Impact of Sire Over-conditioning on Bull Fertility

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Introduction

The main factor influencing productivity in cow-calf operations is the percentage of calves weaned on a yearly basis. There are several aspects related to the cow herd that increases calf crop percentage, such as cow body condition score, days post-partum at the onset of the breeding season, and parity (Lamb and Mercadante, 2016). Moreover, bull optimal fertility is also required to achieve acceptable pregnancy rates within the breeding season. The ability of a bull to successfully breed cows is associated with diverse factors such as a structural musculoskeletal soundness, libido, and semen quality (Wiltbank and Parish, 1986). Considering that over 85% of cow-calf operations in the United States utilize only natural service as their main breeding strategy (USDA, 2020), male reproductive failures have an extensive impact on cow herd reproductive efficiency. In the context of assisted reproductive technologies, male subfertility accounts for reproductive failures and decreased pregnancy rates in artificial insemination and decrease embryo production in both in vivo and in vitro embryo transfer programs (Vasconcelos et al., 2017; Ortega et al., 2018; Zoca et al., 2020).

More recently, studies have demonstrated the paternal influence on fertility and pregnancy success in cattle goes beyond fertilization. For example, bulls that have decreased fertility based on Sire Conception Rates (SCR) estimates had similar cleavage rates in vitro; however, percentage of embryos that successfully developed to the blastocyst are decreased compared with bulls classified as having high SCR. Similarly, Franco et al. (2018) evaluated the impact of sire on pregnancy loss and observed that cows bred by certain bulls had greater chances of undergoing pregnancy loss after a pregnancy had been initially confirmed via ultrasonography. Intriguingly, sires utilized in these studies passed a breeding soundness examination (BSE) and semen quality control analyses, indicating that variations in sire fertility go beyond defects traditionally detected in conventional semen analyses (Koziol and Armstrong, 2018). Therefore, development and utilization of novel methods of semen analysis can provide further insight into estimating sire intrinsic fertility or the impact of management practices (i.e., nutrition) on semen quality. Herein we provide a general overview of studies investigating the impact of sire over conditioning on fertility using traditional and novel methods to investigate male fertility. Moreover, a summary of the practical impacts of sire over conditioning to herd fertility are also be provided.

Over conditioned sires in the beef industry

Sire over-conditioning is a common phenotype observed in the beef industry. Pre- and post-weaning growth are important for profitability; therefore, beef cattle producers are interested in identifying bulls with superior genetics for weaning and yearling weights. Nevertheless, bulls are often not only fed high energy diets to express their genetic potential at the time of yearling

weight collection but often fed these diets until the time of sale. Several Extension programs and bull development stations across the U.S. have reported the general preference of bull buyers for bulls with high rates of average daily gain (ADG) during their growth and development phase. In fact, bull buyers prioritize growth-related traits versus feed efficiency traits such as feed-to-gain ratio (F:G) or residual feed intake (RFI; Oosthuizen et al., 2018). In a previous report from our group, we evaluated the relationship between the growth performance of 829 bulls enrolled in the University of Florida's NFREC Bull Test and sale prices at the NFREC Bull Test Sale. A positive correlation (**Figure 1**) was observed between sale prices and ADG (r = 0.23; $P < 0.01$), body weight (BW) per day of age (r = 0.31; $P < 0.01$), and BW at the end of the test (r = 0.46; $P < 0.01$; Oosthuizen et al., 2018). Moreover, there was no correlation between sale price and RFI or F:G ($P > 0.20$).

Another factor that encourages seedstock producers to increase energy intake during sire development is the neuroendocrine regulatory effect of these dietary strategies on pubertal development. Similar to what has been thoroughly shown in heifers, sires that are exposed to high-energy diets achieve puberty earlier. Although the neuroendocrine changes associated with puberty are less understood in young bulls compared with heifers (Cardoso et al., 2018.; Kenny and Byrne, 2018), enhancing the early life plane of nutrition of bulls stimulates a complex biochemical interplay involving metabolic and neuroendocrine signaling that culminates in earlier onset of sexual maturation (Kenny and Byrne, 2018). Yet, most bulls from British breeds reach puberty prior to yearling body weight assessments and continuing to feed bulls high energy diets later in development have minor effects on advancing puberty (Byrne et al., 2018).

