BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

ANIMAL SCIENCE DEPARTMENT

REPRODUCTIVE EFFICIENCY OF ESTRADIOL CYPIONATE PROTOCOL IN CATTLE AND ACROSS PARITIES IN EXTENSIVE PRODUCTION SYSTEMS IN ZIMBABWE.

DUBE SITHANDIWE

B224258B

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT OF THE BACHELOR OF AGRICULTURAL SCIENCE HONORS DEGREE IN ANIMAL SCIENCE

JUNE 2026

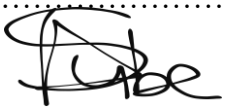
APPROVAL FORM

The signatories confirm that they have read and recommended to the Bindura University of Science Education for acceptance of the project title:

REPRODUCTIVE EFFICIENCY OF ESTRADIOL CYPIONATE PROTOCOL IN CATTLE AND ACROSS PARITIES IN EXTENSIVE PRODUCTION SYSTEMS IN ZIMBABWE.



Supervisor's signature……
Date...25/08/2026



Student's signature……
Date…25/08/2026

Chairperson's signature…… Date

DECLARATION

I Sithandiwe Dube, declare that this project hereby submitted for the Bachelor of Science Honors Degree in Animal Science and Technology at Bindura University of Science Education, is entirely my original work and affirm that it has not been submitted anywhere for the award of a degree or otherwise.

Topic: Reproductive Efficiency of Estradiol Cypionate protocol in cattle and across parities in extensive production systems in Zimbabwe.

Sithandiwe Dube…….. Date…….

Supervisor's declaration:

I certify that l have checked this document and am satisfied that it conforms to the Department of Animal Sciences guidelines for Project Preparation and Presentation. I therefore authorize the student to submit this dissertation for marking.

Supervisor…….. Date…….

DEDICATION

Dedicated to my family.

ACKNOWLEDGEMENTS

I would like to sincerely thank my supervisor for the guidance and constructive feedback provided throughout this study. His mentorship and academic insight greatly contributed to the successful completion of this study.

I also want to extend my deepest gratitude to my family for their constant support throughout this journey and for believing in me, even when l did not believe in myself. Thank you for encouraging me and for standing by me through it all. This achievement would not have been possible without you.

Lastly, l would like to thank myself for not giving up. This journey was not always easy, but through hard work, resilience and determination, I kept going. I am proud of how far I have come and grateful for the strength to see this journey through to the end.

ABSTRACT

Reproductive efficiency in extensive cattle production systems is frequently compromised by inadequate estrus detection, prolonged calving intervals and limited access to quality sires. All of which reduce herd productivity and economic returns. Estradiol Cypionate (ECP) based fixed time artificial insemination protocols are widely used but their effectiveness across different cattle breeds and parity groups under Zimbabwe's extensive production systems has not been well established. This study aimed to evaluate conception rates and calving percentages in Angus, Boran and Red Dane cows subjected to an ECP-based FTAI synchronization protocol and to determine the influence of parity on these reproductive outcomes under semi-arid extensive production conditions. Forty-five multibreed cows (n = 15 per breed) at Harvest Valley Farm, Matobo District, were subjected to an ECP-based FTAI protocol involving intravaginal CIDR insertion with Estradiol Benzoate and Prostaglandin F2α on day zero, followed by CIDR removal and ECP and Prostaglandin F2α on day seven and FTAI performed post 48 to 56 hours post CIDR removal. Data was analyzed using Chi-square analysis, Fisher's exact Test and binary logistic regression in SAS Version 9.4. Overall conception rate and calving percentage were 60% and 51.1% respectively. Boran recorded the highest conception rate (66.7%), while multiparous cows (parity 2–4) demonstrated numerically superior conception (65.4%) and calving outcomes (53.8%) relative to low-parity animals (52.6% and 47.4%, respectively). Neither breed nor parity had a statistically significant effect on conception rates and calving percentages ($P > 0.05$), though multiparous cows numerically outperformed low-parity animals across all breeds. These findings indicate that ECP-based FTAI delivers acceptable fertility outcomes across all breeds and parity groups, supporting its adoption as cost-effective and practically implementable reproductive management strategy in communal and smallholder extensive cattle production systems in Zimbabwe.

