Evaluating factors influencing pregnancy in beef cows and evaluating factors at weaning influencing ability to pass breeding soundness examination in beef bulls

by

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Abstract

The common thread of this research was to identify factors that improve efficiency and subsequent profitability for cow-calf producers. The objective of the literature review was to evaluate factors, such as nutrition, breed, season of birth, exposure to cycling females and hormones that influenced puberty in peri-pubertal bulls. Finding factors that influence puberty are important for both for seedstock producers and commercial cattlemen. Bulls that attain puberty earlier have a higher likelihood of passing the breeding soundness examination by the time of marketing.

The objective of the first study was to determine if factors such as herd size, breeding season length, body condition of cow at mid-gestation, or the timing of breeding season affected the likelihood of pregnancy at the end of the first 21-day interval and at the end of the breeding season. Data were collected by convenience sampling from herds (n=241) consisting of 8,217 head located in the Midwest and Great Plains regions of the US from 2012 to 2017. Pregnancy diagnosis data were recorded in either 20- or 21-day intervals. A logistic regression model was used to evaluate the effect of the relevant factors (herd size category, breeding season length category, body condition score category, and timing of breeding season category) on the probability of pregnancy status at two different time-points (21-day and end of breeding season). Overall, an average 53.6% of cattle across all herds were pregnant by the end of the first 21-day interval, and an average 85.2% of cattle across all herds were pregnant by the end of the breeding season. Herds with short or medium breeding season lengths (<63 days or 63-84 days) had increased probability of pregnancy (65% and 58%, respectively) for the first 21-day interval compared to herds with a long breeding season (49%). Cows in thin body condition at the time of pregnancy diagnosis had reduced probability of having become pregnant during both the first 21-day interval (44%) and the entire breeding season (64%) when compared to cows in moderate (62%, 86%) and fleshy (66%, 91%) condition. Herds with less than 50 head had reduced probability of pregnancy (51%, 78%) as compared to medium sized (50-99 head) herds (63%, 84%) for both the 21-day interval

and overall breeding season. Herds that started the breeding season in the fall had higher probability of pregnancy at the end of the breeding season (88%) as compared to spring start dates (82%). Management factors such as breeding season length, body condition score, herd size, and timing of breeding season had significant impacts on the probability of pregnancy. In the future, more research needs to be conducted to evaluate the economic impacts of these management choices.

The focus of the next study was identifying bulls at a young age with higher likelihood of passing a breeding soundness examination as yearlings. Finding these bulls at weaning may improve management options to optimize production efficiency and profitability. The objective of this study was to evaluate the effect of weaning scrotal circumference and other factors collected at the time of weaning on the likelihood of passing a breeding soundness examination as a yearling. Data, at both weaning and time of breeding soundness examination, were collected from one operation (n = 466 bulls). A logistic regression model was used to evaluate the potential associations of relevant factors (actual weaning scrotal circumference, adjusted weaning scrotal circumference, weight per day of age at weaning, scrotal circumference per day of age at weaning, weaning weight, days of age and breed) on the probability of passing a breeding soundness examination as a yearling. Overall, 92.3% of bulls passed the yearling breeding soundness examination on first evaluation. Weaning scrotal circumference was the only factor of those evaluated associated ($P < 0.01$) with the probability of passing the breeding soundness examination. No significant differences were found between the categories of weaning scrotal circumference. Bulls with weaning scrotal circumference over 31 cm had the lowest probability (80.9%) of passing the yearling breeding soundness examination, but was not statistically significant. Breed was not associated ($P = 0.53$) with the probability of passing the breeding soundness examination. In the future, more research needs to evaluate predictive model development for weaning scrotal circumference and ability to pass breeding soundness examination.

Table of Contents

I. List of Figures

II. List of Tables

III. Acknowledgements

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IV. Chapter 1: Review of Literature

A. Factors influencing puberty in beef bulls

1. Introduction

Bull development with regards to pubertal onset, and later sexual development can be influenced by several factors. A literature review conducted to was to evaluate factors, such as nutrition, breed, season of birth, exposure to cycling females and hormones that influenced puberty in peri-pubertal bulls. Puberty is defined as when a bull can produce ejaculate containing 50 million sperm cells with 10% motility. Identifying factors that can hasten the onset of puberty in bulls can help producers mitigate development costs.

2. Nutrition:

Nutrition is a key component to bull development and for maximizing genetic potential. Poor nutrition in the pre-weaning phase is known to impact the onset of puberty with delayed body and testicular development, regardless of post-weaning nutrition[1]. During the post-weaning phase, nutrition has less overall impact on the onset of puberty. Bulls fed a low plane of nutrition (0% concentrate) post-weaning were lighter as compared to bulls receiving medium nutrition (6.6% concentrate), but did not differ in their sexual development or onset of puberty[1]. Bulls in the same study receiving medium nutrition were older at puberty as compared to both low and high nutrition (37% concentrate) groups despite being heavier[1]. Another study, by Pruitt, also found that higher levels of energy did not hasten the age at first mating or puberty in bulls categorized as Simmental or Hereford, despite larger scrotal circumference measurements in the Simmental group[2]. Post-weaning nutrition has little impact on the onset of puberty, as compared to pre-weaning nutrition when both pre- and post-weaning nutrition is adequate.

