least two breed categories. Table 3 details the distribution of bulls by source ranch and breed category. Over half the bulls in the study population were from one source ranch. Data for age at time of initial evaluation was calculated in days from date of evaluation and date of birth and then categorized by rounding to the nearest month based on a 30 day month interval.

Table 3 - Summary of Source Ranch and Breed Category of Bulls

	Angus	**Charolais**	**Simmental**	**Angus Simmental Cross**	**Total**	**Percentage of Total**
Ranch A	30	0	130	62	**222**	10.8%
Ranch B	54	0	21	0	**75**	3.6%
Ranch C	38	0	0	0	**38**	1.8%
Ranch D	31	0	0	0	**31**	1.5%
Ranch E	21	0	212	80	**313**	15.2%
Ranch F	797	588	0	0	**1385**	67.1%
Total	**971**	**588**	**363**	**142**	**2064**	100.0%
% of Total	47.0%	28.5%	17.6%	6.9%	100.0%	

Statistical Analysis

Basic descriptive statistics were used to describe the number of bulls that were evaluated at each BSE, the age, the scrotal circumference, sperm motility and morphology, and percentage of evaluated bulls that passed initial, second, and third BSE. The physical exam and reproductive exam abnormalities identified at the initial BSE were also tabulated from the dataset. To determine if measured factors could predict risk of passing a subsequent BSE after failing the initial BSE, a general linear mixed model was used. The model considered fixed effects at initial evaluation including breed, age (month), scrotal circumference per day of age, and percentage of morphologically normal spermatozoa. Random effects were included in the model for origin ranch and test year. The model was constructed by including all potential effects and removing nonsignificant

($P > 0.05$) effects one at a time in a backwards stepwise manner. To determine if age or breed were statistically significant predictors of satisfactory initial BSE classification, a generalized linear mixed model was used. The model considered fixed effects including breed, age (month), and interaction between breed and age to determine if each was a significant predictor of passing for the initial evaluation. Random effects were included in the model for origin ranch and test year. The model was constructed by including all potential effects and removing nonsignificant ($P > 0.05$) effects one at a time in a backwards stepwise manner. The final model included only variables with values of $P \leq 0.05$. All analyses were performed with commercial statistical software[b].

Results

Following the removal of bull data that did not meet the age criteria or had missing data (n=741), records of 2,064 bulls evaluated at KABSU for breeding soundness by a single experienced technician were included in the analysis. The proportion of yearling bulls not classified as satisfactory potential breeders during their initial BSE which were later classified as satisfactory in up to two follow up evaluations was 143/287 (49.8%). No significant predictors for risk of eventually passing a BSE after failing an initial BSE were identified. Figure 2 shows the probability of the study bulls passing the initial BSE by age in months and breed. There was a significant interaction between age and breed of bull at initial BSE ($P < 0.01$; Figure 2).

[b] SAS, version 9.3, SAS Institute Inc., Cary, NC.