TABLE OF CONTENTS

DECLARATION I

DEDICATION III

ACKNOWLEDGEMENTS IV

ABSTRACT V

LIST OF TABLES VIII

ABBREVIATIONS IX

CHAPTER 1 1

1.1 INTRODUCTION 1

1.2 BACKGROUND 2

1.3 PROBLEM STATEMENT 3

1.4 JUSTIFICATION 4

1.6 HYPOTHESES 4

1.7 SIGNIFICANCE OF THE STUDY 5

1.8 LIMITATIONS 5

CHAPTER 2: LITERATURE REVIEW 6

2.1 INTRODUCTION 6

2.2 LIVESTOCK PRODUCTION SYSTEMS IN ZIMBABWE 6

2.3 ARTIFICIAL INSEMINATION IN EXTENSIVE SYSTEMS 7

2.4 REPRODUCTIVE PHYSIOLOGY OF THE BOVINE ESTROUS CYCLE 7

2.5 ESTRUS SYNCHRONIZATION 8

2.6 ESTRUS SYNCHRONIZATION PROGRAMS 8

2.6.1 One-Shot Prostaglandin Protocol 8

2.6.2 Two-Shot Prostaglandin Protocol 9

2.6.3 Ovsynch Protocol 9

2.6.4 Co-Synch Protocol 9

2.6.5 Melengestrol Acetate (MGA) Protocol 10

2.6.6 Progesterone-Based Devices: Mechanism, Optimization, and Cost Considerations 10

2.7 Estradiol Cypionate 10

2.8 ESTRADIOL CYPIONATE PROTOCOLS 12

2.9 Breed-Specific Reproductive Responses 13

2.10 Parity-related Reproductive Constraints 13

2.11 Calving Percentages 14

2.12 Conception and Pregnancy Rates 14

2.13 Cost-Effectiveness and Adoption of Reproductive Technologies in Smallholder Systems 15

2.14 Research Gap *15*

CHAPTER 3: METHODOLOGY 17

3.1 STUDY SITE 17
3.2 POPULATION SIZE 18
3.3 DATA COLLECTION 18
3.5 ESTRADIOL CYPIONATE SYNCHRONIZATION PROTOCOL 19
3.6 DATA ANALYSIS 20

CHAPTER 4: RESULTS 21

4.1 OVERALL REPRODUCTIVE PERFORMANCE 21
4.2 BREED-SPECIFIC CONCEPTION RATES AND CALVING PERCENTAGES 22
4.3 INFLUENCE OF PARITY ON CONCEPTION RATES AND CALVING PERCENTAGES 22
4.4 BREED BY PARITY INTERACTION ON CONCEPTION RATES AND CALVING PERCENTAGE 23
4.5 INFLUENCE OF PARITY ON CONCEPTION RATE AND CALVING PERCENTAGE 24

CHAPTER 5: DISCUSSION 26

5.1 OVERALL REPRODUCTIVE PERFORMANCE 26
5.2 BREED- SPECIFIC CONCEPTION RATES 27
5.3 BREED-SPECIFIC CALVING PERCENTAGES 28
5.4 INFLUENCE OF PARITY ON CONCEPTION RATES 28
5.5 INFLUENCE OF PARITY ON CALVING PERCENTAGE 28

CHAPTER 6 29

6.1 CONCLUSION 29
6.2 RECOMMENDATIONS 30

REFERENCES 31

LIST OF FIGURES AND TABLES

FIGURE 2.1: SHOWING THE PHYSIOLOGICAL CHANGES IN HORMONAL LEVELS 12
FIGURE 2.2: SHOWING HORMONAL PROFILE OF ECP PROTOCOL IN CATTLE FROM PROGESTERONE REMOVAL 12
FIGURE 3.1: SHOWING LOCATION OF HARVEST VALLEY FARM 17
FIGURE 3.2 SHOWING THE ECP PROTOCOL ADMINISTRATION 19
TABLE 4.1: OVERALL CONCEPTION RATE AND CALVING PERCENTAGE FOLLOWING ECP-BASED FTAI 21
TABLE 4.2: CONCEPTION AND CALVING PERCENTAGES BY BREED FOLLOWING ECP-BASED FTAI 22
TABLE 4.3: INFLUENCE OF PARITY ON CONCEPTION RATES AND CALVING PERCENTAGES IN CATTLE SUBJECTED TO AN ECP BASED SYNCHRONIZATION PROTOCOL 22
NS = NOT SIGNIFICANT 23
TABLE 4.4: CONCEPTION RATES BY BREED AND PARITY GROUP 23
TABLE 4.5: CALVING PERCENTAGES BY BREED AND PARITY GROUP 24
TABLE 4.6: LOGISTIC REGRESSION ANALYSIS FOR CONCEPTION RATE (N=45) 24
OR = ODDS RATIO: CL = CONFIDENCE INTERVAL: SE =STANDARD ERROR 25
TABLE 4.7: LOGISTIC REGRESSION ANALYSIS FOR CALVING PERCENTAGE (N=45) 25
OR = ODDS RATIO: CL = CONFIDENCE INTERVAL: SE =STANDARD ERROR 26

ABBREVIATIONS

AI	Artificial Insemination
BCS	Body Condition Score
CIDR	Controlled Internal Drug Release
CL	Corpus Luteum
EB	Estradiol Benzoate
ECP	Estradiol Cypionate
FSH	Follicle Stimulating Hormone
FTAI	Fixed- Time Artificial Insemination
GnRH	Gonadotrophin- Releasing Hormone
LH	Luteinizing Hormone
MGA	Melengestrol Acetate
P4	Progesterone
PGF2α	Prostaglandin F2 alpha
TAI	Timed Artificial Insemination

CHAPTER 1

1.1 INTRODUCTION

In Zimbabwe's extensive livestock production systems, the reproductive efficiency of cattle is a critical determinant of productivity and economic viability. Low reproductive performance and seasonal breeding limitations have contributed to low conception rates and prolonged calving intervals. Hormonal reproductive interventions have emerged as promising tools to improve fertility outcomes and the overall performance of cattle herds in resource constrained systems (Magwede et al., 2025).