In a study by Bourgon, bulls were fed either grain (high level) or roughage (moderate level) diets post-weaning, and then were categorized based on feed efficiency. Bulls fed the grain diet had increased scrotal skin thickness, while bulls fed the roughage diet had lesser semen quality (% motility, % normal morphology, etc.) and decreased scrotal skin thickness [3]. Brito did not find a correlation between average daily gain with any end points related to sexual development[4]. There was a negative correlation between body weight at 210, 266, and 294 days of age and age at puberty in Angus x Charolais bulls showing that faster growing bulls had younger age at puberty[4]. A study by Barber found that greater weight per day of age at attainment of puberty was correlated with both lower percent of progressive motile sperm and percent of live sperm in puberal ejaculation [5]. There was no correlation between body weight, age, or scrotal circumference at puberty with any puberal ejaculation traits[5]. A study by Coulter evaluated the effect on moderate (100% forage diet) or high (80% forage, 20% concentrate) nutrition on scrotal surface temperature and semen quality[6]. Bulls fed the high level diet had less progressively motile sperm as compared to bulls fed the moderate level diet[6]. While post-weaning nutrition has little impact on the onset of puberty, it does have an effect on semen quality. Bulls fed high quality diets result in heavier body weights, thicker scrotal skin, and subsequently lower fertility. Inversely, bulls fed low quality diets result in lower fertility.

In the feed efficiency portion of Bourgon's research, efficient grain-fed bulls had greater percentage of normal sperm morphology and increased scrotal circumference as compared to the non-efficient grain-fed bulls. Efficient roughage-fed bulls had smaller scrotal circumference, decreased scrotal skin thickness, lower/less scrotum base average temperature, less pronounced scrotum temperature gradient, lower T3, and lower testosterone, with increased percentage of head abnormalities as compared to non-efficient roughage-fed bulls [3]. This study indicates that in feed efficient bulls, fertility is not compromised with high nutrition which differs from the effect of high nutrition in bulls with lower feed efficient [3].

Scrotal circumference is commonly influenced by body weight, or more specifically body fat. Fat deposition within the scrotum can have detrimental effects on fertility due to impairment of thermoregulation. Another study by Bourgon found that carcass fat was positively correlated with scrotal circumference [7]. Carcass fat was also found to be inversely correlated with percentage of sperm tail defects and vesicular gland area, meaning bulls with increased carcass fat had lower percentage of abnormal sperm cells and smaller vesicular gland area[7]. In contrast, a study by Coulter found that bulls fed a high level diet had a lesser scrotal surface temperature gradient as compared to the moderate level diet[6]. These same bulls had decreased progressive motility and reduced normal morphology[6]. A positive correlation was found between body weight at 238 days of age, between 182-406 days of age, and at 490 days of age with paired testes weight[4]. Another study found moderate to high correlations between body weight, back fat, scrotal circumference, and paired testes volume [8]. Scrotal circumference and testes weight are influenced by body weight. Bulls with excessive fat are at risk for impairment of thermoregulation, and increased abnormal sperm cell development.

3. Breed:

Aside from phenotypic differences in *Bos taurus* and *Bos indicus* breeds, physiologic differences also exist. *Bos indicus* breeds consistently tend to be later maturing, attaining puberty at an older age. *Bos taurus* breeds vary in scrotal circumference development based on maternal or terminal usage. Breeds developed for milk production (Braunvieh, Gelbvieh, Red Poll, Pinzagauer, and Simmental) reach puberty at a younger age, and have larger testes[9]. Conversely, breeds not developed for milk production (Charolais, LImousin, and Hereford) are older at puberty[9].

In a study performed by Lunstra, breed had a significant effect on scrotal circumference at both 230 days of age and as a yearling. Brahman and Boran bulls had smaller scrotal circumference measurements at 230 days of age compared to other breeds[10]. Brahman, Boran, and Tuli bulls had smaller scrotal circumference as yearlings, while Angus had the largest scrotal circumference measurement[10]. Angus bulls also reached puberty 23-82 days earlier than other breeds[10]. Brahman bulls were the oldest and largest when they reached puberty[10]. Another study by Lunstra demonstrated that *Bos taurus* breeds attained puberty on average at 344 days of age, compared to Bos indicus crossbreds who attained puberty on average at 404 days of age[11]. Despite the differences in age at puberty, the scrotal circumference was nearly identical at onset of puberty[11]. A study by Casas also showed that Angus bulls reached puberty at younger ages, as compared to older maturing breeds: Wagyu and Swedish Red White[12]. In this study, scrotal circumference growth rate was not influenced by breed[12]. Another study showed that breed was significant for initial scrotal circumference measurement (first spermatozoa), but not final scrotal circumference measurement (end of trial, roughly yearling age)[13]. In this same study, breed affected age at puberty, body weight, hip height and scrotal circumference at the time of puberty[13]. Brahman x Angus bulls tended to be older at puberty than Senepol x Angus and Tuli x Angus[13]. Another study found that Brown Swiss bulls reached puberty at a younger age, compared to Angus, Red Poll, Hereford x Angus, Angus x Hereford, and Hereford bulls[14]. Hereford bulls were the oldest at the onset of puberty[14]. Puberty appears to be impacted by some breed differences, with *Bos indicus* breeds having a delayed onset of puberty compared to *Bos taurus* breeds. Despite differences in the age at puberty, both *Bos indicus* and *Bos taurus* breeds attained puberty at similar scrotal circumference measurements.

4. Season of birth:

The timing of calving season and subsequent time of year when bull calves are in the first six months of life can impact bull development. These changes could be related to daylight hours or available nutrition. Brahman bulls born in the fall tended to be older than spring-born bulls at first sperm, were numerically older at puberty (37 days), and statistically significantly older at sexual maturity (65 days) [15]. Fall-born Brahman bulls did have greater progressive motility score at puberty and greater sperm motility score at sexual maturity when compared to spring-born bulls[15]. There was no difference between fall and spring-born bulls at first sperm, puberty or sexual maturity for body weight, weight per day of age, hip height, scrotal circumference and paired testes volume[15]. Rawlings evaluated differences between March and April-born bull calves. No differences were for age at puberty for March and April-born bulls [16]. Differences were noted between fall and spring-born bull calves, and could be related to daylight hours or available nutrition. Historically, cattle have not been strongly influenced by daylight hours as compared to other species – horses, sheep, goats, etc. However, nutrition in the first few months of life has shown to be critical in the hormonal development and subsequent onset of puberty[1].

