Strategically using reproductive technology to increase profitability in beef herds

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Introduction

Developments in assisted reproductive technologies (ART) have helped beef cattle producers enhance fertility, improve genetic composition of their cattle, and shorten the calving season, leading to an increase in overall production efficiency of cow-calf systems. More importantly, the use of ART has been shown to add value to the calf crop and increase profitability for both commercial and seedstock operations (Reviewed by Lamb et al., 2016). The main ART currently utilized in the beef cattle industry include estrus synchronization, artificial insemination (AI), sexed semen technology, and *in vivo* and *in vitro* embryo production (Fontes et al., 2019). Herein, we provide a basic description of these technologies and summarize their impact on cattle genetic merit and reproductive efficiency.

Taking advantage of assisted reproductive technologies to improve herd genetic merit

Aritificial insemination

Artificial insemination (AI) is currently the most effective way to rapidly introduce superior genetics into commercial beef herds and increase the genetic merit of the calf crop. Cattle producers that utilize AI benefit from the widespread availability of semen obtained from proven bulls that enable rapid changes in herd genetics. Sires producing semen for AI have expected progeny differences (EPDs) and EPD accuracies that are generally superior to those available for natural service use. Even in situations where EPDs between AI and natural service sires are similar, the greater accuracies of the EPDs from AI sires provide cattle producers greater confidence in the performance characteristics of AI-sired offspring. For these reasons, AI represents a significant opportunity for seedstock and commercial producers to leverage genetically superior sires and improve the genetics of their herd.

Multiple ovulation and embryo transfer (MOET)

Utilization of embryo transfer provides an additional opportunity for genetic improvement in beef cattle. Embryo transfer enables seedstock producers to maximize the use of genetically superior females and generate several calves from a single donor cow within the same breeding season. When coupled with semen from a genetically superior sire, embryos of exceptional genetic quality can be produced and transferred to recipient females of decreased or average genetic merit. Therefore, embryo transfer significantly accelerates genetic progress. In current

MOET protocols (**Figure 1**), donor females are superovulated using follicle-stimulating hormone (FSH), which results in ovulation of multiple follicles. Embryo donor cows are then subjected to AI and embryos are recovered using a uterine flushing procedure. Following embryo recovery, embryos are evaluated for their stage of development and quality. Embryos classified as viable by the embryologist are either transferred fresh to recipient cows or cryopreserved for future use. On average 6.9 viable embryos are recovered per uterine flushing in beef females; however, this number varies depending on breed, cow age, and within-breed variation. Embryo transfer using fresh embryos generally results in pregnancy rates approximately 10% greater than cryopreserved embryos (Lamb et al., 2016; Fontes et al., 2019).