Fixed-time artificial insemination (FTAI) offers a means to overcome estrus detection challenges inherent in extensive production systems by scheduling insemination at a predetermined time following synchronization (Ayatonye et al., 2025). The integration of Estradiol Cypionate (ECP), a long acting synthetic estrogen, has shown potential in synchronizing estrus and enhancing fertility (Pfeifer et al., 2020). The hormone acts by enhancing super ovulatory response, which yields a higher number of viable ova. It also facilitates the sustained suppression of existing dominant follicles allowing for a unified emergence of a new follicular wave (Bosolasco et al., 2021). Estradiol Benzoate is often employed as a preliminary treatment to maximize the precision of ECP based synchronization as it induces a synchronized emergence of a follicular wave (Zeng et al., 2024).

A key advantage of ECP based protocols is the reduction in the number of animals handling times, as ECP is administered concurrently with progesterone device removal eliminating the additional injection required with Estradiol Benzoate- based ovulation induction (Carvalho et al., 2020). Furthermore, studies have demonstrated that ECP administration increases the proportion of cows exhibiting estrus prior to FTAI and that cows displaying estrus have significantly higher pregnancy rates per AI compared with those that do not (Nogueira et al., 2019; Pfeifer et al., 2020).

Breed and parity further influence reproductive outcomes under FTAI protocols. Differences in ovarian dynamics and endocrine profiles between breeds affect estrus expression and conception rates under hormonal synchronization (Sartori et al., 2016). Primiparous cows often experience greater metabolic demands that may reduce responsiveness to synchronization protocols compared with multiparous cows (Reese et al., 2022).

The objective of this study was to evaluate the reproductive performance in terms of conception rate in cattle subjected to an Estradiol Cypionate synchronization protocol and

assessing how it performs under local conditions. This is crucial for developing impactful breeding strategies and improving herd fertility, shortening calving intervals and enhancing overall reproductive performance. The research further aims to analyze breed-specific reproductive responses to the Estradiol Cypionate protocol, incorporating parity as a key variable to identify practical strategies that improve fertility outcomes and livestock productivity among communal farmers in resource constrained systems.

1.2 BACKGROUND

Reproductive performance is a key determinant of profitability in cattle herds (Sharma et al., 2018). Globally, suboptimal reproductive efficiency reflected in low conception rates and extended calving intervals results in economic losses for beef producers, with pregnancy rates in extensively managed herds falling below 60% (Vasconcelos et al., 2017). Poor reproductive performance reduces the number of calves born per breeding season, limits genetic progress and increases the cost of production per unit of beef output. The economic significance of fertility has driven the development and adoption of assisted reproductive technologies particularly estrus synchronization and artificial insemination (AI) as tools to improve conception outcomes in both commercial and smallholder cattle production systems (D' Ochhio et al., 2019).

Across sub-Saharan Africa, reproductive inefficiency in cattle herds managed under extensive production systems remain a persistent challenge. Seasonal forage scarcity, nutritional stress and prolonged postpartum anestrus contribute to low conception rates and extended calving intervals in the region (Parker et al., 2024). In Zimbabwe, limited availability of high-quality sires has become the main obstacle to the development of extensively managed herds hence the adoption of artificial insemination (AI) (Chawala et al., 2021). Reproductive efficiency in communal and smallholder farms depends on timely estrus detection and revolves around increasing the rate at which mature cycling cows become pregnant within an optimal breeding period (Silper et.,al 2017).

Estrus synchronization combined with fixed-time artificial insemination provide a practical solution to overcome estrus detection challenges inherent in extensive systems by enabling planned breeding without reliance on heat observation. These protocols help schedule breeding and parturition times, improving fertility and providing economic returns by improving animal production efficiency (Samkange *et al*., 2019). Estrus synchronization involves the controlled use of reproductive hormones to ensure that a large proportion of

females exhibit estrus within a defined period facilitating planned breeding and artificial insemination (Kefelegn et.al., 2021). For estrus synchronization protocols to be effective, they must to synchronize follicular waves and luteal wave regression and resulting in the majority of animals showing standing estrus at the beginning of the breeding season (Salverson et al., 2020).

Various hormonal approaches are available to manage and control reproductive cyclicity. (Bihon et al 2021). Prostaglandin F2α (PGF2α) induces corpus luteum regression and control heat cycle length; Progesterone devices to suppress ovarian cyclicity and Gonadotropin-releasing hormone (GnRH) to regulate follicular development and ovulation (Arya et al., 2023). Protocols currently used in estrus synchronization in Zimbabwe include the One-shot prostaglandin, Two-shot prostaglandin, combination of Progesterone and Estradiol, Ovsynch, Melengesterol Acetate. Each protocol has limitations regarding labour requirements and animal handling frequency.

Previous studies have demonstrated the efficacy Estradiol Cypionate in timed artificial insemination at the time of progesterone device removal to induce ovulation and minimize the number of times animals are handled compared to other synchronization protocols (Pfeifer et al., 2020). Estradiol has been shown to regulate ovarian follicle growth and increase AI pregnancy rates in anestrous cattle (Bó and Menchaca, 2023). Cows displaying estrus after removal of the progesterone devices and before timed artificial insemination results in greater conception rates per AI (Nogueira et al., 2019).