5. Exposure to cycling females:

In a study by Miller, prepubertal bulls were exposed to cycling females to evaluate effect on puberty development. There was no statistical difference between exposed and non-exposed bulls at the time of puberty for age, body weight, semen characteristics or scrotal circumference. There was also no differences for likelihood to pass a breeding soundness examination for exposed and non-exposed bulls[17]. This is in contrast to exposing prepubertal females to bulls, which significantly reduces the age at attainment of puberty[18]. Heifers and bulls differ in their response to the opposite gender as a stimulus to incite improved fertility.

6. Hormones:

The concentration of certain metabolic and steroid hormones are critical for the onset of puberty and fertility. The hypothalamic-anterior pituitary-testicular axis is the regulator of hormonal secretion and pubertal development. Brito evaluated circulating hormones in peripubertal bulls and their association with testicular development. Serum concentrations of leptin, insulin, and IGF-I accounted for 63% of the variation in scrotal circumference [8]. There was an age effect on serum concentration of leptin, insulin, growth hormone, IGF-I, and testosterone [8]. Testosterone continued to increase for 4 weeks after the onset of puberty, while gonadotropins remained unchanged [8]. In a study by Lunstra, both LH and testosterone concentrations increased linearly from 7 to 13 months of age[14]. LH concentrations between 7 months of age and puberty were not associated with breed, but breeds that had higher testosterone concentration experienced puberty at a younger age[14]. Bulls fed a higher plane of nutrition (grain) had increased concentrations of triiodothyronine (T_3) and leptin as compared to bulls fed a lower plane of nutrition (roughage). Timing and concentrations of hormones during the peripubertal phase are essential to attainment of puberty. Post-weaning has limited effect on hormone concentration; pre-weaning nutrition has a much greater effect on hormone concentrations and timing of puberty[1].

7. Conclusion

Nutrition in the post-weaning phase had less impact on the onset of puberty or subsequent fertility, as compared to pre-weaning nutrition. Bulls developed for feed efficiency had reduced fertility and delayed onset of puberty if fed below adequate nutrition. Bulls fed either high nutrition or low nutrition are at risk of poor fertility for contrasting reasons. High nutrition can lead to increased fat accumulation in the scrotum and impaired thermoregulation. Poor nutrition does not impact the onset of puberty, but can result in decreased fertility. *Bos indicus* breeds tend to be older at puberty, as compared to *Bos taurus* breeds. However, both *Bos indicus* and *Bos taurus* breeds attain puberty at nearly the same scrotal circumference measurement. Limited research has evaluated season of birth, and limited differences have been found between fall and spring born progeny as related to pubertal or sexual development. Pre-pubertal bulls exposed to cycling females did not hasten the onset to puberty, inversely of the exposure of bulls to non-cycling females. Hormones concentrations were correlated to age, but not influenced to post-weaning nutrition. To make a larger impact on bull puberty and fertility, nutrition should be of primary focus prior to weaning.

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V. Chapter 2: Herd level factors associated with pregnancy success and distribution in beef cow-calf herds

A. Introduction

Managing herds to calve in a front-loaded scenario, where 60% or more of the cows become pregnant in the first 21 day interval of the breeding season, can lead to increased pounds of calf weaned per cow exposed for breeding [1]. Front-loaded herds enable a larger percentage of the herd to finish the post-partum anestrus period before the breeding season begins. This creates a reproductive momentum, allowing a greater percentage of the herd to be cycling prior to the breeding season, and thus greater likelihood of breeding back on time. In turn, this allows for more pounds weaned over a cows' lifetime [2]. Progeny born in the first 21-d of calving season will weigh more at weaning, and subsequently weigh more at later economically important times of life, heifers will have greater success during breeding, and steers will have higher amounts of marbling and increased carcass value [3]. Herds that can attain these management goals can have economic success in the short term and long term due to increased efficiency.

Veterinarians who estimate fetal age by 21-day intervals can use the resulting herd pregnancy distribution to help differentiate between potential causes of reproductive failure due to nutrition, male fertility, female fertility, or pregnancy loss [1]. The objective of this study was to determine if factors such as herd size, breeding season length, body condition of cow at mid-gestation, or the time of year when the breeding season starts affected the likelihood of pregnancy at the end of the first 21-day interval and at the end of the breeding season.

B. Materials & Methods

1. Herd Description:

Pregnancy status data were collected from veterinarians and producers throughout the Midwest. Herds were included based on the availability and completion of datasets. To be included, fetal age estimation had to be collected in a manner that allowed categorizing individual cows into 20- or 21-day intervals. If a herd was presented with fetal age estimated by month or trimester, the entire herd was excluded. The initial dataset included 625 herds with pregnancy diagnosis staged into 20- or 21-day intervals. Only herds with maximum pregnancy diagnosis less than 140 days, and herd size over 10 head were included in the final model (Figure 1). The final dataset included 241 herds representing 8,217 cattle from herd sizes from 11 to 233 animals. A total of 384 herds were removed due to the exclusion criterion. Each dataset included an individual cow identification number, date of pregnancy diagnosis, days bred, and a total animal count for herd size.

2. Pregnancy Intervals

Pregnancy examination data were collected in either 20- or 21-day intervals. Herds that collected data in 20-day intervals were adjusted by multiplying the percentage identified as pregnant in the first 20 days by 1.05 (5% increase) to equilibrate to a standard percentage pregnant during the first 21 days of the breeding season for all herds. Percent of cows bred were evaluated at two endpoints, those cows that were categorized as becoming pregnant in the first 21 days of the breeding season, and those categorized as becoming pregnant by the end of the breeding season regardless of breeding season length.