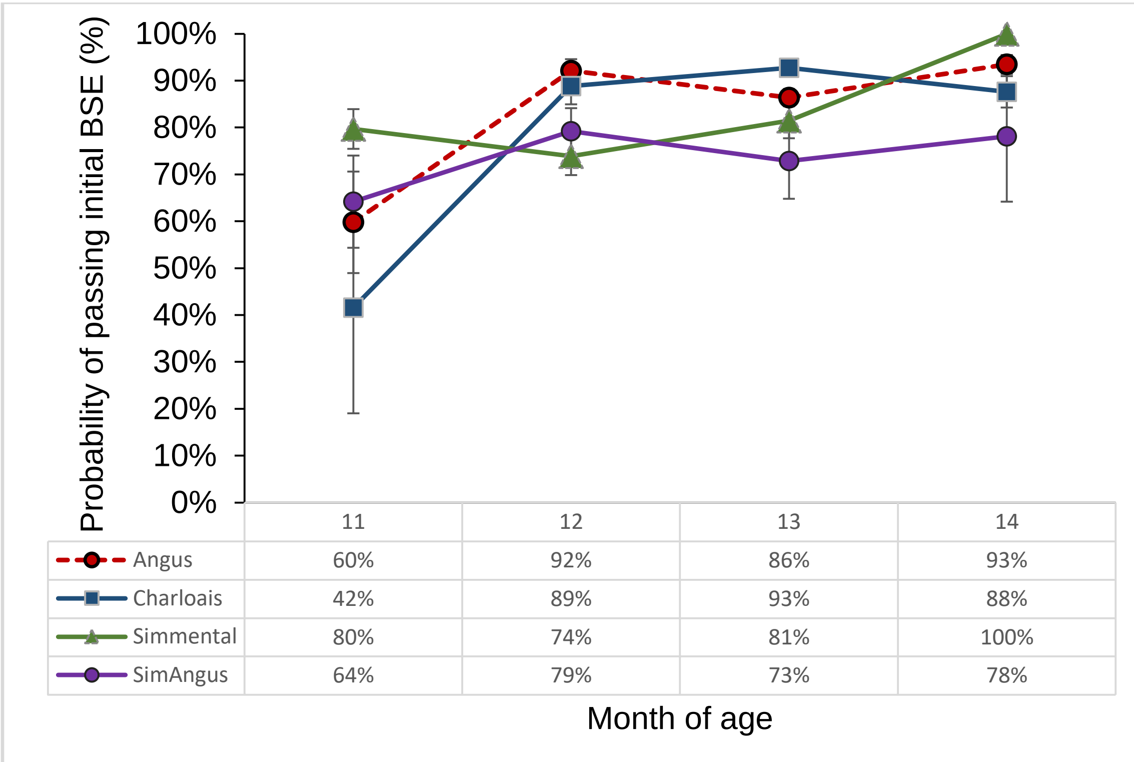

Figure 2 - Probability of Passing Initial BSE by Age (mo) and Breed

(Angus [dashed line with open circles]; Charolais [light grey line with closed squares]; Simmental [dark grey line with closed triangles]; and Angus-Simmental cross [black line with closed circles]). The interaction between age and breed was significant ($P < 0.01$).

Table 4 summarizes the breed and age of the bulls at initial BSE. Table 5 summarizes pass and fail status of each component of the initial BSE. At initial BSE, 1,777 of the 2,064 bulls (86.1%) were classified as satisfactory potential breeders. The SFT classification of 12 of the 287 bulls that failed the initial BSE was unsatisfactory potential breed; the remaining 275 were classified as decision deferred.

Physical exam abnormalities noted at initial evaluation included corneal ulceration (5), right front lameness (4), right hind lameness (1), left hind lameness (6), swollen feet/footrot (3), unspecified joint abnormality (1), sick/fever (1), hernia (1), neck abscess (1), and flank abscess (1). Reproductive exam abnormalities detected at initial evaluation in bulls that failed included white blood cells in the semen sample (36), red blood cells in the semen sample (2), enlarged seminal vesicles/seminal vesiculitis (8), warts (9), cryptorchidism (4), bilateral cryptorchidism (1), abnormal testicular palpation (10), penile injury (3), and persistent frenulum (13). Some bulls had more than one reproductive system abnormality noted. Persistent frenulums were found and treated in 7 additional bulls that passed the initial evaluation based on satisfactory performance in the other SFT categories. Scrotal circumference at initial BSE ranged from 26.0 cm to 45.5 cm. Ten bulls did not meet the minimum scrotal circumference requirement, but only one of those ten failed the BSE based on scrotal circumference alone. Motility did not meet the minimum guidelines in 134 bulls at initial evaluation. Morphology also did not meet minimum guidelines in 129 of the 134 bulls. Three of the 134 bulls with poor motility had reproductive system abnormalities as well. The minimum requirement for normal semen morphology was not met in 197 bulls at initial evaluation. There were 125 bulls that had > 50% primary morphologic defects on evaluation. Fifty bulls had 100% primary defects recorded. There were eleven bulls that had > 50% secondary morphologic defects. Forty-two bulls either did not provide a sample or provided a sample that lacked spermatozoa at initial evaluation. Ten bulls did not extend during the initial evaluation.

Table 4 - Summary Breed and Age (mo) Data at Initial BSE

	Angus	Charolais	Simmental	Angus Simmental Cross	Total
11 months	23	5	105	25	**158**
12 months	129	75	136	76	**416**
13 months	649	395	120	32	**1196**
14 months	170	113	2	9	**294**
Total	**971**	**588**	**363**	**142**	**2064**

Table 5 - Summary of Initial BSE Findings

	PE	RE	SC	Motility	Morphology	No Sample	No Extension	Overall BSE Result
# Pass	2033	1946	2054	1882	1816	2011	2055	**1777**
# Fail	31	118	10	182	248	53	9	**287**
% Pass	98.5%	94.3%	99.5%	91.2%	88.0%	97.4%	99.6%	**86.1%**
Total								**2064**

PE – Physical Exam; RE – Reproductive System Exam

Of the 287 that failed the initial BSE 234 were evaluated again. None of the bulls classified by the supervising veterinarian as SFT unsatisfactory were reevaluated. The reevaluation was done 7 to 67 days after the initial BSE. The average interval between BSE was 24.8 ± 1.2 days. The breed and age of the bulls at BSE 2 is summarized in Table 6. Table 7 summarizes the pass and fail status of each component of BSE 2. At second evaluation 120 bulls passed (51.3%) and 114 failed to meet the criteria. In the population of bulls that failed BSE 2, 7 were classified as SFT unsatisfactory by the supervising veterinarian and 107 were classified as decision deferred.