1.3 PROBLEM STATEMENT

Zimbabwe's cattle sector contributes significantly to rural livelihoods. The Ministry of Finance, Economic Development and Investment Promotion (2025) estimates that there is approximately 5.74 million cattle in Zimbabwe. The majority of which are managed under extensive communal systems. These systems have reduced pregnancy rates, increased inbreeding and longer calving intervals due to open mating and limited access to high quality sires. In order to improve herd performance and sustainability, recent evaluations by the Ministry of Lands, Agriculture, Fisheries, Water and Rural Development highlight the need for climate-smart breeding practices and reproductive technologies. The use of hormonal protocols such as Estradiol Cypionate is limited and under researched in Zimbabwe's extensive production systems particularly across different parities. There is an urgent need to evaluate the reproductive efficiency of such protocols in order to develop scalable, specific

locally adapted interventions that can improve conception rates, shorten calving intervals and ultimately contribute to national herd growth and breed improvement.

1.4 JUSTIFICATION

Despite the availability of hormonal protocols, limited research exists on how different cattle breeds respond under extensive production systems in Zimbabwe. As a result, farmers lack tailored strategies to boost fertility and productivity. Evaluating the reproductive performance in cattle following the Estradiol Cypionate treatment in extensive production systems aims to develop practical applications that guide breed selection and protocol adoption, enhancing livestock productivity and economic resilience among communal and resource constrained farmers.

1.5 OBJECTIVES

1.5.1 Main Objective

To evaluate the reproductive efficiency of an Estradiol Cypionate based protocol in cattle breeds across different parities under an extensive production system in Zimbabwe.

1.5.2 Specific Objectives

1. To assess conception rates in cattle treated with the Estradiol Cypionate based estrus synchronization protocol.

2. To compare the calving percentages among cattle breeds following an Estradiol Cypionate based protocol.

3. To evaluate the influence of parity on conception rates and calving percentages in cattle submitted to Estradiol Cypionate synchronization protocol

1.6 HYPOTHESES

H_0 - There is no significant difference in conception rates among cattle breeds subjected to an Estradiol Cypionate protocol under extensive production systems.

H_1 -There is a significant difference in conception rates among cattle breeds subjected to an Estradiol Cypionate based protocol under extensive production systems.

H_0 -There is no significant difference in calving percentage in cattle breeds subjected to an Estradiol Cypionate based protocol under extensive production.

H_1 - There is a significant difference in calving percentages in cattle breeds subjected to an Estradiol Cypionate based protocol under extensive production.

H_0 - There is no significant difference on the influence of parity on conception rates and calving percentages in cattle breeds submitted to Estradiol Cypionate synchronization protocol.

H_1 - Parity has a significant influence on conception rates and calving percentages in cattle subjected to an Estradiol Cypionate based protocol.

1.7 SIGNIFICANCE OF THE STUDY

This research addresses the low reproductive performance observed in Zimbabwe's extensive production systems by evaluating the effectiveness of the Estradiol Cypionate (ECP) protocol across diverse parities and breeds, including Red Dane, Boran, and Angus. The study holds particular relevance to communal farmers who often struggle with labour demands of heat detection and the high costs of traditional breeding methods. Through the validation of a cost-effective Fixed-Time Artificial Insemination (FTAI) protocol under natural grazing conditions, the research provides a practical framework to improve conception rates, shorten calving intervals, and enhance the genetic quality of communal herds. These findings serve as a basis for increasing livestock off-take and improving the livelihoods and food security of smallholder farming communities.

1.8 LIMITATIONS

The relatively small sample size may constrain the statistical power of breed-level and parity-level comparisons limiting the generalizability of findings to the broader population of each breed in Zimbabwe. Environmental and nutritional factors common in extensive production systems such as seasonal variation in pasture quality and animal body condition could not be fully controlled throughout the study period. Challenges related to resources and management at the study site resulted in the study being conducted at a single location, which may limit the applicability of the findings to other agro-ecological regions.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Reproductive efficiency is widely recognized as an important factor that determines productivity and profitability in extensive beef production systems globally (Vasconcelos et al., 2017). Seasonal forage scarcity and resource limitations contribute to the low conception rates and extended calving intervals in Zimbabwe (Parker et al., 2024). Hormonal interventions particularly protocols based on Estradiol Cypionate (ECP) have increasingly been recognized as practical tools to synchronize estrus and improve reproductive outcomes in low-input systems (Wiltbank and Sartori, 2021).

2.2 Livestock Production Systems in Zimbabwe

Cattle production is an important part of Zimbabwe's agricultural sector and supports rural livelihoods, food scarcity and the country's economy. The country has an estimated national herd of more than five million cattle with the majority of the animals being owned by smallholder farmers in communal and resettlement areas (FAO, 2020). Smallholder farmers are estimated are estimated to own about 90% of the national herd highlighting their significant role in the livestock industry and the beef value chain in Zimbabwe (Muteyo et al.,

2025). Livestock production systems therefore play an important role in sustaining rural livelihoods with cattle being the main livestock species raised by farmers. Most communal and smallholder farmers rear cattle under extensive production systems where cattle graze on natural pastures and communal rangelands (Huruba, 2026).