3. Categories based on factors evaluated:

Herds were categorized based on number of cows examined for pregnancy diagnosis into three categories: Small (<50 head), Medium (50-99 head), and Large (100-233head). Breeding season length was calculated across all data sources by finding the difference between the earliest estimated conception date and the latest estimated conception date. Herds were categorized based on breeding season length into three categories: Short (<63 days), Medium (63-84 days), and Long (>84 days). Body condition score data collected at the time of pregnancy diagnosis were based on a 9-point scale where classification 1 is associated with extremely thin cattle, and classification 9 is associated with extremely obese cattle. [4] The 9-point scale was collapsed into three categories for the data set with the thin category including cows classified as having a score less than or equal to 4, the moderate category including cows classified as having a score of 5 or 6, and cows classified as having a score of 7 or greater being categorized as being fleshy.

The start of each breeding season was determined by finding the earliest estimated conception date in each herd. The start of the breeding season was then categorized into quarters: winter, spring, summer and fall. Winter breeding season started between January 1st and March 31st. Spring breeding season started between April 1st and June 30th. Summer breeding season started between July 1st and September 29th. Fall breeding season started between September 30th and December 31st.

4. Statistical Analysis

a) Inclusion Criteria

Before analyzing the data, only herds with more than 10 head and with individual cattle diagnosed with pregnancies less than 140 days were included. The criterion to include only pregnancies less than 140 days was established to minimize inaccuracy when staging the pregnancies to 21-day intervals.

b) Statistical Model

All statistical analyses were conducted in RStudio (RStudio, Version 3.3.3, Boston, MA). A logistic regression model was used to evaluate the effect of the relevant factors (herd size category, breeding season length category, body condition score category, and timing of breeding season category) on the probability of pregnancy status at two different time-points (21 days and end of breeding season) for herds with data for all the variable categories (241 herds, 8,217 cattle). Interactions were evaluated using a type III Wald (chi-square) test.

C. Results

1. Pregnancy Intervals

On average, 85.3% of each herd was pregnant at the time of pregnancy diagnosis, with 53.6% becoming pregnant by the end of the first 21-day interval (Figure 2). For the first (21-day) interval model, factors that were significantly associated (P <0.05) for increasing or decreasing the probability of pregnancy included: herd size, cow body condition, and breeding season length. For the overall pregnancy model, factors that were significantly associated (P<0.05) include: herd size, body condition, and timing of breeding season.

2. Herd Size

Herds ranged in size from 10 to 233 cows, with a median of 45. Herd size was associated with the probability of pregnancy diagnosis for the first 21-day interval (Figure 3, P = 0.03, and the end of the breeding season (P < 0.01). For both 1st 21-day interval and overall breeding season, small herds had reduced probability of pregnancy (51%, 78%) compared to medium (63%, 84%) and large (57%, 86%) herds.

3. Breeding Season Length

Over half the herds (65.2%) had a breeding season that was classified as short (less than 63 days). Breeding season length was associated (P < 0.01) with the probability of pregnancy in the 1st 21-day interval with short season length herds having an increased probability of pregnancy (65%) as compared to medium (58%) and long (49%) season length herds. No association (P = 0.14) was found between breeding season length and probability of pregnancy diagnosis at the end of the breeding season.

4. Body Condition Score

The majority (87.5%) of cows in the data set were described as having moderate body condition, while 4.6% were classified as thin, and 7.8% were classified as fleshy. Body condition was significant for both the first 21-day model (P < 0.01) and overall breeding season (P < 0.01). Thin cows had reduced probability of pregnancy (44%) as compared to moderate (62%) and fleshy (66%) cows for the first 21-day outcome. For the end of breeding season, thin cows had the lowest probability of pregnancy (64%), while the fleshy cows had the highest probability of pregnancy (91%).

5. Start of the Breeding Season

The start of the breeding season was associated with the probability of pregnancy at the end of breeding season ($P < 0.01$), but was not associated with the first 21-day interval ($P = 0.26$). Herds starting the breeding season in spring had reduced probability of pregnancy (82%) compared to herds starting the breeding season in the fall (88%). Herds starting the breeding season in the winter and summer had numerically (but not statistically) reduced probabilities of pregnancy (81%, 78%) as compared to spring and fall.

D. Discussion

While this dataset is not representative of the entire cow-calf industry, it does describe a relevant sub-set of U.S. beef herds. Similar to industry averages, the majority of the herds in this dataset were less than 50 head, with herds categorized as “small” herds (<50 head) accounting for 80% of the population. Cattle producers, regardless of type, rely on cow herd productivity in order to be economically sustainable. Herd size can play a factor in profitability and efficiency—larger herds tend to have decreased overhead costs and feed costs per head[5]. In this dataset, smaller herds did have reduced probability of pregnancy during the first 21 days of breeding and for the entire breeding season, and the probability of pregnancy increased with increasing herd size category. The reduced probability of pregnancy for smaller herds could be a result of off-farm income, and subsequent less time and management directed to the cow herds’ productivity compared to larger herds.

Management techniques can be implemented in order to change the reproductive momentum of the herd from one breeding season to the next. Cow-calf production is limited by the 365 days in a year and a 283-day pregnancy, requiring that cows conceive within 82 days after calving to maintain a 365-day calving interval or less. A herd's breeding season length can have important impacts on the subsequent and future calf crops. Over 50% of operations in the US do not have defined breeding seasons, totaling 34.1% of the US cow herd [6]. Of the operations that had defined breeding seasons, nearly 70% calved in a three-month period [6]. According to the USDA NAHMS survey, the length of the breeding season for herds identifying as having a single defined breeding season averaged 110-days, which is nearly twice as long as the median breeding season length (60 days) of this dataset. Based on this dataset, the herds with a short or medium season length tended to have increased probability of pregnancy at 21 days. Herds with reduced time allotment to become pregnant, may have indirectly selected for cows that are capable of completing the post-partum anestrous period prior to the start of breeding or early in the breeding season. An extended breeding season results in an extended calving season that will result in an increased proportion of cows having few days available after calving to complete post-partum anestrus prior to the start of the subsequent breeding season[1]. In this dataset, there was no difference between season length and probability of becoming pregnant by the end of the breeding season. There were no differences in the probability of pregnancy for the different season lengths due to the increased mating opportunities in the long breeding season herds. The shorter season length herds had already attained 65% bred by the first 21-day interval, thus fewer cows were available to settle in the remaining 21-day periods of the breeding season.