Table 6 - Summary Breed and Age (mo) Data at BSE 2

	Angus	Charolais	Simmental	Angus Simmental Cross	Total
11 months	1	1	13	1	**16**
12 months	5	2	17	16	**40**
13 months	14	9	35	7	**65**
14 months	69	25	12	7	**113**
Total	**89**	**37**	**77**	**31**	**234**

Table 7 - Summary of BSE 2 Findings

	PE	RE	SC	Motility	Morphology	No Sample	No Extension	Overall BSE Result
# Pass	233	199	232	161	129	219	234	**120**
# Fail	1	35	2	73	105	15	0	**114**
% Pass	99.6%	85.0%	99.1%	68.8%	55.1%	93.6%	100.0%	**51.3%**
Total								**234**

Forty-four of the bulls that failed the recheck evaluation were reevaluated. Two of the bulls classified by the supervising veterinarian as SFT unsatisfactory were reevaluated. The remaining 42 bulls were previously classified as decision deferred. The reevaluation was done 14 to 56 days after BSE 2. The average interval between BSE was 27.7 ± 3.0 days. The breed and age of the bulls at BSE 3 is summarized in Table 8. Table 9 summarizes the pass and fail status of each component of BSE 3.

Table 8 - Summary Breed and Age (mo) Data at BSE 3

	Angus	Charolais	Simmental	Angus Simmental Cross	Total
12 months	1	0	3	1	**5**
13 months	0	0	11	3	**14**
14 months	7	2	10	6	**25**
Total	**8**	**2**	**24**	**10**	**44**

Table 9 - Summary of BSE 3 Findings

	PE	RE	SC	Motility	Morphology	No Sample	No Extension	Overall BSE Result
# Pass	44	36	44	29	25	39	43	**24**
# Fail	0	8	0	15	19	5	1	**20**
% Pass	100.0%	81.8%	100.0%	65.9%	56.8%	88.6%	97.7%	**54.5%**
Total								**44**

At the third BSE 24 of the bulls passed (54.5%) and 20 of the bulls failed to meet the criteria to be classified as satisfactory potential breeders. One of the two bulls that was classified as unsatisfactory at BSE 2 was classified as satisfactory at BSE 3. Of the 2,064 bulls that were presented for evaluation, 1,921 (93.1%) bulls passed after a maximum of three evaluations (Figure 3).

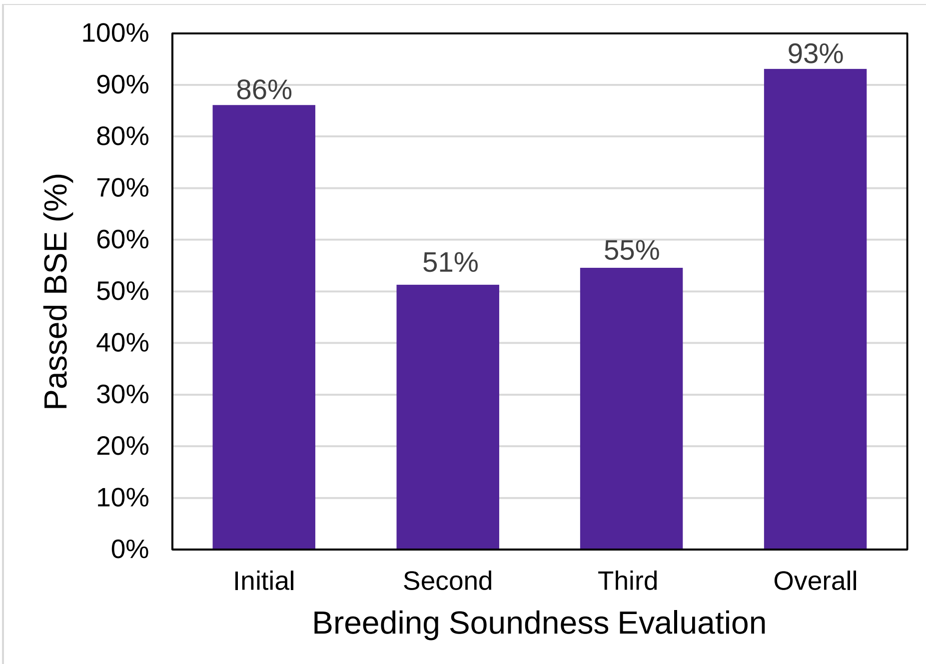

Figure 3 - Percentage of Yearling Bulls Evaluated that Passed BSE Requirements

Discussion

The present study was conducted to determine the proportion of yearling bulls that were not classified as satisfactory potential breeders during their initial breeding soundness evaluation that were later classified as satisfactory in follow up evaluations. Overall 86% of the bulls in the current dataset passed initial evaluation and 93% of the bulls in the dataset passed after three evaluations were done. And, of bulls that failed an initial BSE, 49.8% eventually passed one of two subsequent reevaluations. Breed, age (month), scrotal circumference per day of age, and percentage of morphologically normal spermatozoa at initial BSE of 2,064 bulls were not associated with risk of passing subsequent evaluations. Previous research has looked at factors that can be used to predict puberty or maturity status, but no studies have looked specifically at factors that can predict the risk of passing subsequent evaluations utilizing the data collected at initial BSE.[17,18,52,56,58,59,61,62,67,72,78,82,89]