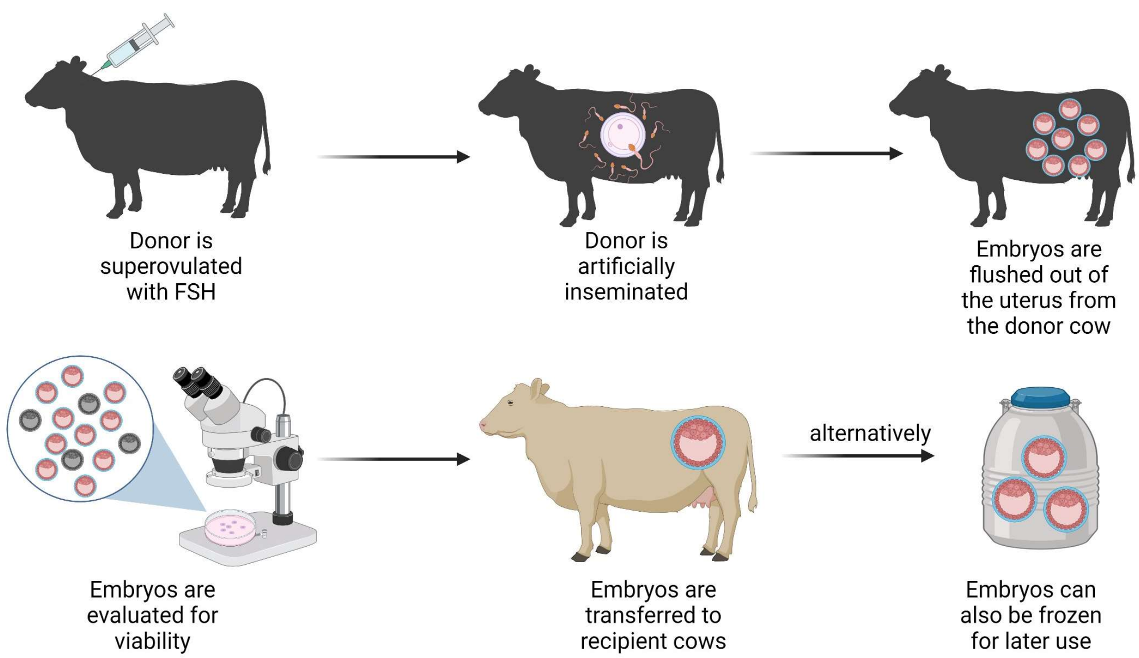

Figure 1. Diagram describing conventional (*in vivo*) embryo production through multiple ovulation and embryo transfer (MOET; Biorender).

In vitro fertilization and in vitro embryo production

Embryo production in cattle can also be successfully performed using an *in vitro* production system. The term *in vitro* refers to procedures conducted outside of a living organism. In cattle embryo transfer programs, *in vitro* embryo production consists of the following steps (**Figure 2**): 1) Ovum pick-up (OPU) is performed and oocytes are collected from the donor female. During OPU, ovaries of the donor female are accessed using a transvaginal ultrasound device equipped with a needle attached to a vacuum pump. This device allows the embryologist to harvest several oocytes by aspirating them directly from the donor's ovaries. 2) These oocytes are then evaluated, placed in maturation media to prepare for fertilization, and are shipped to a laboratory. 3) *In vitro* fertilization (IVF) is then performed by placing semen with the oocytes in the laboratory. 4) After IVF, fertilized embryos stay in culture media for approximately 6 to 8 days. 5). Embryos are then evaluated for their developmental stage and quality. 6) Finally, embryos are shipped to the farm where they will be transferred fresh to embryo recipient cows that were synchronized to be on day 6 to 8 of their estrous cycle or embryos are frozen in the laboratory for later use (Lamb et al., 2016; Fontes et al., 2019).