Factors such as body condition at various times during the annual production cycle have been shown to influence both the length of the postpartum anestrus interval [7, 8] and fertility [9], and should be managed accordingly. Cows with lower BCS at the time of calving have been shown to have longer post-partum anestrus when compared to cows with a higher BCS [7]. This dataset indicates that cows classified as having thin body condition at the time of pregnancy diagnosis were less likely to have become pregnant in the first 21-day interval, and by the end of the preceding breeding season. The reduction in pregnancies for thin cows could be attributed to the previously mentioned prolonged anestrus period or as an indication of health constraints during the breeding season or early gestation that negatively impacts both body condition and fertility [7-9]. However, little research has been conducted to investigate the effect of body condition at the time of pregnancy diagnosis on fertility during the preceding breeding season.

Considering environmental constraints, particularly periods of peak and nadir forage availability, when determining the date to start the breeding season can impact the reproductive success of beef cow herds. Improved reproductive success is associated with improved post-partum plane of nutrition, and subsequent short post-partum anestrous interval. Results from this study indicate that cows exposed to bulls starting in the spring season had reduced probability of pregnancy as compared to fall breeding seasons. However, both the spring and fall breeding season herds had numerically increased probability of pregnancy as compared to winter and summer breeding season herds. The impact of day length at the start of the breeding season or the change in day length post-calving and/or available forage quantity and quality at different times of the year may influence the length of the postpartum anestrus period and fertility of beef cows [10]. Herds that start their breeding season in the winter or summer may have reduced probability of pregnancy due to environmental challenges (extreme temperatures, poor forage availability, etc.) or other environmental factors. These results provide additional considerations when determining the optimum breeding season start date.

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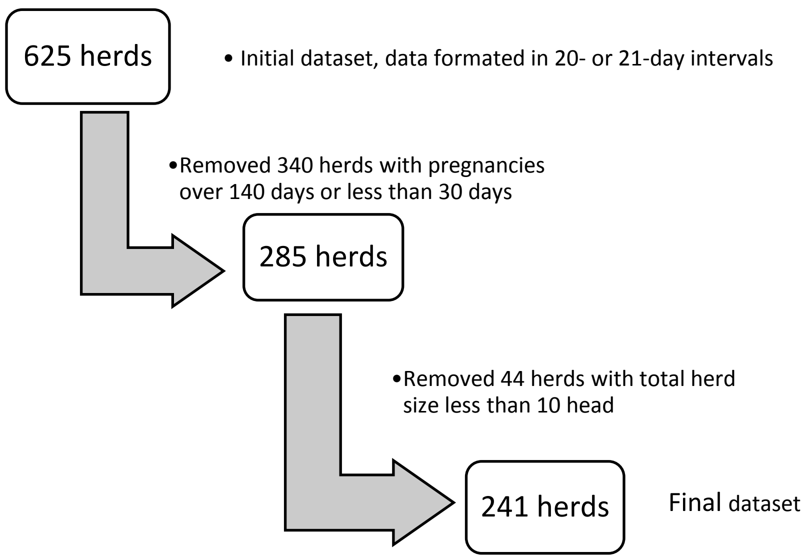

Figure 1. Flow chart depicting the number of herds retained for every exclusion criteria set in place

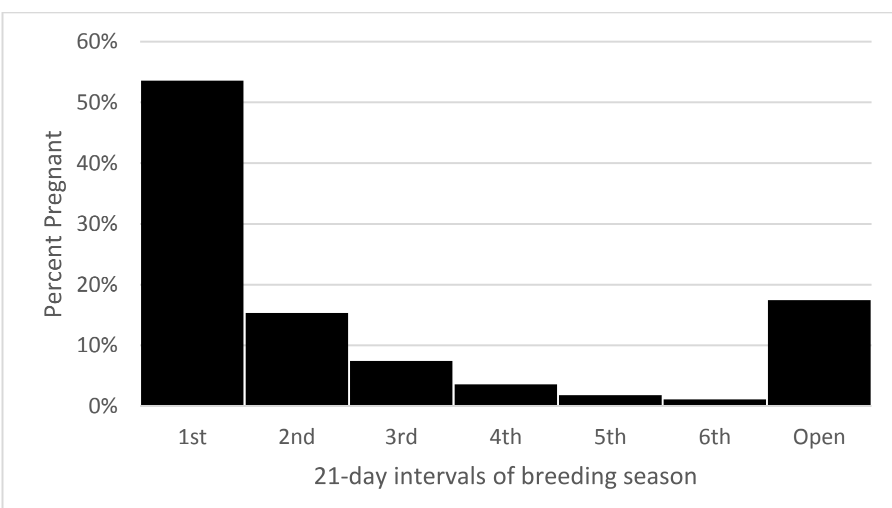

Figure 2. Overall raw average percent pregnant by 21-day interval throughout the breeding season for beef cow-calf herds included in the study (n=8,217 cows)

