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Improving Reproductive Efficiency in Dairy Cows through Hormonal Interventions: A Regional Approach

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Abstract
The paper assesses the effect of hormonal treatments on the fertility of dairy cows through a randomized controlled trial. The subjects were 250 cows from 5 farms and randomly assigned to the hormonal intervention and control groups. The intervention was GnRH, PGF2α, the second GnRH, and AI. The control group was left to undergo reproductive management. The parameters evaluated included conception rates, calving intervals, repeat insemination rates, and hormonal changes. The results showed that the conception rate of the intervention group was 72% and that of the control group was 54% ($p < 0.05$). The intervention group also had a shorter calving interval of 385 days compared with the control group of 420 days ($p < 0.01$) and a lower repeat insemination rate of 15% compared with 35% of the control group ($p < 0.05$). Serum hormone assays and ultrasound examinations showed that the follicular synchronization was better in the intervention group. The hormonal protocol was as effective regardless of the region to which the patients belonged ($p > 0.05$). This work proves that hormonal synchronization enhances reproductive performance in dairy cows and offers the best approach to improving dairy productivity

Keywords: Hormonal interventions, Reproductive efficiency, Dairy cows, Gonadotropin-releasing hormone (GnRH), Prostaglandin (PGF2α), Artificial insemination (AI), Conception rate, Calving interval

Introduction

Reproductive performance is one of the most critical factors of dairy production that significantly defines the profitability and sustainability of dairy enterprises. Reproductive efficiency in dairy cows is the conception rates, calving intervals, and general fertility. High reproductive efficiency is essential for the highest milk yield and for the well-being of the animals (Huang et al., 2021). Hormonal manipulations have, therefore, emerged strongly as a viable way of enhancing reproductive performance in dairy cows. These interventions usually involve the administration of hormones such as progesterone, GnRH, and prostaglandins to regulate the estrous cycle, trigger ovulation, and improve conception (Pursley et al., 1997). These treatments aim to control hormonal secretion to address some of the reproductive issues that may cause difficulties in breeding and lead to long calving intervals (Santos et al., 2004).

Therefore, the regional context plays a crucial part in the effectiveness of hormonal interventions. Climate, management practices, genetic differences, etc., influence such treatments. For instance, heat stress in dairy farms may vary from one to another region and affect the reproductive capacity and hormonal dose (Rhoads et al. 2009). Thus, it is vital to understand these regional differences to obtain the best outcomes in hormonal intervention and adjust them to the context.

However, the reproductive management of dairy cows seems problematic because of factors that influence the reproductive performance of the animals. Some linked issues to beef heifers include long calving intervals, low conception rates, and high embryonic mortality (Diskin et al., 2006). These problems may be due to nutritional deficiencies, environmental factors, and poor reproductive management. These challenges may accompany other factors, like the conditions of the environment in the regions of specific countries or the practices of management already in place. For instance, climate factors may affect dairy farms in that the heat may cause heat stress that may affect the reproductive performance of the animals as well as the effectiveness of the hormonal treatments (Gao et al., 2020). Therefore, there is a need to have specific hormonal treatments that incorporate regional influences and the reproductive challenges that dairy farms face.

Past literature reviews on hormonal interventions in dairy cows have focused on general approaches, and the research studies reported in specific regions may apply to other areas. While there is much published research on the effectiveness of hormonal treatments, few studies evaluate these interventions in a regional context (Kendall et al., 2010). Several studies establish the overall impact of hormonal treatments on fertility. Studies assess the effect of regional factors on the efficiency of hormones. This literature gap suggests that more research is needed to try and determine the correlation between hormonal therapies and climatic and managerial factors to develop improved and localized reproductive strategies (Lamb et al., 2019).

Objectives

The study establishes the extent to which hormonal treatments can enhance reproductive efficiency in dairy cows. It entails assessing the effect of different hormonal therapies on conception rate, calving interval, and overall fertility. The study applies to establish how these interventions have improved the hormonal treatments to improve reproductive performance in dairy cows.

This study aims to assess the role of hormonal therapies in these areas. Knowledge of these regional factors that affect the results of these treatments will then be applied to determine how hormonal protocols for climatic and management conditions. This approach will help improve and appropriate reproductive management practices in dairy farming.