Age of the bull at initial evaluation as well as age at presumed sexual maturity are important to consider. Bulls going through puberty have high numbers of morphologic sperm abnormalities, especially proximal droplets, as well as low sperm motility.[18,58,61,87] Barth also presented a retrospective study on yearling Simmental bulls that showed high prevalence of primary defects including proximal protoplasmic droplets compared to secondary defects in bulls that failed to pass the BSE due to morphology.[15] The data used in the current study did not specify the morphologic defects noted on evaluation but instead numerically reported the number of normal sperm, sperm with primary defects, and sperm with secondary defects as defined by 1993 SFT guidelines. Due to this limitation, the present study had limited ability to describe the proportion and character of the morphologic defects, especially proximal droplets, encountered during BSE. Within the limitations of the study, the finding that 96% of the bulls that failed the initial BSE did not meet the minimum guidelines for morphology is consistent with findings in previous studies.[18,58,61]

In the current study, bulls that were older were more likely to pass a BSE than younger bulls, which is consistent with previous studies that evaluated semen quality in bulls less than 16 months old at a single timepoint.[17,18,68,69,90] Chenoweth reported that qualitative semen traits in beef bulls in Florida increased from 12 to 18 months of age.[61]

Johnson reported that the percent morphologically normal spermatozoa obtained from beef bulls in his study increased with increased age within bull group (10-12 mo, 13-18 mo, 19-24 mo, ≥ 25 mo).[70] Coe and colleagues found that Angus, Simmental, Hereford, and Limousin yearling bulls (8 to 15 mo) that produced ≥ 70% morphologically normal spermatozoa were significantly older than bulls of the same breed that produced spermatozoa with unsatisfactory morphology. Population statistics in Coe's study showed that the risk of failing to produce an adequate number of morphologically normal spermatozoa decreased as age increased. Coe and colleagues concluded age at first BSE was more important than scrotal circumference for predicting semen quality in their population of yearling bulls.[67] Age at initial BSE in months was evaluated as a possible predictor of passing reevaluation after failing the initial BSE and was not a significant predictor in the study population.

In the present study 73% of the bulls that were 11 months of age at initial BSE met SFT requirements for classification as satisfactory potential breeders. Similarly, 83%, 88%, and 91% of the study population bulls met the SFT minimum requirements at 12, 13, and 14 months of age at initial BSE respectively. A study of 11 to 15 month old beef bulls in Canada defined mature spermiograms as the production of ≥ 400 x 10^6/mL sperm with ≥ 60% progressive motility and ≥ 70% normal morphology.[18,57] At 11 months of age only 20% of the bulls had mature spermiograms.[4] At 12, 13, 14, and 15 months of age 30%, 51%, 52%, and 61% of the bulls had mature spermiograms, respectively.[18] Combining all age categories of the 11 to 15 month old bulls in the study, 42% of the bulls met all the criteria for a mature spermiograms and only 57% had ≥ 70% morphologically normal sperm.[18] Based on analysis of BSEs from yearling bulls presented to Western College of Veterinary Medicine, Barth reports that most bulls (81-100%) will have satisfactory semen quality by 16 months of age.[2,15,91]

Bulls reach maturity when their testes are fully functional and semen quality has attained adult levels. Semen quality of young bulls is expected to be similar to that of mature bulls by 12 to 16 months of age or 16 weeks after the onset of puberty.[15,18,58] Onset of puberty in beef bulls occurs between 8 and 12 months of age when puberty is defined as the first production of at least 50 million spermatozoa with at least 10% having progressive motility.[56] Young bulls still going through puberty have low sperm motility and a high percentage of morphologic defects.[18,58,61,70,87] Various studies have looked at the onset of puberty of bulls by breed.[57,58,60] The onset of puberty in Angus and Hereford bulls has been reported to occur between 9 and 12 months.[57,58] The onset of puberty in Charolais bulls has been reported to occur between 7.5 and 12.5 months of age.[60] Onset of puberty in Simmental and Simmental cross bulls has not been previously reported, but Barth reported that in a population of 93 Simmental yearling bulls 35.3% of the 12 mo bulls had satisfactory semen quality. The percentage of Simmental bulls with satisfactory semen quality improved with age and 56.5%, 61.2%, and 83.3% of the bulls had satisfactory semen at 13, 14, and 15 months of age respectively. Barth's findings are consistent with the findings of the study described above as well as previous studies of morphologic sperm defects of yearling bulls that found that older bulls are more likely to have satisfactory semen quality at initial BSE.[20,58] Percentage of morphologically normal spermatozoa was evaluated as a possible predictor of passing reevaluation after failing the initial BSE and was not a significant predictor in the study population.