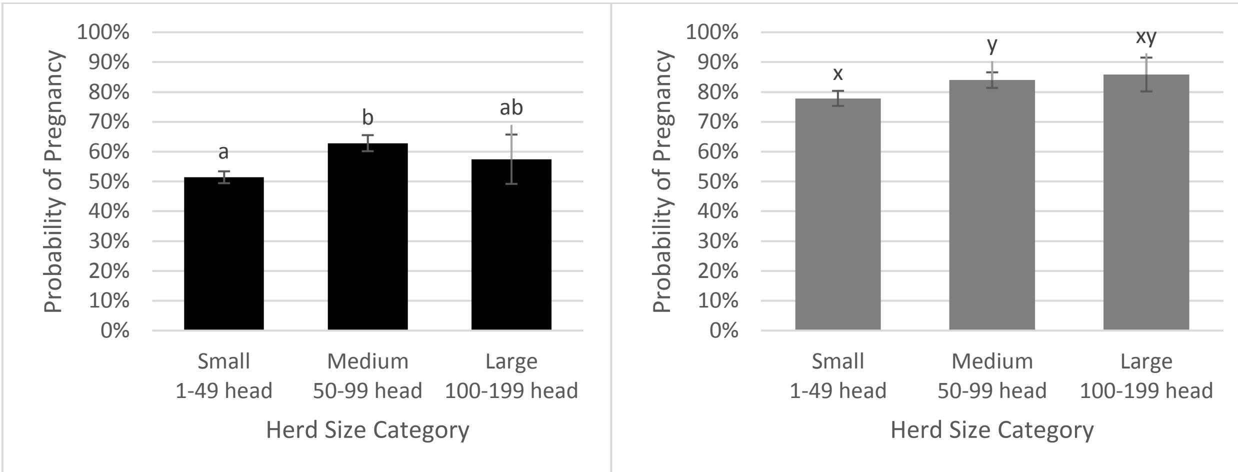

Figure 3. Model-adjusted probability of pregnancy for the first 21-day interval (left chart – black columns) and overall breeding season (right chart – grey columns) by herd size (n=241 herds).

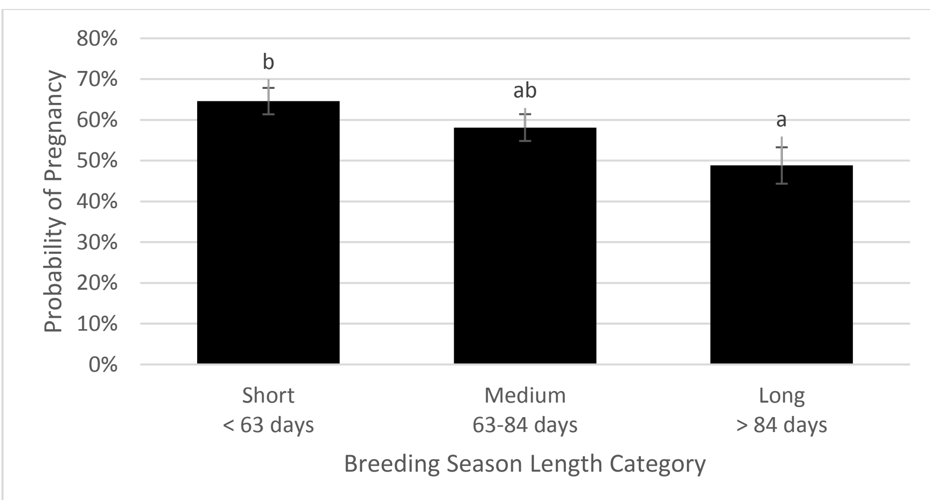

Figure 4. Model-adjusted probability of pregnancy for the first 21-day interval by breeding season length (n=241 herds).

VI. Chapter 3: Scrotal circumference at weaning in beef bulls and subsequent ability to pass a breeding soundness examination as a yearling

A. Introduction

Producers developing bulls traditionally use criteria such as performance, genetic potential or phenotype when deciding to keep or cull bulls after weaning. The primary cause of yearling bull's inability to pass a semen evaluation is a high percent of abnormal sperm [1]. The increased percentage of abnormal sperm is commonly a result of immaturity and associated low testosterone [2, 3]. A reliable predictor of the onset of puberty is scrotal circumference, which may be a better indicator than age, weight or breed [4]. Increased testicular size generally indicates earlier puberty, increased percentage of normal sperm, and more total sperm. Testicular size is highly heritable[5]. Little research has evaluated the impact of weaning age parameters on the likelihood of passing a yearling breeding soundness examination. Finding weaning criteria to help producers identify bulls with a lower likelihood of passing a semen evaluation as yearlings may provide an important advantage to producers. The objective of this study was to evaluate the effect of weaning scrotal circumference and other relevant factors collected at weaning on the likelihood of passing a breeding soundness examination as a yearling for a producer weaning approximately 450 bulls per year of three different breed types.

B. Materials & Methods

1. Data Collection

Data were collected on 466 bulls from one operation at two different time points (weaning and yearling breeding semen evaluation) from one calf crop. Scrotal circumference measurements were taken by two trained individuals at weaning on April 17-20, 2017. Weaning weight, age, and breed were provided by the producer. Yearling breeding soundness evaluations were performed by a veterinarian on September 18-20, 2017. 12 bulls were removed from the study for missing weaning data, and another

10 bulls were removed due to missing yearling data. A total of 444 bulls were included in the analysis (Figure 5).

2. Breeding Soundness Examination

Yearling breeding soundness evaluations were performed by a veterinarian and registered veterinarian technician following the guidelines set by Society for Theriogenology. A physical examination evaluated body condition score, feet/legs, eyes, accessory sex glands, penis, scrotum, testes, and epididymis. Semen examination evaluated gross motility, and individual morphology with regards to normal sperm, abnormal sperm, and white blood cell/ red blood cell percentages. Gross motility was assessed at 400x power, and individual morphology was assessed at a higher power with eosin-nigrosin stain. Bulls were classified as 'satisfactory' if a semen sample was classified as having 30% or greater motility and 70% or more morphologically normal sperm cells. Bulls who were deferred and unsatisfactory were classified together as unsatisfactory.