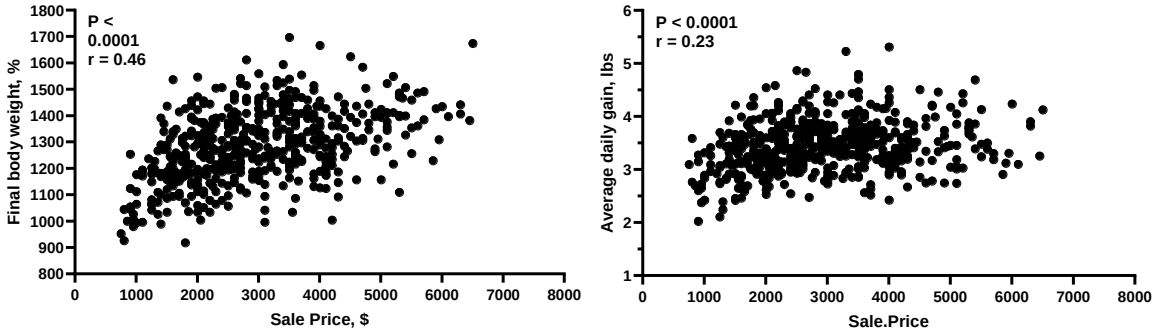

Figure 1. Final BW and ADG were significantly correlated with the sale price. Residual feed intake (RFI) and feed-to-gain ratio (F: G) were not associated with the sale price (Adapted from Oosthuizen et al,. 2018).

Epidemiological evidence for an impact of sire over-conditioning on semen quality

As previously mentioned, over-conditioned bulls are attractive to bull buyers and body weight gain is positively correlated with greater bull sale prices. Yet, over-conditioning might have negative consequences to semen quality and muscle skeletal soundness. Although studies have shown that the post-puberty negative energy balance impairs reproduction in both heifers and bulls, research has been done evaluating the impacts of excessive growth and fat deposition on bull fertility outcomes evaluating techniques that are commonly utilized in breeding soundness examination. A recent field study from Bartenslager (2018) observed that bulls weighing ≥ 1100

lbs. at the beginning of a bull test program had 12.5 times greater odds of failing the BSE compared to bulls weighing 770 – 880 lb. Furthermore, the same study reported that bulls having greater scrotal circumference growth during the test, which is related to subcutaneous fat deposition, had increased chances of yielding major defects in semen morphology. Similar results were reported by Barth and Waldner (2002) when evaluating 1,635 BSE records of beef bulls. Significantly fewer over-conditioned bulls (body condition score ≥ 4 using a 1 to 5 scale) were classified as satisfactory potential breeders compared with bulls with adequate body condition scores (body condition score = 3).

Impact of sire over-conditioning on semen quality in controlled studies

Previously mentioned observational studies indicated a negative relationship between bull over-conditioning and the ability of bulls to have a satisfactory breeding soundness examination. More specifically, these studies indicated a negative impact of excessive body weight gain and fat deposition on semen quality. While these studies were observational and lacked the controlled experimental conditions necessary to isolate the effect of nutritional status on semen parameters, controlled studies using different diets also show a detrimental effect of diet-induced highly anabolic conditions on semen quality. Coulter et al. (1997) evaluated the impact of feeding young bulls a moderate-gain diet primarily comprised of forage (Control) versus a high-energy diet consisting of 80% concentrate and 20% forage (High Gain) for a period of 168 days after weaning. As expected, bulls fed to the High Gain diets were heavier by the end of the feeding period and had greater backfat thickness compared with Control bulls. Notably, bulls in the High Gain diet had greater percentage of secondary sperm defects (28.7% vs. 9.9%) and decreased average sperm motility (44.5% vs. 53.4%) compared to Control bulls (**Figure 2.A**). Moreover, the High Gain bulls also had greater scrotal circumference and decreased changes in scrotal surface temperature gradient (measured with infrared camera; **Figure 2.B**) from the top portion of the scrotum compared with the bottom portion of the scrotum. This data indicates that High Gain bulls may have experienced impaired testicular thermoregulation, potentially associated with increased fat deposition in the neck region of the scrotum, which could explain the decrease in semen quality.

Previous studies have shown that experimentally induced scrotal insulation had a negative impact on semen quality. More specifically, scrotal insulation is associated with decrease sperm motility, decrease sperm cells that are morphologically normal, impaired sperm chromatin structure, and decrease fertilization and blastocyst formation during in vitro embryo production (Ferrer et al., 2020; Lucio et al., 2016; Mitchell et al., 2010).