In the population described by this study, very few bulls failed to meet the minimum requirement for scrotal circumference. Data on pre- and post-weaning bull management and genetic selection was not available for review but the study population of bulls was being bred and raised for sale and use as yearling bulls. The producers that participated in the study were motivated to select for early maturing bulls and to manage the bulls so that optimal weight and condition would be met by sale time. The expected selection and growth pressure presumed in the study population could explain the low number of bulls with small scrotal circumference seen in the study. Several studies have shown that scrotal circumference can be utilized to select for early maturing bulls.[18,46,52,56,87] Coe et al. reported that only 27% of the bulls in his study with scrotal circumference > 30 cm produced <70% morphologically normal sperm.[67] In the current study, 10 of the 2,064 bulls (0.5%) had <30 cm scrotal circumference and 197 (9.5%) had <70% morphologically normal sperm. Previous research has suggested that scrotal circumference may be a more accurate predictor of the time of onset of puberty than either age or weight regardless of breed.[58,67,87] Scrotal circumference per day of age was evaluated as a possible predictor of passing reevaluation after failing the initial BSE and was not a significant predictor in the study population.

Previously studies evaluating the onset of puberty based on breed, age, or scrotal circumference report that the average age of pubertal onset varies by as much as 62 days among the six beef breed groups and 88 days among bulls within the breed groups evaluated.[58] The variation in the onset and duration of puberty and the effects of nutrition and environment on growing bull calves makes estimating the age at which bulls will have mature spermiograms very difficult. Due to estimation of timing mature spermiograms difficulty, it is common to have bulls that were young at initial BSE reevaluated to try and separate bulls that failed due to immaturity from those that are sufficiently mature but are unsatisfactory potential breeders.

The secondary objective of the study was to determine if age or breed play a role in the likelihood to fail the initial breeding soundness evaluation and then create guidelines for the minimum age at which Angus, Simmental, and Charolais bulls from the study populations are evaluated for breeding soundness. Based on the limitations of the current study we were unable to develop recommendations for minimal age to test different breeds of beef bulls. Chase and colleagues previously looked at the effect of breed on growth and reproductive development and identified significant breed-by-age interactions in yearling beef bulls for body, testicular, skeletal, and pelvic growth traits. Chase's study concluded that the breeds of bulls in the study population had different patterns of body, testicular, skeletal, and pelvic growth between 8 and 20 months of age.[59] Breed was evaluated as a possible predictor of passing reevaluation after failing the initial BSE and was not a significant predictor in the study population.

A similar study looking specifically at reproductive traits and BSE categorization by Chenoweth concluded qualitative semen traits increased with age from 12 to 18 months of age and breed influenced sperm motility, percentage normal sperm morphology, and percentage primary morphologic defects.[61] These two studies were also not able to identify an age based on breed that could be significantly associated with maturation in their study populations. Coe and colleagues looked at the proportion of bulls that had values less than the population means for age, scrotal circumference, and percent morphologic normal sperm within breed at a single time point.[67] Coe's study concluded that among yearling bulls in their study population the older bulls with larger scrotal circumference measures were more likely to produce >70% morphologically normal sperm but age and scrotal circumference were not significant predictors of semen quality.[67] Menon recently studied the association between sperm abnormalities and breed, age group (11-13 mo, 13.5-18 mo, 19-26 mo, and > 26mo), scrotal circumference, and the percentage of beef bulls in Alberta with satisfactory sperm morphology.[72] Menon did not find significant association between mean percentage of sperm abnormalities, total abnormal and normal sperm, age, and scrotal circumference of the beef bulls.[72] Due to the breed and age interactions identified in multiple studies, further research designed to look at weight, physical exam abnormalities, reproductive exam findings, scrotal circumference, sperm motility, and sperm morphology in a single breed group from 11 months of age to 16 or 18 months of age would be better suited to developing recommendations for minimal age to test different breeds of beef bulls.

Limitations of this study includes the drawback that the data was limited to bulls that the participating producers chose to bring back for reevaluation. The investigators did not have control over which bulls were reevaluated and which bulls were culled from the sale population without reevaluation. The investigators were also not privy to the reasons behind selection for culling or reevaluation. The statistical inferences with the data available were also limited by the fact that bulls that were classified as satisfactory were not presented for reevaluation alongside the bulls that had previously been classified as unsatisfactory so each evaluation was treated as a separate event rather than evaluating pass and fail risk over time. Also detailed information on the number and type of morphologic defects for each bull at each evaluation was not available. The study population was also limited to a small number of ranches that met the inclusion criteria in a limited geographic area of Kansas. Charolais bulls in the study were all from one ranch. The other breed groups included in the study were composed of bulls from at least 2 different ranches. Within that population of 2,805, there were 741 bulls that had to be excluded due to missing data or because they did not meet the inclusion criteria. In order to avoid variations in sperm motility and morphology assessment between evaluators, only results from BSEs done by a single highly trained and experienced technician were included in the study dataset.

Conclusions

Analysis of up to three BSE results of 2,064 beef bulls comprised of 4 common breed groups in Kansas revealed no significant predictors for risk of passing subsequent evaluations in the yearling bulls that failed initial BSE. The older yearling bulls were more successful at initial BSE than younger bulls. Age and breed information should be considered when deciding at what age initial BSE is scheduled for a yearling bull cohort and when selecting yearling beef bulls that failed initial BSE for reevaluation.