One of the main challenges in communal cattle production is the continued use of natural mating with limited access to genetically superior sires. This has resulted in problems such as inbreeding, lengthened calving intervals and lower pregnancy rates. In a study carried out under Zimbabwean dairy production conditions, Magwede et al. 2025 found that the type of synchronization protocol used affected fertility and reproductive performance. The findings suggest that the reproductive technologies should be suited to local production conditions. However, the study focused on dairy cattle and did not consider extensive production systems which differ in nutrition, herd management and labour requirements.

2.3 Artificial insemination in extensive systems

Artificial insemination particularly fixed-time artificial insemination (FTAI) has improved reproductive efficiency in extensive production systems. FTAI reduces the need for heat detection by allowing insemination at predetermined times making it suitable for large and dispersed herds (Dias et al., 2020). The use of semen from genetically superior bulls helps improve fertility, growth performance, milk yield and carcass quality while reducing the cost of maintaining bulls and lowering the risk of venereal diseases associated with natural mating (Rashidi et al., 2024). AI also helps shorten breeding and calving season resulting in calves that are uniform in age and size making herd management easier. Zuidema et al. (2021) reported that improved semen evaluation methods and sex-sorted semen could further increase conception rates and overall production efficiency.

2.4 Reproductive physiology of the bovine estrous cycle

ln cattle, the estrus cycle averages about 21 days and is controlled by hormones released by the hypothalamus, pituitary gland and ovaries (Pal & Dar, 2020). Hormones such as gonadotrophin releasing hormone (GnRH), follicle stimulating hormone (FSH), luteinizing hormone (LH), estrogen and progesterone work together to regulate follicle development and ovulation (Consentini et al., 2021). The cycle is divided into four stages: proestrus, estrus, metestrus and diestrus. Each stage is characterized by specific hormonal and physiological changes in the reproductive tract. During proestrus, the corpus luteum regresses causing progesterone levels to decline and increased follicular growth under the influence of FSH and LH (Consentini et al., 2021; Doležalóva et al., 2024). Estrus is a stage when the cow is

receptive to mating and is characterized by high estrogen concentrations produced by the dominant follicle. Ovulation occurs shortly after the end of estrus following the release of LH (Hassanein et al., 2024). Metesrus begins after ovulation and is marked by the formation of the corpus luteum which starts producing progesterone to prepare the uterus for pregnancy. Diestrus is the longest stage of the cycle and is characterized by high progesterone levels that maintain conditions required for embryo development until the corpus luteum regresses if pregnancy does not occur (Hasbi & Gustina, 2020).

2.5 Estrus synchronization

Heat synchronization methods have improved over the years and now provide farmers with different options for improving reproductive performance and the success of artificial insemination (Magwede et al., 2025). These methods use hormones to control different stages of the estrus cycle. Prostaglandins are used to induce luteolysis, progesterone-releasing devices regulate luteal activity and gonadotrophin-releasing hormone is used to control follicle growth and ovulation (Pal & Dar, 2020). Such protocols can be useful in large herds managed under extensive grazing conditions where heat detection is often difficult in beef production systems. Their use has the potential in improving breeding management, increase reproductive efficiency and support the adoption of fixed-time artificial insemination in smallholder and communal cattle production systems (Ferré et al., 2025).

2.6 Estrus synchronization programs

2.6.1 One-Shot Prostaglandin Protocol

The one-shot prostaglandin protocol involves a single injection of prostaglandin F2α (PGF2α) or one of its synthetic analogues to cows that are cycling naturally. The treatment causes regression of the corpus luteum in animals that possess a functional luteal structure during the luteal stage of the estrus cycle (Bihon et al., 2021). PGF2α is only effective when given between day 7 and 17 of the cycle because immature corpora lutea do not respond to the hormone (Corpron et al., 2019). As a result, some animals fail to respond reducing the overall synchronization rate within the herd (Bihon et al., 2021). Cows that respond generally exhibit estrus within 48-96 hours of injection and are inseminated according to the AM-PM rule (Dodicho et al., 2024). This protocol minimizes hormone use and animal handling times but its reliance on heat detection and inability to synchronize the entire herd makes it less practical for large herds managed under extensive conditions.

2.6.2 Two-Shot Prostaglandin Protocol

The two-injection prostaglandin protocol improves synchronization by administering a second prostaglandin injection 11 to 14 days after the first ensuring previously unresponsive animals are treated during a responsive luteal phase. This approach increases the proportion of animals exhibiting synchronized estrus compared to a single injection (Dodicho et al., 2024). A common modification involves breeding animals that respond to the first injection and treating only non-responders with the second, thereby reducing costs and labour. Despite improved synchrony, the protocol still relies on estrus detection and does not effectively address anestrous animals, limiting its use in postpartum cattle (Bihon & Assefa, 2021). Inappropriate presynchronization with PGF2α may negatively affect fertility when poorly timed relative to subsequent protocols (Monn et al., 2019).

2.6.3 Ovsynch Protocol

The Ovsynch protocol is a GnRH- based synchronization program developed to regulate follicular growth and ovulation making fixed-time artificial insemination possible without observing estrus (Moniruzzaman et al., 2024). It begins with a GnRH injection that induces ovulation and initiates a new follicular wave followed by PGF2α to regress the corpus luteum and a second GnRH treatment to synchronize ovulation before insemination (Berean et al 2025). The protocol provides high rates of ovulation synchronization and is well suited for managing large herds (Moniruzzaman et al., 2024). Its performance may decline when animals are not properly pre synchronized and reproductive outcomes are influenced by the physiological condition of cows at the start of treatment (Berean et al., 2025).