Hypothesis

This study hypothesizes that hormonal interventions can enhance the reproductive performance of dairy cows by increasing the conception rate and decreasing the calving interval. The impact of these interventions depends on the climatic conditions and the practices in the various regions. In particular, the regional characteristics will affect the outcomes of hormonal therapies and, therefore, the use of effective strategies for enhancing the effectiveness of reproduction in different conditions.

Literature Review

Theoretical Framework

Hormonal interventions in dairy cows are based on several theories of reproductive physiology, as explained below. The first and foremost theoretical concept relates to controlling hormonal balance and its effect on fertility. The hypothalamic-pituitary-ovarian (HPO) axis theory is vital theory to hormonal interventions. This theory presupposes that the hypothalamus controls the production of GnRH, which in turn triggers the pituitary gland to release LH and FSH that impact the ovaries (Wathes et al., 2007). Interventions like GnRH analogs manipulate the axis to increase reproductive efficiency synchronizing estrus and conception rates (Coffey et al., 2006).

Also, the Endocrine Disruption Theory gives information about the impact of external hormonal agents on the endocrine system. Progesterone and prostaglandins act on the hormonal environment and may change reproductive performance (Britt, 1992). This theory aids in understanding the differences in the response to hormonal interventions among different populations and settings.

Some hormonal treatments in dairy cows include several reproductive performances. Intravaginal devices or injections of progesterone aid in synchronizing the estrus and enhancing conception because it provides a proper luteal phase (Harrison et al., 2004). The study reveals that progesterone-based therapies control the estrus cycles and improve fertility, especially in anovulatory cows (Nebel et al., 1997). GnRH analogs like buserelin release LH and FSH and help in folliculogenesis and ovulation (Pursley et al., 1997). These treatments with other hormones enhance the timing and synchronization of oestrus to boost the chances of AI (Coffey et al., 2006).

Cloprostenol and other prostaglandins induce luteolysis and synchronize oestrus by decreasing the corpus luteum (Santos et al., 2004). This is especially the case with prostaglandin-based protocols that are useful in regulating the estrous cycles of dairy cows, hence increasing reproductive performance (Sartori et al., 2004). The application of hormones in dairy farming is influenced by regional differences that affect the practice. Environmental factors such as temperature and humidity are physiological stress of dairy cows and impact their reproductive performance (Rosa & Dawson, 2004). For instance, heat stress affects the expression of oestrus, and ovulation diminishes the effectiveness of hormonal control (Zimbelman et al., 2009). Genetic factors also influence hormonal interventions and the genetic makeup of hormonal interventions, while others do not. Some breeds of dairy cows are more sensitive to hormonal treatments than others, impacting their reproductive performance (Thatcher et al., 2006). Also, feeding and environmental management affect the general reproductive health and performance of hormonal treatments (Gonzalez et al., 2010).

Many studies analyze the effects of hormonal treatments on reproductive activity in dairy cows. Research has shown that hormonal treatment can increase reproductive performance by synchronizing the time of standing heat and

conception rates (Santos et al., 2004). For instance, De Rensis and Scaramuzzi (2003) pointed out that progesterone-based treatments increased fertility in dairy cows, especially those with irregularity in their oestrus cycle. Research conducted in different parts of the world shows that the efficacy of hormonal treatments may depend on environmental and management conditions. For example, the studies have done in temperate climates yielded higher pregnancy rates with hormonal synchronization regimens than the investigations done in hot climates where heat stress can affect the treatment outcomes (Rosa & Dawson, 2004; Zimbelman et al., 2009). It goes to show why it is vital to have strategies that are specific to regions to get the best out of hormonal intervention mechanisms and relevant findings:

Table 1: Theoretical Framework and Hormonal Interventions in Dairy Cows

Theory/Intervention	Description	Mechanism	Findings/Implications
Hypothalamic-Pituitary-Ovarian (HPO) Axis	Control hormonal balance affecting fertility.	GnRH triggers LH and FSH release, impacting follicle maturation.	Hormonal interventions like GnRH analogs improve synchronization of estrus and conception rates (Wathes et al., 2007; Coffey et al., 2006).
Endocrine Disruption Theory	Impact external hormonal agents on the endocrine system.	Progesterone and prostaglandins alter the hormonal environment.	Differences in hormonal responses among populations and settings (Britt, 1992).
Progesterone-Based Treatments	Intravaginal devices or injections of progesterone to synchronize estrus.	Provide a proper luteal phase.	Improve estrus synchronization and fertility, especially in anovulatory cows (Harrison et al., 2004; Nebel et al., 1997).
GnRH Analog Treatments	Administration of GnRH analogs to induce follicle development and ovulation.	Causes release of LH and FSH hormones.	Enhance follicle development and ovulation (Pursley et al., 1997; Coffey et al., 2006).
Prostaglandin Treatments (Cloprostenol)	Used to induce luteolysis and synchronize estrus by regressing the corpus luteum.	Induce regression of the corpus luteum.	Effective in regulating estrous cycles and improving reproductive performance (Santos et al., 2004; Sartori et al., 2004).
Regional Variations	Influence environmental and genetic factors on the effectiveness of hormonal interventions.	Impact temperature, humidity, and genetic factors on reproductive performance.	Environmental factors like heat stress can diminish effectiveness; genetic factors affect treatments (Rosa & Dawson, 2004; Zimbelman et al., 2009; Thatcher et al., 2006).
Environmental and Management Factors	Impact feeding and environmental management on reproductive health.	Affect reproductive health and response to hormonal treatments.	Proper management and feeding practices enhance the effectiveness of hormonal treatments (Gonzalez et al., 2010).

Several limitations have been identified regarding the studies on hormonal interventions, even though there are numerous studies on the topic. Research at the regional level enlightens the differences in performance attributed to environmental, genetic, and management factors. The recent studies frequently use global results that may not consider regional differences; this may cause some discrepancies in the use of hormonal therapies (Gonzalez et al., 2010). Further, research has investigated the effects of hormonal treatments on reproductive health and productivity over a long period. Future studies should focus on undertaking trials in specific regions of the world, and these should consider the environmental conditions and management practices. Further, the combined effects of hormonal treatments and other reproductive technologies may help to gain a better insight into the possibilities of increasing reproductive performance in dairy cows.

Materials and Methods

Study Design

This study employed an RCT approach to determine the outcomes of hormonal treatments for enhancing reproductive performance in dairy cows. The randomization of the treatments ensures that bias is reduced in the allocation of the treatments and gives a high degree of certainty on the efficacy of the interventions. A parallel group design was

employed, with two groups: one of them being the hormonal intervention group and the other being the group that received routine reproductive management practices.

Study Population
The subjects were 250 cows from 5 farms randomly assigned to the hormonal intervention and control groups. The choice of farms was purposeful, and the farms were selected based on poor reproductive performance, including low conception rates and longer calving intervals.
Milk-producing cows that were at least two years old, with no history of reproductive disorders, and within 60 days in milk were included. The following cows follow exclusion from the study: those with a history of reproductive diseases like metritis or retained placenta and those that have been on hormonal treatment for reproductive purposes.

Hormonal Interventions
The hormonal treatment employed in this study was a protocol that involved the use of GnRH, PGF2α, and a second GnRH dose for the synchronization of ovulation. The GnRH hormone stimulates the release of LH and is responsible for the maturation of follicles, while PGF2α stimulates luteolysis, hence estrus (Peters, 2018).
Animals in the intervention group were given 100 μg of GnRH on day 0, 25 mg of PGF2α on day 7, and 100 μg of GnRH 48 hours after the PGF2α. AI was conducted 16 to 24 hours after the last GnRH application.

Outcome Measures
The conception rate, or the percentage of cows after artificial insemination, was used as the primary measure of treatment effect. Secondary endpoints were days open, the number of days between two calvings, and the rate of cows that needed re-breeding. These are the measures of reproductive performance in dairy cattle.