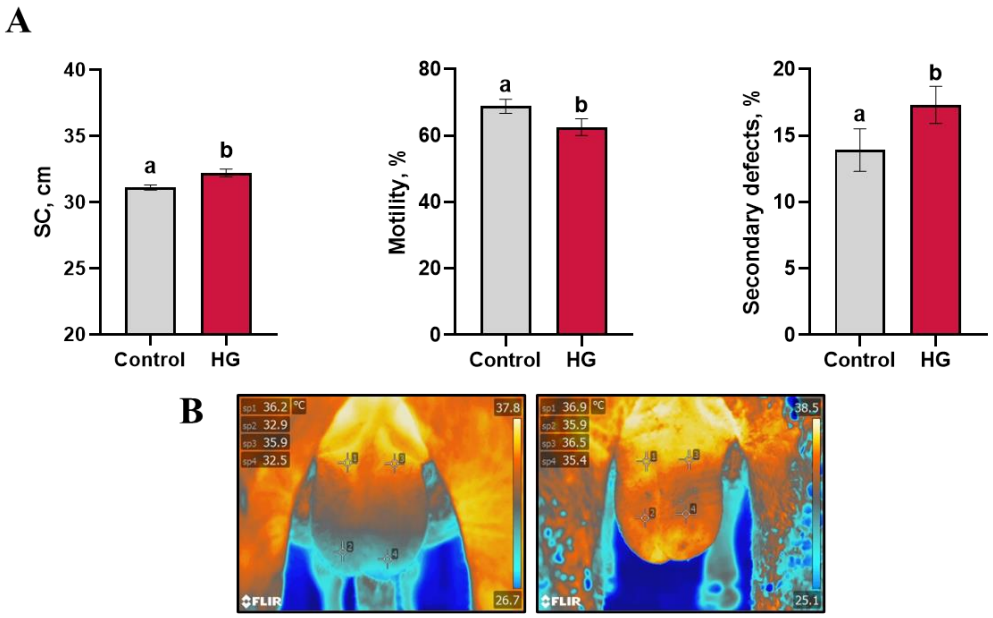

Figure 2. A) Effect of inclusion of high-gain diets for young bulls and its impact in scrotal circumference, sperm progressive motility, and sperm secondary defects. Adapted from: Coulter et al., (1997). **B)** Representation of infrared thermal imaging of the scrotum with different gradients of scrotal surface in young beef bulls.

Impact of over-conditioning on bull fertility using novel estimates of sire fertility

Veterinarians can assess semen quality of bulls prior to the breeding season and the potential of semen samples to generate pregnancies based on sperm motility and morphology through a traditional BSE (Wiltbank et al., 1986; Nevile et al., 1988; Koziol and Armstrong, 2018). While BSE is a convenient and accurate tool to recognize infertile bulls, the ability of current breeding soundness examination standards to recognize sub-fertile sires is limited (DeJarnette, 2005). Therefore, novel techniques are being utilized to further understand semen quality and estimate male fertility. Examples include, but are not limited to, computer-assisted semen analysis (CASA) and flow cytometry (DeJarnette et al., 2022).

Computer-assisted sperm analysis utilizes specialized software and digital imaging to assess various parameters of sperm movement, enabling the possibility to objectively assess sperm kinematics (Horst et al., 2018). Hence, CASA provides a more thorough description of sperm cell movement compared with subjective estimates of sperm motility utilized during traditional BSE. Flow cytometry is a technology that allows for fast multi-parametric analyses of large numbers of cells individually. The use of this technology for evaluating sperm cells in semen analysis has provided further information on the physical and functional properties of sperm cells (Graham et al., 1990). Flow cytometry has allowed scientists, genetic companies, and veterinarians to gain insight into sperm cell plasma membrane, chromatin, and acrosome integrity, as well as sperm capacitation status, mitochondrial activity, and oxidative stress (de Lima Rosa et al., 2023; Zoca et al., 2020; 2023).

Recent studies have also indicated that sperm cells not only play a role in fertilization but also influence the subsequent embryo development and pregnancy establishment. Although fertilization rates are relatively high in beef cattle (> 80%; Santos et al., 2004), pregnancy rates 30 days after breeding in beef females that are exposed to artificial insemination generally range between 40 and 60% (Lamb et al., 2010), indicating that pregnancy loss between fertilization and the first pregnancy diagnosis occurs in a considerably high proportion of cows and heifers (Reese et al., 2020).

Most research on embryonic mortality in cattle has focused on factors associated with the female. More recently, research from other species has shown that sperm plays an important role in early embryonic development and postfertilization infertility (Daigneault, 2021). In humans, observation studies reported that couples where males were obese (body mass index > 28) had decreased in vitro embryo production during fertility treatment and decreased pregnancy rates after embryos were transferred (Yang et al., 2016). Similar results were found in mice, where paternal high-fat diets were also related to decreasing in vitro embryo production and impaired pregnancy establishment (Mitchell et al., 2011).

Currently, our group has focused on utilizing these new technologies to further understand the impact high energy diets on the fertility of beef bulls. Moreover, we are currently investigating the consequences of these diets to embryo development and pregnancy establishment. In a recent study (Seekford et al., 2023), mature bulls (n = 8) that had previously passed a breeding soundness examination were randomly assigned to either receive a diet designed for a target ADG of 4 lbs/d (High Gain) or a diet designed to maintain body weight (Control). Bulls were fed individually their respective diets for 67 days and semen collections were performed, and semen was frozen at the end of the feeding trial. Semen was analyzed using CASA and flow cytometry and utilized to produce embryos in vitro. There were no differences in sperm kinematics between High Gain and Control bulls. However, High Gain bulls had a greater proportion of sperm cells with post-thaw acrosome damage compared with Control bulls. Moreover, semen from High Gain bulls tended to have a greater percentage of sperm cells starting to undergo cell death (early necrotic) and approached a statistical tendency for having fewer sperm cells classified a viable after thawing compared with Control bulls (**Figure 3**).