2.6.4 Co-Synch Protocol

The Co-synch protocol is an adaptation of the Ovsynch program in which the second GnRH injection is administered at the same time as FTAI. This modification reduces the number of handling times and improves its suitability for extensive production systems where labour is limited (Corpron et al., 2019). The addition of progesterone releasing devices such as CIDR improves synchronization particularly in anestrous cows by supplying progesterone during the treatment period. In some cases, two PGF2α injections at CIDR removal are recommended to achieve complete luteolysis although increasing the dose of a single injection may produce similar results (Corpron et al., 2019).

2.6.5 Melengestrol Acetate (MGA) Protocol

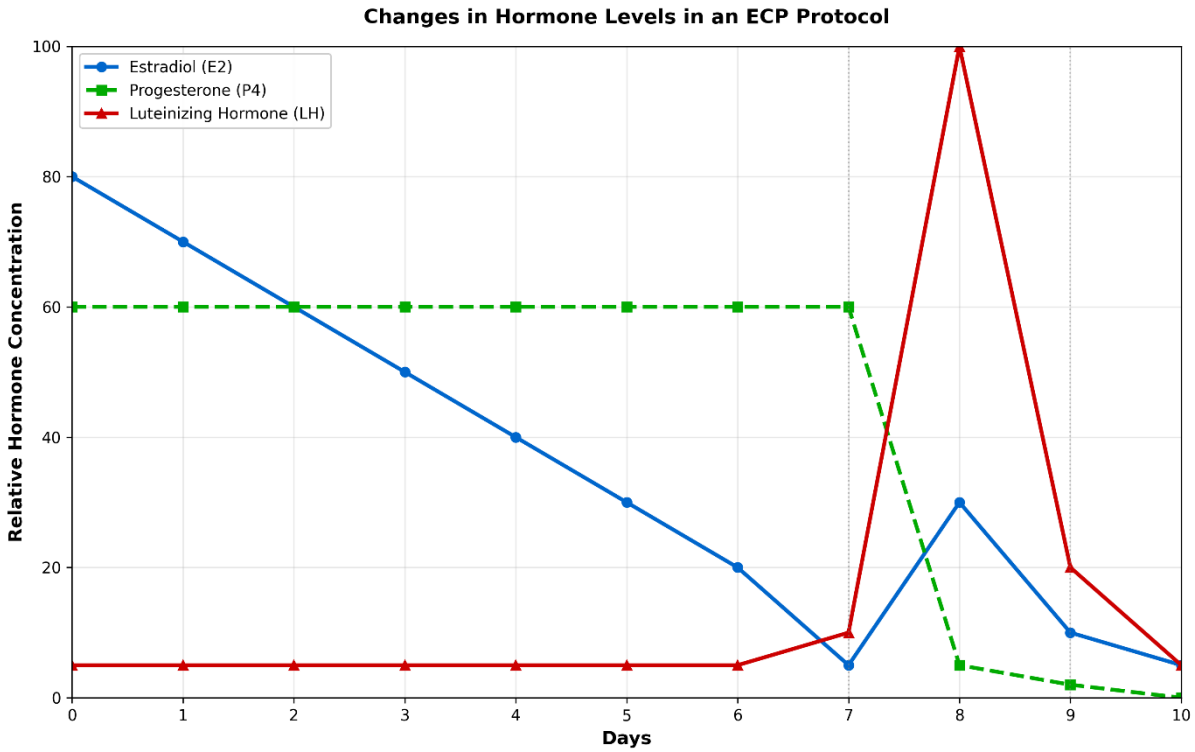
Melengestrol acetate (MGA) is an orally administered synthetic progestin used as an alternative to intravaginal progesterone devices for estrus synchronization in beef cattle. It is supplied in feed at 0.5mg per animal each day for 14 consecutive days with research showing that treatment periods ranging from 14 to 18 days produce comparable reproductive performance (Christenson et al., 2022). MGA suppresses estrus and ovulation by maintaining elevated circulating progestin concentrations thereby creating a hormonal environment similar to the diestrus phase of the estrus cycle. Cyclic cows generally exhibit estrus within two to five days following withdrawal of MGA. However, fertility during this first estrus is usually poor because persistent dominant follicles may develop during treatment. As a result breeding is recommended at the second estrus after MGA withdrawal (Arya et al., 2023). The main advantage of MGA is that it is administered orally eliminating injections and intravaginal insertions while reducing labour demands. The dependence on consistent daily feed intake and accurate estrus detection restricts its use in extensive communal grazing systems where individual feed management is difficult.