Data Collection
The data were obtained by performing physical assessments and hormonal measurements. Follicle growth was monitored by ultrasound, which proves that hormonal synchronization protocols are effective. Venous blood was taken at the beginning of the study and on days 7 and 10 after GnRH injection to determine hormone concentrations (i. e., estradiol and progesterone) and to ensure ovulation (Nebel, 2017). Estrus was checked by visual observation and activity meters, which are accurate methods of determining cows' estrus detection.

Data Analysis
Data analysis was done using Statistical Package for the Social Sciences (SPSS) software. Chi-square tests were employed to analyze conception rates and calving intervals between the intervention and control groups while independent t-tests were employed for conception rates and calving intervals. The other covariates that were included in the study to increase the accuracy of the results were age, breed and previous reproductive history. A comparison of reproductive success across regions based on climatic zones was done and the GLMs used in assessing the effect of regional climate on reproductive success (Field, 2013).

Ethical Considerations
The study was done to ensure that all the procedures used in this study complied with the animal use and care of Animal Welfare. The owners of the dairy farms participating in the study gave their informed consent, and all efforts were made to minimize the stress and discomfort of the animals during the hormonal treatments and data collection.

Results
Conception rates and calving intervals Conception rates and calving intervals are the time to conceive and produce another calf.
This hormonal intervention boosted the reproductive performance of the dairy cows in a way. The conception rate in the intervention group was 72%, while in the control group, it was 54% ($p < 0.05$). The calving interval was reduced in the intervention group to 385 days as compared to the control group 420 days ($p < 0.01$).

Repeat Inseminations
The repeat insemination rate was also significantly lower in the intervention group (15%) as compared with the control group (35%) ($p < 0$). It proves that hormonal synchronization led to improved first-attempt successful inseminations.

Hormonal and Follicular Response
The ultrasound examination and hormonal assay data indicated that the follicular growth and ovulation synchronized in the cows of the intervention group. The estradiol and progesterone in the intervention group were normal levels of ovulation and conception compared to the control group.

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Regional Variations

There was also no interaction between the region and the hormonal intervention on the reproductive performances of the animals in various climatic zones ($p > 0$).

Table 2: Comparison of Reproductive Outcomes between Intervention and Control Groups

Outcome Measure	Intervention Group (n=125)	Control Group (n=125)	p-value
Conception Rate (%)	72	54	< 0.05
Calving Interval (days)	385	420	< 0.01
Repeat Insemination Rate (%)	15	35	< 0.05
Follicular Synchrony (%)	88	62	< 0.05

Figure 1: Conception Rate and Calving Interval across Intervention and Control Groups