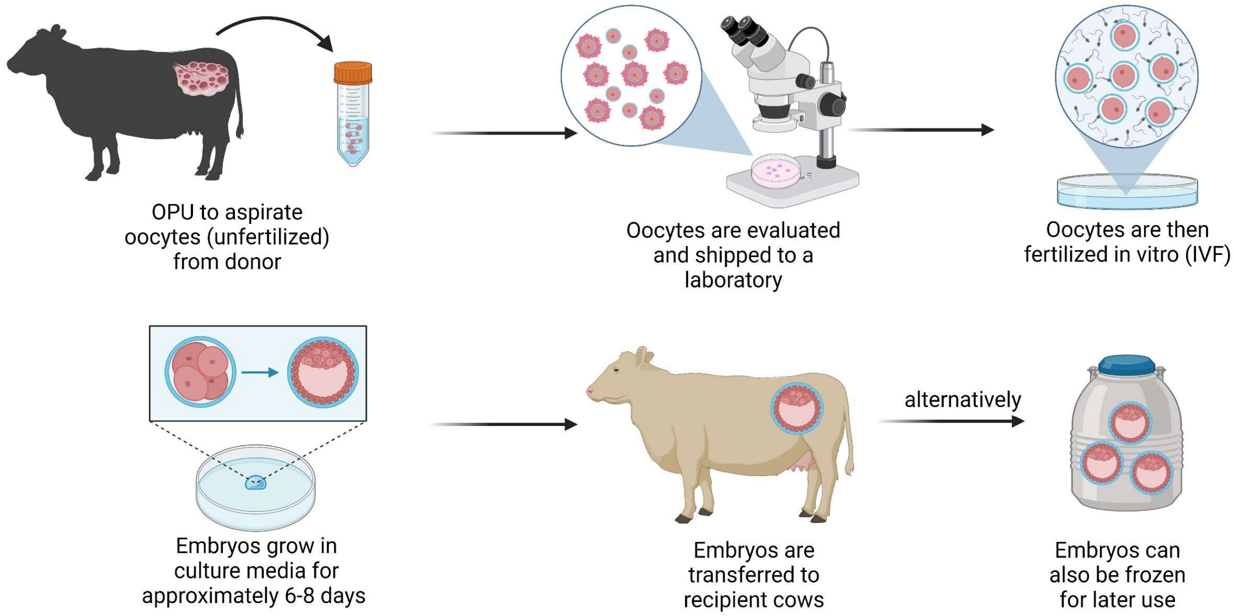

Figure 2. Diagram describing *in vitro* embryo production (Biorender).

Determining which embryo production method to utilize (IVF vs. MOET)

Both *in vivo* and *in vitro* embryo production are well-established technologies that allow for faster genetic progress. Unfortunately, there is no "one size fits all" recommendation when it comes to embryo transfer programs. Instead, cattle producers should educate themselves on the key differences between these methods and work with their embryologist to determine which method best fits the goals of their operation. Some of the advantages of conventional (or *in vivo*) embryo production include: (1) generation of more transferable embryos per superovulation cycle on average compared with *in vitro* production, (2) minor laboratory work is required and professionals with expertise are more readily available, (3) conception rates after transfer are greater compared with *in vitro* produced embryos, and (4) pregnancy losses between pregnancy diagnosis and calving are decreased compared with *in vitro* embryo production. On the other hand, advantages of *in vitro* embryo production include: (1) shorter interval between oocyte collections compared with the interval required between conventional embryo flushing procedures, (2) shorter interval between oocyte collections generally results in greater number of embryos produced from a single donor over time, (3) OPU can be performed in pregnant donors during the first months of gestation, (4) maximizes the use of expensive semen straws because a single straw can fertilize hundreds of oocytes *in vitro*, and (5) allows some of the females that do not respond well to FSH treatment to produce embryos without superovulation.

Describing the impact of assisted reproductive technology beyond genetic improvement

One of the most beneficial aspects of utilizing ART in combination with estrus synchronization protocols is the shift in calving distribution elicited by exposing beef cows or heifers to exogenous progesterone prior to beginning of the breeding season. After parturition, beef cows undergo a transitional period of anestrus characterized by a wave-like pattern of follicular growth where dominant follicles undergo atresia prior to ovulation due to a lack of luteinizing hormone (LH) pulses (Short et al., 1990; Yavas and Walton, 2000). Results of multi-location studies evaluating postpartum cyclicity of *Bos taurus* beef cows in the US indicate that approximately 50% of beef cows are in anestrus at the beginning of the breeding season. These studies also demonstrated great variation among different locations, with the proportion of cyclic cows ranging from 17 to 67% (Day, 2024). Because beef cows in anestrus at the beginning of the breeding season have lower fertility when compared to cyclic cows, strategies that increase the proportion of cows cycling prior to the time of breeding have the potential to improve reproductive efficiency of beef herds (Stevenson et al., 2003).