2.6.6 Progesterone-Based Devices: Mechanism and Optimization

Controlled Internal Drug Release (CIDR) devices are T-shaped intravaginal progesterone releasing implants designed to deliver a continuous and predictable dose of progesterone to the bloodstream after insertion (Moniruzzaman et al., 2024). The progesterone absorbed through the vaginal lining and suppresses hypothalamic GnRH secretion, reduces LH release and prevents premature ovulation of developing follicles throughout the synchronization period. This hormonal regulation creates similar endocrine conditions among animals improving synchronization when CIDR is combined with other reproductive hormones (Corpron et al., 2019). CIDR-based protocols are particularly effective in both cyclic and anestrous animals due to their ability to provide exogenous progesterone support (Moniruzzaman et al., 2024). However, their higher cost relative to prostaglandin-based protocols may limit widespread adoption, particularly in resource-constrained production systems where CIDR devices represent a significant per-animal input cost.

2.7 Estradiol Cypionate

Estradiol Cypionate (ECP) is a long-acting estrogen that effectively resets follicular waves and induces estrus when administered following progesterone device removal (Dutra Okada et al., 2025). Administration of Estradiol Cypionate at progesterone device removal enhances estrus expression and synchrony. Lemos et al., 2026 found that cows receiving 0.5-1mg



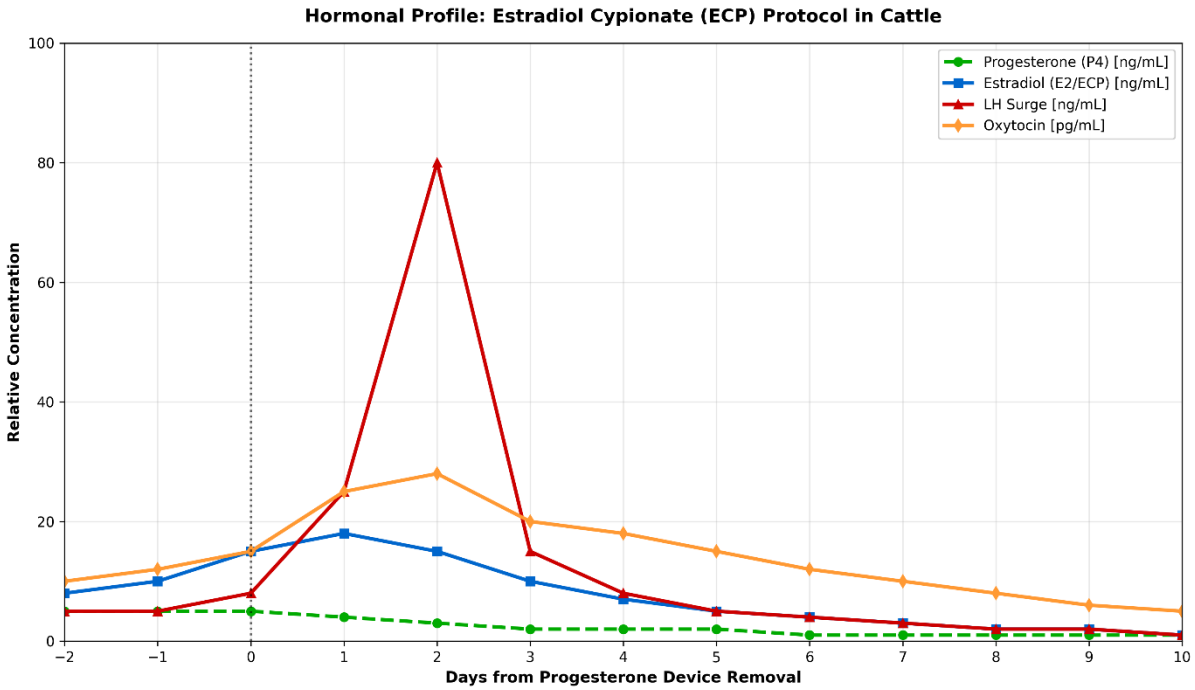
showed significantly greater estrus behavior than cows that were not given Estradiol Cypionate. The treatment has also been associated with low body condition scores where reproductive performance is often compromised (Okada et al., 2025). In addition, ECP induces a luteinizing hormone surge after progesterone device removal, promoting synchronized ovulation and enhancing the success of fixed-time artificial insemination (Bosolasco et al., 2021).

Figure 2.1: showing the physiological changes in hormonal levels

Figure 2.2: showing hormonal profile of ECP protocol in cattle from progesterone removal

2.8 Estradiol Cypionate protocols

Research has shown that administering Estradiol Cypionate at the time of progesterone device removal improves ovarian activity, increases the expression of estrus and promotes ovulation leading to better pregnancy outcomes (Bosolasco et al., 2021; Pfeifer et al., 2020; Sales et al., 2023). The use of ECP has also been linked to improved corpus luteum function and a uterine environment that supports embryo development thereby enhancing fertility and overall reproductive performance (Bosolasco et al., 2021). An advantage of ECP-based synchronization protocols is that the hormone is given when the progesterone device is removed eliminating the extra injection required in estradiol benzoate protocols. This simplifies the procedure by reducing labour requirements, animal handling and stress (Carvalho et al., 2020). As a result these protocols are easier to apply in large herds managed



under extensive grazing conditions. ECP protocols are relatively affordable compared to other synchronization methods and provide a cost effective option for producers with limited resources while still achieving similar pregnancy rates. (Carvalho et al., 2020). ECP has been reported to improve reproductive performance in cows with low body condition scores, a

common challenge in extensive production systems, by supporting follicular development and increasing pregnancy per artificial insemination (Sales et al., 2023).