Chapter 5 - Thesis Conclusion

Appropriate selection of young replacement heifers is important for improving or maintain herd reproductive performance. Appropriate replacement heifer selection is the most productive way to adjust inefficient calving distributions by shifting a higher percentage of the herd to calve early in the calving season and thereby increasing the pounds of calf weaned in the year. The potential of introducing heifers that will increase productivity of the herd will only be realized if appropriate measures are taken to select heifers that are actively cycling at the beginning of the heifer breeding season.

Similarly, selecting young bulls to use in the herd bull battery can have the benefit of reducing generation interval for genetic improvement of the herd and will decrease the cost per cow exposed compared to the purchase of older bulls but comes with the same risk of inconsistent reproductive performance. The use of younger bulls can result in decreased herd reproductive performance if the bulls are not sufficiently sexually mature. Both the ability of a bull to transfer desired genetics and to support optimum herd reproductive performance are dependent on the fertility of the bull. Young bulls are hypothesized to be less efficient due to inexperience, unknown or decreased libido, and potentially less than desirable semen quantity and quality due to immaturity.[15-23]

The first study in this thesis was a prospective study designed to evaluate the novel RIP management-driven matrix as a possible tool for augmenting current management decisions and selecting replacement heifers that meet individual producer goals for AI and pasture breeding situations. This original, small, very controlled study found that the RIP matrix can be useful for classifying heifers in preparation of the breeding season. Heifers that are classified as Problems are less likely to become pregnant to single AI exposure, pregnant in the first 21 days of the breeding season, and pregnant during the breeding season compared to heifers that are classified as Ready. Further research is needed to evaluate the matrix in a commercial setting and in populations of heifers more representative of the U.S. beef heifer herd as a whole as well as at different intervals between evaluation and the start of breeding season. Additional research that evaluates the performance of classified heifers at 2 and over the productive lifetime of the cow (6-9 years or more) would also be of value.

The second study was a retrospective study designed to investigate the factors associated with passing subsequent BSEs after failing an initial evaluation in yearling bulls. The study determined the proportion of yearling bulls that were not classified as satisfactory potential breeders during their initial breeding soundness evaluation that were later classified as satisfactory in follow up evaluations. Overall 86% of the bulls in the study dataset were classified as satisfactory potential breeders by SFT standards at initial evaluation which increased to 93% of the bulls in the dataset after three evaluations were done. Specifically, of the bulls that failed the initial BSE, 49.8% eventually passed one of two subsequent reevaluations. Breed, age (month), scrotal circumference per day of age, and percentage of morphologically normal spermatozoa at initial BSE were not associated with risk of passing subsequent evaluations. As age at initial evaluation was positively correlated with the percentage of bulls in that age group that passed initial evaluation. At 11, 12, 13, and 14 months of age, 73%, 83%, 88%, and 91% of the bulls in that age cohort passed initial evaluation respectively.

Identification of suitable peripubertal replacement animals remains a challenge for producers. There are several factors that can affect replacement animals' ability to perform according to expectations at the beginning of the breeding season. Classification of heifers into categories that can predict performance during breeding season with reasonable confidence can assist producers in identifying heifers that complement the reproductive performance goals of the herd. Utilizing BSE to identify bulls that have adequate semen quality as well as other traits important for breeding soundness is similarly important in reducing the risks of using young bulls for breeding. BSE will not evaluate a bull's ability to achieve intromission or libido but will classify the bull as a satisfactory or unsatisfactory potential breeder based on semen quality.

Chapter 6 - References

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Appendix A - RIP Summary Data

Ranch	A	B	C	D	E	F	Overall
Population							
# Enrolled	44	32	119	97	31	18	**341**
# AI Program	44	32	75	97	31	18	**297**
Avg. Age (d) RIP	431	445	372	414	418	423	**405**
# BCS ≥ 5	44	32	119	97	31	18	**341**
Avg %MBW	65%	71%	62%	63%	61%	65%	**64%**
# MBW <%50	0	0	1	0	3	0	**4**
Avg. PA (cm^2)	173.3	197.6	175.2	149.4	163.1	178.3	**168.8**
# PA ≤ 130 cm^2	0	0	0	11	2	0	**13**
CSU RTS							
1	0	0	0	0	0	0	**0**
2	0	0	1	1	1	0	**3**
3	1	1	6	35	5	2	**49**
4	22	13	48	34	6	5	**128**
5	21	18	67	28	19	11	**161**
RIP							
R	41	30	106	36	22	17	**252**
I	3	1	6	34	3	1	**48**
P	0	1	7	27	6	0	**41**
Pregnancy							
# Bred	42	30	108	78	24	16	**298**
% Bred	95.5%	93.8%	90.8%	80.4%	77.4%	88.9%	**87.4%**
# AI Bred	32	15	41	41	6	12	**147**
% AI Bred	72.7%	46.9%	54.7%	42.3%	19.4%	66.7%	**49.5%**
# Bull Bred	10	15	67	37	18	4	**151**
% Bull Bred	22.7%	46.9%	56.3%	38.1%	58.1%	22.2%	**44.3%**
# Open	2	2	11	19	7	2	**43**
% Open	4.5%	6.3%	9.2%	19.6%	22.6%	11.1%	**12.6%**
Pregnancy by 21 day cycle							
1	35	22	77	51	7	12	**204**
2	2	6	15	18	15	0	**56**
3	5	1	10	4	2	1	**23**
4	0	1	6	5	0	3	**15**