Estrus synchronization protocols that use exogenous progesterone have the ability to induce cyclicity in anestrous cows and prepubertal heifers. Therefore, beef cattle producers can leverage estrus synchronization to alter calving distribution and increase the proportion of females that become pregnant in the beginning of the breeding season. To estimate the impact of estrus synchronization program on offspring performance, Rodgers et al., (2012) randomly assigned commercial postpartum cows to 1 of 2 treatments: 1) cows were exposed to a natural service only breeding season (**NS**), or 2) cows were exposed to an industry-standard estrus synchronization and fixed-time AI protocol (7-day CO-Synch + CIDR) followed by natural service for the rest of the breeding season (TAI). Exposing cows to a round of estrus synchronization and fixed-time AI increased the proportion of cows calving in the beginning of the breeding season (**Figure 3**) and increased the weaning weight per cow exposed to the breeding season by 38 pounds. Several other studies replicated similar results (Lamb et al., 2008; Oosthuizen et al., 2018; Patterson et al., 2018), indicating that estrus synchronization can successfully shift the calving distribution and increase the proportion of cows or heifers calving in the beginning of the calving season. The impact of this shift in calving distribution will be discussed further.

Impact of early calving on subsequent replacement heifer and feeder calf performance

Day of conception within the breeding season is an important driver of cow-calf production efficiency. Replacement heifers born within the first 21 days of the calving season have greater weaning weights and are heavier at the beginning of the breeding season compared with their counterparts born later in the calving season. Heifers born in the beginning of the calving season are older at the beginning of their first breeding season as replacement. Therefore,

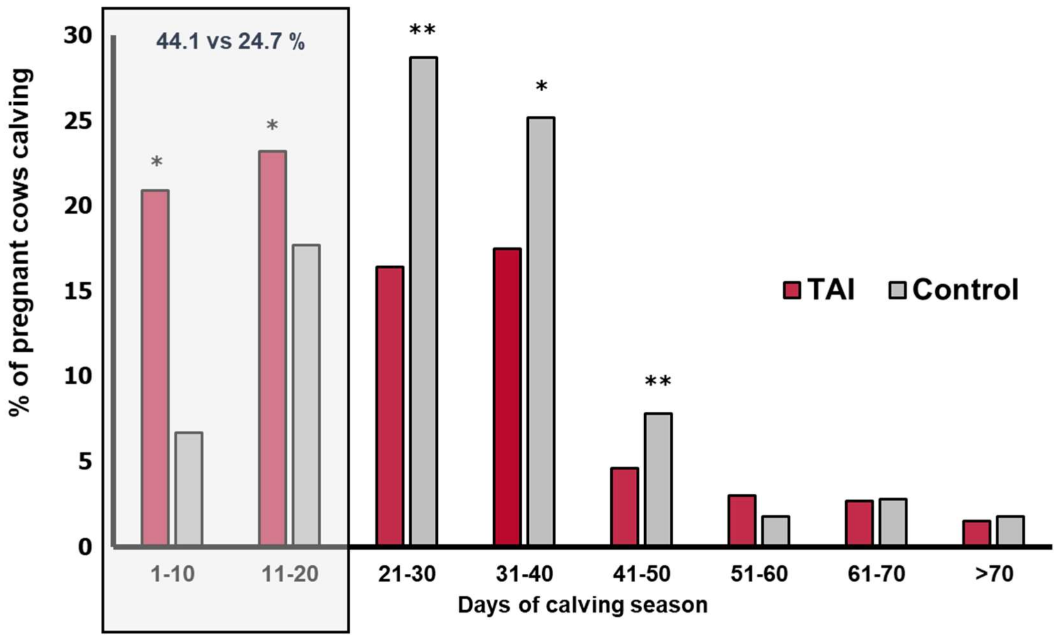

Figure 3. Exposing postpartum beef cows (n = 1,197) to estrus synchronization and fixed-time artificial insemination resulted in a greater ($P < 0.01$) percentage of cows calving early in the subsequent calving season (Adapted from Rodgers et al., 2012). TAI: fixed-time AI followed by natural service breeding. Control: Natural service breeding only.