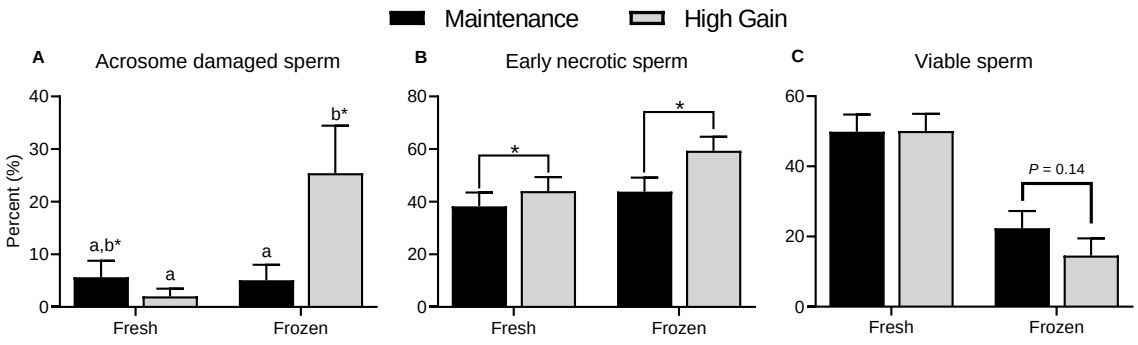

Figure 3. Flow cytometer comparison between bulls fed to moderate gain or high-gain diets prior and after cryopreservation and its impacts in acrosome damaged (a), early necrotic sperm (b), and viable sperm percentage (c). Different superscripts indicate statistical difference (P < 0.05), and different symbols indicate a tendency (P < 0.10). Source: Seekford et al., 2023.

Although no differences were observed in cleavage rates between High Gain and Control bulls, blastocyst rates relative to the number of oocytes tended to be decreased in High Gain bulls. Moreover, blastocyst rates relative to the number of cleaved oocytes (oocytes that had undergone fertilization) were reduced when semen from High Gain compared with semen from Control bulls (**Figure 4**). These results indicate that paternal highly anabolic conditions can also induce negative post-fertilization changes in embryo development in cattle.

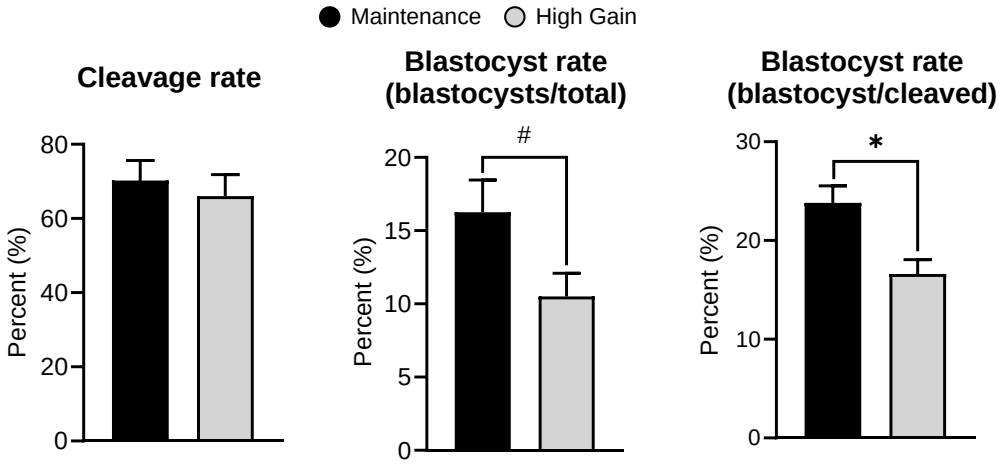

Figure 4. Effect of sire diet on in vitro embryo production. Different superscripts indicate statistical difference ($P < 0.05$) or tendency ($P < 0.10$). Adapted from Seekford et al., (2023).

Conclusion

Although sire over conditioning is a common practice in the beef cattle industry, both observational studies and controlled experiments have shown that excessive fat deposition in bulls had detrimental effects on semen quality. Intriguingly, consequences of sire over conditioning to fertility go beyond decrease sperm motility and increased sperm morphology defects. Recent studies indicate that paternal highly anabolic diets also negatively impact post-fertilization embryo development. Therefore, while high energy diets should be utilized to allow young bulls to express the genetic potential for post-weaning growth, producers should be cautious to avoid excessively feeding bulls to an extent that semen quality is compromised.

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