Appendix B - RIP Heifer Classification Herd Data

Herd	A
Date of RIS Classification:	4/4/15
Date Start Breeding Season:	AI dates: 4/7/15 x2 Date Bull(s) in: 5/1/15 Date Bull(s) out: 7/1/15
Synchronization protocol and dates	MGA from 3/3/15 until 3/16/15, Lutalyse 4/4/15
Dates of Calving Season:	12/27/13-3/6/14
Age Range:	394-463
Date of Weaning (Age at Weaning)	8/29/14
Weight at Weaning (range)	485-622 lbs
Average mature cow weight	1400
Diet(s) post weaning	Up for 1 month on corn distillers grain mix and prairie hay, Dec1-Mar 1 on pasture wheat, switch from wheat to prairie now
Date Preg Check	8/4/15

Herd	B
Date of RIS Classification:	4/21/15
Date Start Breeding Season:	AI dates: 4/30/15 Date Bull(s) in: 5/4/15 Date Bull(s) out: 6/18/15
Synchronization protocol and dates	CIDRs + GnRH 4/21/15, CIDRs + lutalyse in 7 days, GnGH on insemination
Dates of Calving Season:	10/13/13-4/2/14
Age Range:	384-555
Average mature cow weight	1400
Date Preg Check	8/31/15

Herd	C
Date of RIS Classification:	3/30/15
Date Start Breeding Season:	AI dates: 5/18/15-5/19/15 (timed AI, then watch) Date Bull(s) in: 5/28/15 (pasture bred), 5/28/15 (AI) Date Bull(s) out: 7/15/15
Synchronization protocol and dates	Synch with CIDRs & cystorelin, pull CIDRs at 7 days and give lutalyse, bred off heat and time AI on second morning
Dates of Calving Season:	2/11/14-5/7/14
Age Range:	341-411
Date of Weaning (Age at Weaning)	9/17/14 and 9/22/14 (138-218 days)
Weight at Weaning (range)	498-760
Average mature cow weight	1400 lbs (1250-1700)
Diet(s) post weaning	Corn gluten and brome hay, Swithced to prairie hay around March 1. Started gluten at 2 lbs. per head per day. Worked up to a max of 5 lbs.
Date Preg Check	8/31/15

Herd	D
Date of RIS Classification:	6/2/14
Date Start Breeding Season:	AI dates: 6/12/14 (timed) Date Bull(s) in: 6/14/14 Date Bull(s) out: 7/27/14 Renegade bull in: 8/18/14
Synchronization protocol and dates	6/3/14 CIDRs in, fentagyl, 6/10/14 CIDRs out, Estrumate
Dates of Calving Season:	3/22/15-5/4/15 (43 days)
Age Range:	377-433 days
Date of Weaning (Age at Weaning)	8/7/213 (78-134 days)
Weight at Weaning (range)	126-378 lbs
Average mature cow weight	1600 lbs
Diet(s) post weaning	Native range, 7 lbs wet corn gluten feed from 10/1/13-4/30/14
Date Preg Check	9/26/14

Herd	E
Date of RIS Classification:	4/4/15
Date Start Breeding Season:	AI dates: 4/29/15-5/14/15 Date Bull(s) in: 5/19/15 Date Bull(s) out:
Synchronization protocol and dates	No synch program. Bred on heat detection.
Dates of Calving Season:	1/2/14-4/30/14
Age Range:	339-457
Average mature cow weight	1400

Herd	F
Date of RIS Classification:	3/31/15
Date Start Breeding Season:	AI dates: 4/10/15 Date Bull(s) in: 5/20/15 Date Bull(s) out: 7/1/15
Synchronization protocol and dates	7 day CIDR, Cysterelin day1, Lutalyse day 7
Dates of Calving Season:	1/9/14-3/8/14
Age Range:	388-446 days
Date of Weaning (Age at Weaning)	8/17/15
Weight at Weaning (range)	550-700
Average mature cow weight	1200 lbs
Diet(s) post weaning	For 45 days 0.48 NEg then Brome pasture and 3 lbs protein supplement and mineral until 3/7/15 when they were brought up and offered 0.54 NEg until bred, back on grass May 20
Date Preg Check	8/7/15