a greater proportion of these heifers are cycling at the beginning of their first breeding season compared with the heifers that are born later in the calving season (Funston et al., 2012). For this reason, heifers that are born in the beginning of the calving season have greater pregnancy rates in their first breeding season and a greater proportion of these heifers breed within the first 21 days of their first breeding season when compared to heifers from the same cohort that were born later in the season (Funston et al., 2012). Similar increases in performance are observed in steers. Feeder calves born to cows that conceived early in the breeding season are not only heavier at weaning (Rodgers et al., 2012; Funston et al., 2012), but also produce heavier carcasses with greater marbling scores compared with steers born to cows that conceived later in the breeding season. These differences in performance and carcass quality translated into differences in carcass value (Funston et al., 2012).

Impact of early calving on cow herd fertility

To maintain a 365-day calving interval, beef cows must overcome a variety of challenges associated with the early postpartum period. These challenges include, but are not limited to, a linear increase in nutrient requirements and a substantial remodeling of the uterine tissue during involution. Not surprisingly, a positive linear relationship exists between days postpartum and the probability of pregnancy, where the probability of pregnancy early in the breeding season increases as days postpartum increase (**Figure 4**; Fontes lab, unpublished; Stevenson et al., 2003; 2015). As mentioned previously, estrus synchronization programs that make use of exogenous progesterone increases the proportion of females that calve early in the subsequent calving season (Rodgers et al., 2012), resulting in cows having greater days postpartum before the begging of the next breeding season (Fontes et al., 2019). Therefore, consistent use of estrus synchronization programs results in greater overall herd fertility over time (Mercadante and Lamb, 2016). Increasing the proportion of females that conceive early is particularly important in replacement heifers. Replacement heifers that conceive at the beginning of their first breeding season produce more kilograms of calves at weaning during their productive lives when compared to their counterparts that conceive later in the season (Cushman et al., 2013). Moreover, decreasing the day of conception increases fertility in the subsequent breeding season, resulting in greater female longevity in the herd (Cushman et al., 2013).

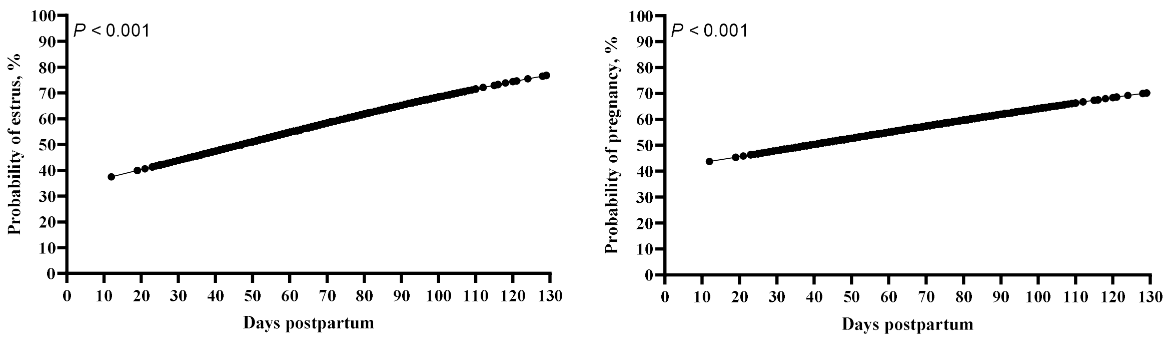

Figure 4. Relationship between the probability of estrus expression and pregnancy rates to fixed-time AI based on days postpartum. A positive linear relationship was observed for both response variables (*P* < 0.001). Data from Fontes lab (unpublished).