3. Categories based on factors evaluated

Bulls were categorized based on their actual weaning scrotal circumference into 9 categories: <=24 cm, 1 cm increments between 25 and 30, and >=31 cm. Breeds were classified as Angus, Charolais or Crossbred. Adjusted weaning scrotal circumference was calculated based on age and breed adjustment factors from the Beef Improvement Federation. Adjusted weaning scrotal circumference was divided into 15 categories: <=15 cm, 15-20 cm, 20-22 cm, 22-24 cm, 24 cm, 25 cm, 26 cm, 27 cm, 28 cm, 29 cm, 30 cm, 31 cm, 32-34 cm, 34-36 cm, and >= 36 cm. Bulls were categorized into 8 weaning weight categories: <=500 lbs, 50 lbs increments between 500 and 800 lbs, and >= 800 lbs. Weight per day of age was calculated by dividing weaning weight by days of age at weaning. Weight per day of age was then divided into 13 categories in 0.1 lb increments, starting at 2.3 lbs and ending at 3.3 lbs. Scrotal circumference per day of age was calculated by dividing the actual weaning scrotal circumference by days of age at weaning. Scrotal circumference per day of age was then categorized into 7 categories:

<=0.085, 0.01 cm increments between 0.085 and 0.135, and >= 0.135. Days of age at weaning was categorized into 4 categories: <215 days, 215-230 days, 230-245 days, and > 245 days.

4. Statistical Analysis

a) Data Manipulation

Results from the breeding soundness examination were classified as either satisfactory or unsatisfactory. Any bulls classified as deferred or unsatisfactory were labeled as unsatisfactory.

b) Statistical Model

All statistical analyses were conducted in RStudio (RStudio, Version 3.3.3, Boston, MA). A logistic regression model was used to evaluate the effect of the relevant factors (actual weaning scrotal circumference, adjusted weaning scrotal circumference, weight per day of age at weaning, scrotal circumference per day of age at weaning, days of age at weaning, weaning weight, and breed) on the probability of passing yearling breeding semen evaluation for bulls with complete data (444 head). Factors were removed individually based on lack of statistical significance (p-value > 0.05). The final model was iteratively developed until only significant variables or variables of interest remained. Breed was not significant, but deemed as a variable of interest. The final model included weaning scrotal circumference and breed. Interactions were evaluated using a type III Wald (chi-square) test.

C. Results

At weaning, the average scrotal circumference was 26 cm, with a range of 20 cm to 34 cm and standard deviation of 2.8. Weaning weight ranged from 359 pounds to 911 pounds with an average of 641 pounds, and standard deviation of 91.3. Bulls ranged from 155 days of age to 285 days of age, with an average of 231 days of age and standard deviation of 15.6. Average weight per day of age was 2.77 and standard deviation of 0.35, with a range from 1.41 to 3.68 pounds per day of age. Scrotal circumference per day of age at weaning ranged from 0.07 to 0.15, with an average of 0.11 and standard deviation of 0.01(Table 1).

Overall, 92.3% of the bulls evaluated passed the yearling breeding soundness evaluation. Yearling scrotal circumference measurements ranged from 31 cm to 46 cm, with an average of 37 cm (Table 2). Weaning scrotal circumference measurement was associated with the probability of passing the breeding soundness examination ($P < 0.01$). No significant difference was found between the categories of weaning scrotal circumference (Figure 6). Breed classification was not significantly associated ($P=0.53$) with the probability of passing the breeding soundness examination. Angus (n=258) bulls had a 93.3% probability of passing the breeding soundness examination, while Charolais (n=169) bulls had a 95.5% probability. The Angus x Charolais cross (n=17) bulls had a 96.3% probability of passing the breeding soundness examination.

D. Discussion

In this study, breed did not have a significant association with the probability of passing the breeding soundness examination. Prior research evaluating cut-off values for weaning scrotal circumference indicated that different cut-off values were needed based on the breed of the bull [6, 7]. The lack of statistically significant different findings by breed in this project could be due to actual similar performance of breeds in this study, or due to difference in outcome of interest compared to other studies, lack of large numbers of bulls at the upper and lower ends of the variable distributions, or unequal distribution of breeds. Previous studies were interested in creating weaning scrotal circumference cut-off values rather than probability of passing breeding soundness examination. Weaning scrotal circumference category was significantly associated with the probability of passing the breeding soundness examination; however, no pair-wise comparison of categories returned a significant difference. The lowest probability (80.9%) of passing the breeding soundness examination occurred in the >31 cm group of bulls. In previous research, bulls with weaning scrotal circumference above 23 cm had a 95% probability of reaching 34 cm by 12 months of age [8]. In the same study, bulls with less than 23 cm at weaning had only a 54% probability of reaching 34 cm by 12 months of age [8]. A study by

Lunstra et al. (1978) reported that scrotal circumference was a more accurate measure of puberty as compared to age, weight or breed [4]. In this same study, the range in scrotal circumference at the time of puberty ranged from 25.9 – 30.1 cm. and 97% of bulls measuring 30 cm or more had reached puberty [4]. Our study was not in complete agreeance with Lunstra, as bulls with weaning scrotal circumferences greater than 31 cm tended to have a reduced probability of passing the yearling breeding soundness examination. A potential reason for the differences noted is the timing of scrotal circumference measurement, at weaning versus puberty. The bulls measuring over 31 cm at weaning were potentially over-conditioned (increased average weaning weight: 717 lbs), which can have a negative impact on subsequent fertility [9].

E. References

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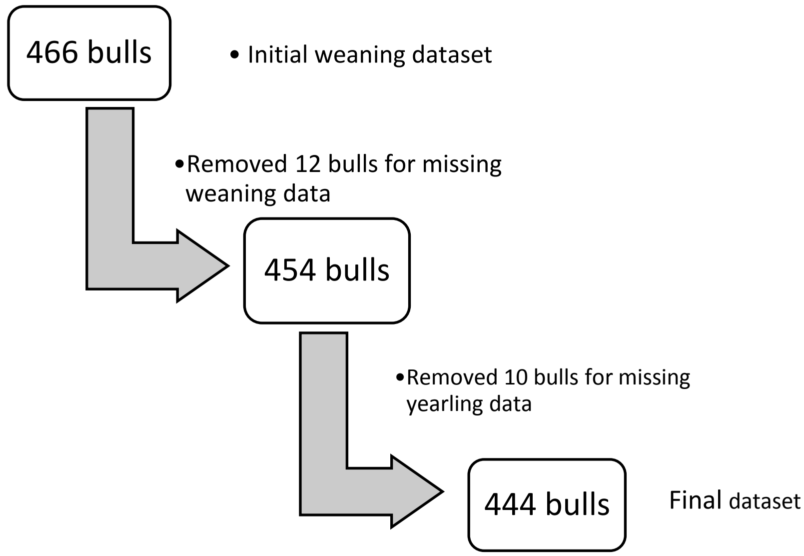

Figure 5. Flow chart depicting the number of bulls retained for each exclusion criteria set in place.