Appendix C - Yearling BSE Result Summary Data by Ranch

BSE 1

Ranch	A	B	C	D	E	F	Overall
# Enrolled	222	75	38	31	313	1385	**2064**
BSE Overall Result							
# Pass	179	54	37	30	235	1242	**1777**
# Fail	43	21	1	1	78	143	**287**
Physical Exam							
# Pass	220	75	38	31	310	1375	**2049**
# Fail	2	0	0	0	3	10	**15**
Reproductive Exam							
# Pass	204	71	38	31	288	1358	**1990**
# Fail	18	4	0	0	25	27	**74**
Scrotal Circumference							
SC Min (cm)	29.0	30.5	33.5	35.0	26.0	27.5	**26.0**
SC Max (cm)	44.0	45.5	44.5	44.0	44.0	45.0	**45.5**
SC Avg (cm)	36.5	37.2	38.7	34.8	36.2	36.8	**36.8**
# Pass	221	75	38	31	310	1382	**2057**
# Fail	1	0	0	0	3	3	**7**
Motility							
Min % Progressive Motile	0	0	10	30	0	0	**0**
Max % Progressive Motile	70	60	70	60	90	70	**90**
Average	40	34	48	49	46	43	**43**
# Pass	208	57	37	31	290	1330	**1953**
# Fail	14	18	1	0	23	55	**111**
Morphology							
Normal Min	0	0	40	20	0	0	**0**
Normal Max	90	80	90	90	95	90	**95**
Normal Avg	69	59	81	78	74	74	**73**
1° Abnormality Min	0	2	5	0	0	5	**0**
1° Abnormality Max	100	100	41	15	100	100	**100**

1° Abnormality Avg	18	24	8	8	16	16	**16**
2° Abnormality Min	0	0	5	5	0	0	**0**
2° Abnormality Max	80	60	20	80	80	80	**80**
2° Abnormality Avg	13	18	11	14	11	13	**13**
# Pass	207	54	37	30	280	1305	**1913**
# Fail	15	21	1	1	33	80	**151**

BSE 2

Ranch	**A**	**B**	**D**	**E**	**F**	**Overall**
# Enrolled	43	13	1	69	108	**234**
BSE Overall Result						
# Pass	11	8	0	34	67	**120**
# Fail	32	5	1	35	41	**114**
Physical Exam						
# Pass	43	13	1	68	108	**233**
# Fail	0	0	0	1	0	**1**
Reproductive Exam						
# Pass	36	11	1	57	99	**204**
# Fail	7	2	0	12	9	**30**
Scrotal Circumference						
SC Min (cm)	30.0	34.0	36.0	29.0	29.0	**29.0**
SC Max (cm)	40.0	44.0	36.0	42.5	47.0	**47.0**
SC Avg (cm)	35.0	37.0	36.0	35.5	36.5	**40.0**
# Pass	43	13	1	68	107	**232**
# Fail	0	0	0	1	1	**2**
Motility						
Min % Progressive Motile	0	0	30	10	0	**0**
Max % Progressive Motile	60	50	30	70	70	**70**
Average	20	32	30	38	39	**35**
# Pass	11	10	1	49	81	**152**

# Fail	32	3	0	20	27	**82**
Morphology						
Normal Min	0	0	20	5	0	**0**
Normal Max	85	80	20	90	95	**95**
Normal Avg	27	51	20	61	68	**58**
1° Abnormality Min	5	10	0	0	5	**0**
1° Abnormality Max	100	100	0	92	100	**100**
1° Abnormality Avg	60	40	0	27	31	**35**
2° Abnormality Min	0	0	80	0	0	**0**
2° Abnormality Max	60	30	80	50	40	**80**
2° Abnormality Avg	13	10	80	15	2	**9**
# Pass	11	8	0	34	67	**120**
# Fail	32	5	1	35	41	**114**

BSE 3

Ranch	**A**	**B**	**E**	**F**	**Overall**
# Enrolled	17	4	19	4	**44**
BSE Overall Result					
# Pass	8	2	11	3	**24**
# Fail	9	2	8	1	**20**
Physical Exam					
# Pass	17	4	19	4	**44**
# Fail	0	0	0	0	**0**
Reproductive Exam					
# Pass	15	2	15	4	**36**
# Fail	2	2	4	0	**8**
Scrotal Circumference					
SC Min (cm)	31.0	34.0	32.0	32.0	**31.0**
SC Max (cm)	40.0	38.0	40.0	36.0	**40.0**
SC Avg (cm)	35.0	35.0	35.0	34.0	**35.0**
# Pass	17	4	19	4	**44**

# Fail	0	0	0	0	**0**
Motility					
Min % Progressive Motile	10	0	0	35	**0**
Max % Progressive Motile	60	40	50	60	**60**
Average	30	26	35	44	**33**
# Pass	9	3	14	4	**30**
# Fail	8	1	5	0	**14**
Morphology					
Normal Min	0	0	0	60	**0**
Normal Max	80	75	90	95	**95**
Normal Avg	52	46	66	79	**60**
1° Abnormality Min	5	10	0	5	**0**
1° Abnormality Max	90	100	100	40	**100**
1° Abnormality Avg	40	44	25	21	**33**
2° Abnormality Min	0	0	0	0	**0**
2° Abnormality Max	50	20	30	0	**50**
2° Abnormality Avg	16	10	10	0	**12**
# Pass	9	2	11	3	**25**
# Fail	8	2	8	1	**19**