Long-term impact of production and economic impact of implementing estrus synchronization and fixed-time artificial insemination

Utilization of estrus synchronization in combination with fixed-time AI has the potential to shorten the calving season, increase calf crop uniformity, and increase the proportion of cows calving early in the calving season. Collectively, these production changes can add value to the calf crop and potentially increase profitability in cow-calf systems. In a study performed by Mercadante and Lamb (2016), the long-term impact of estrus synchronization and fixed-time AI on production efficiency was evaluated. Over the course of 5 years, a commercial herd with approximately 300 cows transitioned from 120 days to 70 days long breeding season. This was accomplished by gradually decreasing the length of the breeding season and leveraging the ability of estrus synchronization protocols to shift the calving distribution. After 5 years, the authors observed a clear increase in the proportion of cows calving in the beginning of the breeding season (**Figure 5.A**). Interestingly, although the breeding season and weaning events occurred at the same time each year across the study, the average age of calves at weaning increased by 42 days (**Figure 5.B**). These differences in age at weaning resulted from a greater proportion of cows calving early in the calving season. If genetic improvement for pre-weaning growth is disregarded and a 2 pound per day average daily gain is assumed between birth and weaning, the differences observed in calving distribution increased the average weaning weight by 84 pounds. Using current feeder calf prices in Georgia for September of 2024 ($261/cwt; Medium and Large 1 steers; USDA Georgia Livestock Report), this increase in weaning weights would represent an added value of $220 per weaned calf.

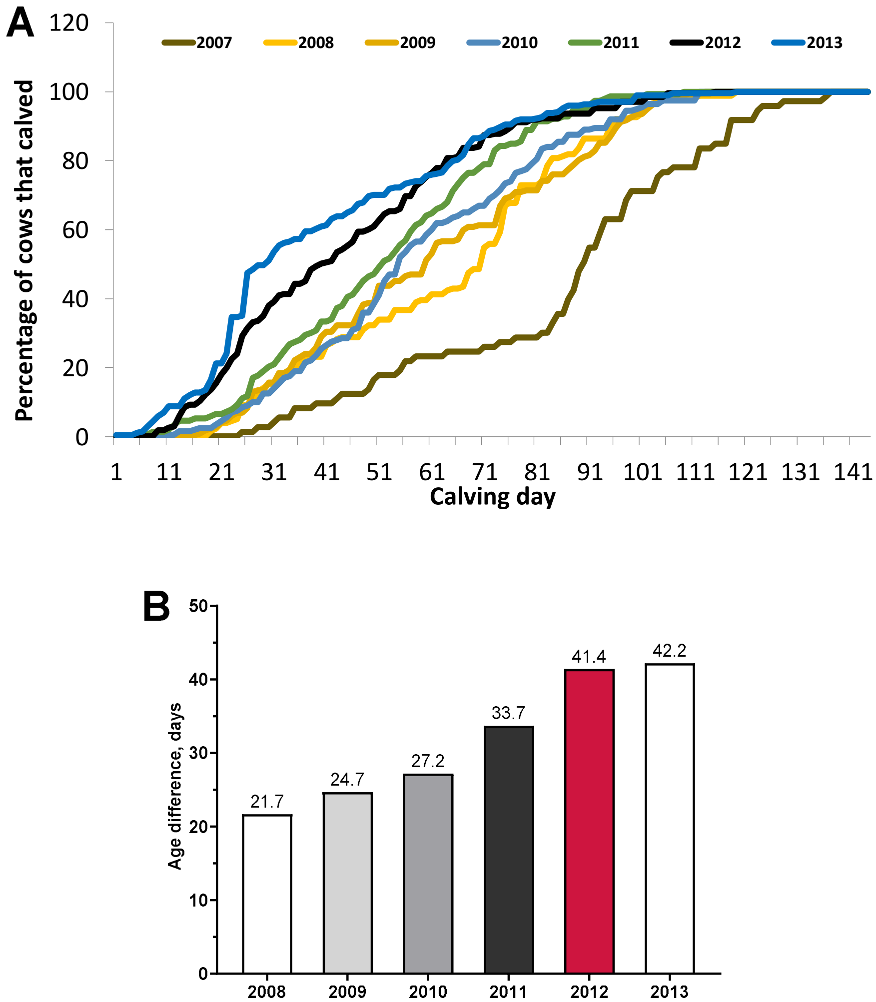

Figure 5.A. Survival analyses describing the percentage of cows calving according to the year of the breeding season. Estrus synchronization and fixed-time artificial insemination started to be adopted in 2008. **B.** Changes in average weaning age according to year (Mercadante and Lamb, 2016).