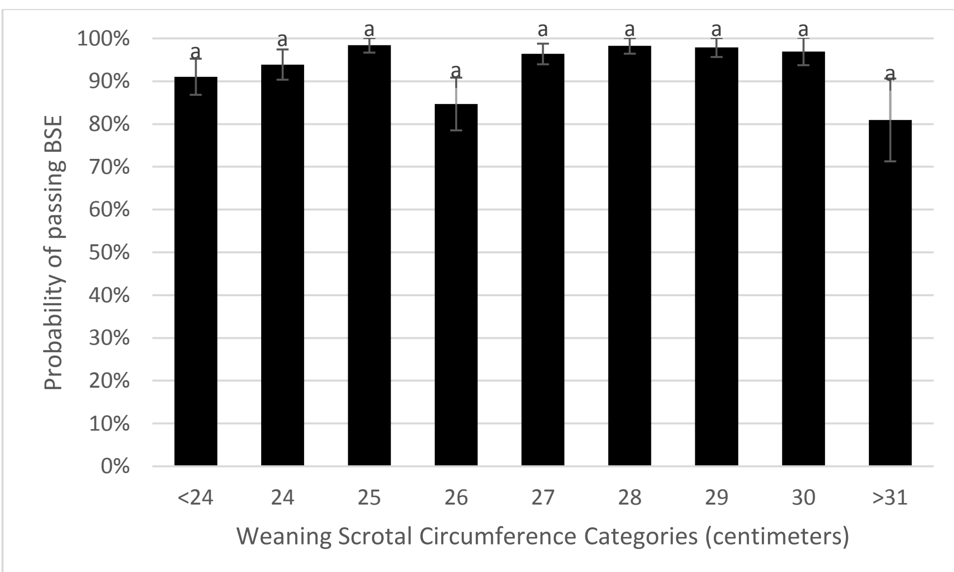

Figure 6. Probability of passing a breeding soundness examination (BSE) as a yearling by weaning scrotal circumference category

Factor	Mean	Median	(Minimum, Maximum)
Scrotal circumference	26.9	27	(20,34)
Weaning weight	641.9	641.5	(359,911)
Days of age	231.4	232	(155,285)
Weight per day of age	2.77	2.74	(1.41,3.68)
Scrotal circumference per day of age	0.11	0.11	(0.07,0.15)

Table 1. Mean, median and range for factors evaluated at the time of weaning.

Factor	Mean	Median	(Minimum, Maximum)
Scrotal Circumference	37	37	(31,46)
% Normal Sperm	76%	80%	(0%,90%)
Scrotal circumference per day of age	0.09	0.09	(0.07,0.12)

Table 2. Mean, median and range for factors evaluated at the time of breeding soundness examination.

VII. Chapter 4: CONCLUSION

In the literature review we evaluated factors, such as nutrition, breed, season of birth, exposure to cycling females and hormones that influenced puberty in peri-pubertal bulls. Nutrition in the post-weaning phase had less impact on the onset of puberty or subsequent fertility, as compared to pre-weaning nutrition. Bulls developed for feed efficiency had reduced fertility and delayed onset of puberty if fed below adequate nutrition. There is a balancing act for maintaining the ideal body condition score, and reducing the negative impact on fertility. Breed does have a substantial impact on the onset of puberty with Bos indicus breeds have significantly delayed puberty. Bulls are not responsive to cycling females with regards to hastening time to puberty. More research needs to be conducted in evaluating the effect of season of birth, with respects to nutrition and daylight hours. Hormones concentrations were correlated to age, but not influenced to post-weaning nutrition. To make a larger impact on bull puberty and fertility, nutrition should be of primary focus prior to weaning.

Overall, an average 53.6% of cattle across all herds were pregnant by the end of the first 21-day interval, and an average 85.2% of cattle across all herds were pregnant by the end of the breeding season. Herds with short or medium breeding season lengths (<63 days or 63-84 days) had increased probability of pregnancy (65% and 58%, respectively) for the first 21-day interval compared to herds with a long breeding season (49%). Cows in thin body condition at the time of pregnancy diagnosis had reduced probability of having become pregnant during both the first 21-day interval (44%) and the entire breeding season (64%) when compared to cows in moderate (62%, 86%) and fleshy (66%, 91%) condition. Herds with less than 50 head had reduced probability of pregnancy (51%, 78%) as compared to medium sized (50-99 head) herds (63%, 84%) for both the 21-day interval and overall breeding season. Herds that started the breeding season in the fall had higher probability of pregnancy at the end of the breeding season (88%) as compared to spring start dates (82%). Management factors such as breeding season length, body condition score, herd size, and timing of breeding season had significant impacts on the probability of pregnancy. In the future, more research needs to be conducted to evaluate the economic impacts of these management choices.

Overall, 92.3% of bulls passed the yearling breeding soundness examination on first evaluation. Weaning scrotal circumference was the only factor of those evaluated associated ($P < 0.01$) with the probability of passing the breeding soundness examination. No significant differences were found between the categories of weaning scrotal circumference. Bulls with weaning scrotal circumference over 31 cm had the lowest probability (80.9%) of passing the yearling breeding soundness examination, but was not statistically significant. Breed was not associated ($P = 0.53$) with the probability of passing the breeding soundness examination. In the future, more research needs to evaluate predictive model development for weaning scrotal circumference and ability to pass breeding soundness examination.