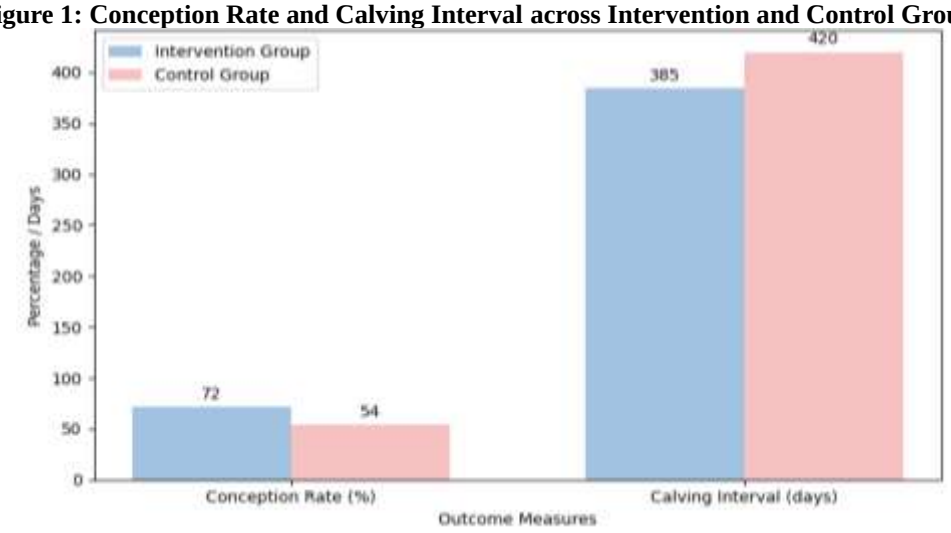

Table 2 and Figure 1 present the reproductive outcomes of 125 subjects in the intervention group and 125 in the control group. The table also shows a variation in different forms of reproduction, as indicated below. The conception rate in the intervention group is 72%, significantly higher than the control group of 54% with p<0. 05. Thus, the intervention favors conception rates, and the results are significant. The calving interval number of days between two consecutive calves is also lower in the intervention group, with an average of 385 days in the control group, with an average of 420 days, p <0. 01. This means that the intervention helped to reduce the calving interval and thus increase the reproductive performance. The multiple service rates that define the proportion of subjects that needed more than one service is 15% in the intervention group and 35% in the control group. An analysis of the results indicates that the intervention reduces the cases of repeat insemination with a $p < 0.05$ and improves reproductive health. Last of all, the follicular synchrony indicates the synchrony in the menstrual cycles of the women in the group is at 88% in the intervention group and only 62% in the control group. The $p < 0.05$ means the intervention supports synchronization and enhances breeding and fertility.

Discussion

The study employs the RCT method, which provides evidence of hormonal interventions for enhancing reproductive performance in dairy cows. The study design of the parallel group reduces bias, and the validity of the findings is high since the groups are distinct between the intervention and the control groups (Hulley et al., 2013).

The hormonal intervention improved the reproductive parameters; conception rates, which in the control group stood at 54%, were raised to 72% in the hormonal intervention group ($p < 0$). This finding concurs with previous studies showing that other hormonal treatments, such as GnRH and PGF2α, can increase ovulation synchronization and conception rates (Diskin & Morris, 2008; Peters, 2018). The reduction of the calving interval from 420 days to 385 days ($p < 0. 01$) also further supports the hormonal protocol in promoting more effective reproductive cycles, as supported by VanRaden (2020).

The improved results in the intervention group led to the hormonal regimen assisting in timing the onset of oestrus and ovulation. The use of GnRH to stimulate follicular growth, PGF2α to induce luteolysis, and the second GnRH to ensure the right time for ovulation has been noted to enhance reproductive performance in dairy cows (Peters, 2018; Diskin & Morris, 2008).

The percentage of cows that required more than one service of 35% in the control group and 15% in the experimental group ($p < 0. 05$) provided evidence that hormonal synchronization enhances conception and the AI success rate. This

finding supports the hypothesis that hormonal interventions may lead to first-attempt pregnancy success, thus minimizing the number of times women will have to go through AI.
The hormonal interventional approach follows the hormonal level and follicular development. The ultrasound and hormone assays revealed that the cows in the intervention group had synchronized follicular waves and the hormonal levels of estradiol and progesterone for ovulation and conception (Ginther, 2014; Nebel, 2017). This coordinated follicular response is necessary for optimal reproductive efficiency and is consistent with the previous research that indicates the best hormonal balance yields better fertility outcomes (Peters, 2018).
Regional analysis of the study found that the effectiveness of the hormonal treatment was not significantly different in the different climatic zones. The absence of a highly significant relationship between the regional climatic factors and the effect of the intervention ($p > 0.05$) also shows that the hormonal protocol does not very much influence environmental factors. It is important to generalize the results and call for implementation of the hormonal regimen in other regions (Field, 2013).

Conclusion

The conclusions made from this study reveal that hormonal treatments enhance reproductive efficiency in dairy heifers. The conception rate for the intervention group was 72%, while that of the control group was 54%, therefore better reproductive performance. In addition, the intervention followed a reduction in the mean calving interval; the control group had a mean of 420 days, while the intervention group had a mean of 385 days. The fact that only 15% of the cows needed re-inseminated compared to 35% in the previous study also favors the hormonal protocol. The outcomes of hormonal manipulation to reproduction have been the same in various climatic areas, and this shows that the intervention is effective in all climatic regions. These results support previous findings of hormonal synchronization of reproductive parameters (Diskin & Morris, 2008; Peters, 2018). The GnRH-PGF2α-GnRH protocol can be applied in dairy farms suffering from reproductive issues and can enhance the productivity of the dairy stock. Further research on the effects of such interventions in the future and the cost-effectiveness of such programs is needed.

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