Besides adding value to feeder calves that are sold at weaning, the use of artificial insemination has been shown to increase the value of bred replacement heifers. The University of Georgia coordinates the Heifer Evaluation and Reproductive Development (HERD) program where consigned heifers undergo are exposed to a heifer development protocol that includes estrus synchronization and fixed-time AI followed by a conventional natural service breeding season (Credille et al., 2023). Commercial and purebred heifers that become pregnant are eligible for a heifer sale at the University of Georgia's Tifton and Calhoun facilities. Historical data compiled over the last 15 years indicate that heifers carrying an artificial insemination pregnancy were sold on average for an additional $190 compared with heifers that became pregnant by natural service (**Figure 6.A**). Interestingly, this additional value was observed across varying points in the cattle cycle (**Figure 6.B**). Similar economic advantages were reported when producers in the Southeast retained ownership of feeder calves in the feedlot and marketed them on a grid. Steers that were sired by artificial insemination were more likely to receive a superior quality grade and had greater carcass value compared to steers sired by natural service (Sutphin, 2007).

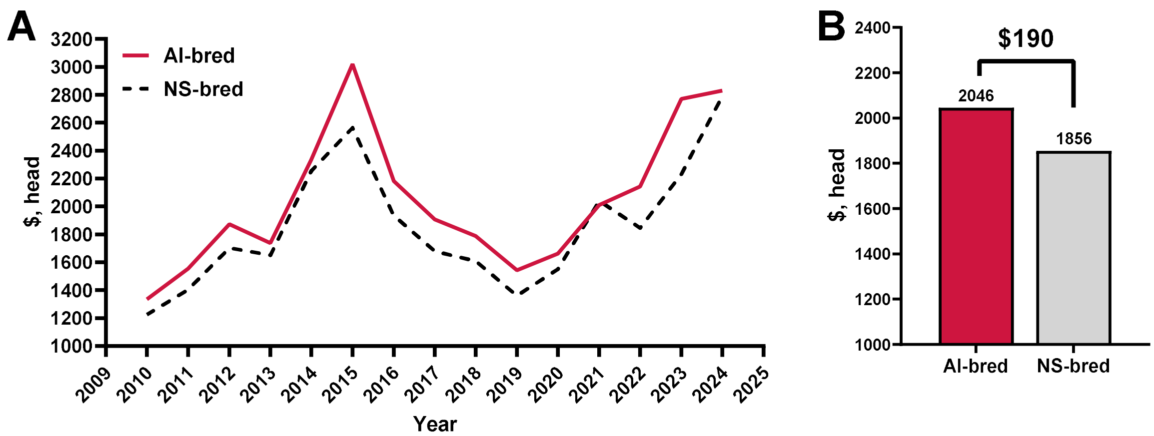

Figure 6.A. Yearly replacement heifer average sale price at the University of Georgia's Heifer Evaluation and Reproductive Development (HERD) program according to pregnancy status. **B.** Fifteen-year average replacement heifer price according to pregnancy status. AI-bred: heifers carrying an artificial insemination pregnancy. NS-bred: Heifers that were carrying a natural service pregnancy.

Conclusions

In summary, scientific literature and decades of successful implementation of reproductive technologies indicate that these technologies can significantly increase production efficiency and profitability in beef herds. Moreover, reproductive technologies not only add value by increasing the genetic merit of the calf crop, but also induce changes in calving distribution. These changes in calving distribution are associated with improvements in cow herd fertility, increased replacement heifer performance, and greater feeder calf value.

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