2.9 Breed-Specific Reproductive Responses

Breed differences have a major influence on fertility and the effectiveness of hormonal synchronization protocols in beef cattle (Andrade et al., 2024). Variations in reproductive physiology between Bos indicus and Bos Taurus cattle contribute to differences in ovarian follicle development, hormone secretion and reproductive performance among Boran, Red Dane and Angus (Sartori et al., 2010). Boran cattle, which belong to the Bos indicus group generally, develop smaller ovulatory follicles and corpora lutea than Bos Taurus breeds such as Angus and Red Dane. However they usually maintain higher circulating levels of reproductive hormones including progesterone and estrogen which affect follicular development and ovulation patterns (Sartori et al., 2010; Baldrighi et al.,2022). These physiological characteristics can influence estrus expression and fertility during breeding and artificial insemination programs (Sartori et al., 2010).

Andrade et al. (2024) reported that Bos indicus heifers treated with estradiol-based synchronization protocols in combination with progesterone devices showed improved follicular development and better synchronization of ovulation demonstrating the importance of hormonal control in improving reproductive efficiency in tropical breeds. The response to these protocols may also be affected by factors such as body condition score, metabolic status, and physiological stage of the animal which influence subsequent conception rates (Lemos et al., 2026).

2.10 Parity-related Reproductive Constraints

Parity has been associated with variations in estrus expression and reproductive behaviour, which both influence the success of breeding programs and the timing of artificial insemination (Catalano et al., 2025). Differences in hormonal activity and recovery of the reproductive tract between primiparous and multiparous cows contribute to variation in conception rates and reproductive performance (Fodor et al., 2019). Physiological, metabolic and endocrine changes associated with parity play a significant role reproductive performance in beef cattle Primiparous cows often experience greater metabolic stress because they must allocate nutrients to body growth, lactation and reproduction simultaneously which can delay the return of ovarian activity after calving and reduce fertility compared with multiparous cows (Reese et al., 2022).

2.11 Calving Percentages

Changule (2022) explained that calving percentage is a key metric that reflects the overall fertility and management success of the herd. It is not determined by a single factor and reflects the interaction of cow physiology, nutrition, health status, environmental conditions and reproductive management, all of which must be optimized to improve herd fertility and productivity. Multiparous cows tend to achieve higher pregnancy and calving rates under well-managed synchronization programs (Simões et al., 2024). Estrus synchronization is an economically beneficial practice, primarily as it shortens the calving interval, thereby improving reproductive efficiency and offspring survival rates (Arya et al., 2023). Postpartum health disorders such as dystocia and metritis reduce calving percentages as they interfere with uterine recovery and delay rebreeding (Bahrami-Yekdangi et al., 2022; Tsaousioti et al.,2024). Recent studies indicate that environmental stressors such as limited forage availability, heat stress and disease outbreaks negatively affect fertility and embryo survival leading to decline in calving percentages particularly in extensive production systems (Washaya et al., 2024; Temesgen et al., 2022). Management practices including estrus synchronization efficiency, timing of insemination, bull fertility and heat detection accuracy play a major role in determining whether cows conceive within the breeding season, which in turn influences the proportion of cows that calve the following season (Moorey & Biase, 2020). Seasonal breeding management also affects calving outcomes, as cows bred early in the breeding season generally have higher chances of conceiving again on time and maintaining annual calving rates compared with late-calving cows (Moorey & Biase, 2020).

2.12 Conception and Pregnancy Rates

Conception and pregnancy rates are widely used as indicators of reproductive performance in beef cattle enterprises. Adequate nutritional status and body condition support earlier return to ovarian cyclicity, improved follicle development and enhanced oocyte competence resulting in increased pregnancy rates after artificial insemination (D'Occhio et al. 2019; (Kasimanickam & Kasimanickam, 2026). In contrast, poor body condition and extended postpartum anestrus may disrupt follicular development and reduce the response to synchronization protocols resulting in lower conception rates. Multiparous cows generally exhibit better pregnancy outcomes than primiparous cows because they experience less metabolic stress and recover more rapidly post-partum(Reese et al., 2022).

Estrogen-based synchronization protocols improve fertility outcomes in by promoting optimal follicular development and ovulation timing, thereby increasing the chances of successful conception (Taghizadeh et al., 2024). Research by Menchaca et al., 2021 demonstrated increased pregnancy per artificial insemination with estradiol cypionate-based synchronization protocols in postpartum beef cows. Conception rates reported in ECP trials vary considerably, ranging from approximately 40% to 65% depending on breed, parity, BCS, environmental conditions and protocol design (Bó et al., 2018: Sales et al., 2023). The variation highlight the importance of assessing reproductive technologies under Zimbabwean communal farming conditions rather than relying on findings from other production systems.

2.13 Cost-Effectiveness and Adoption of Reproductive Technologies in Smallholder Systems

The economic value of estrus synchronization and fixed-time artificial insemination (FTAI) in smallholder production systems depends on whether the benefits outweigh the cost of hormone treatments, semen, equipment and skilled labour. Potential benefits include improved conception rates, shorter calving intervals and production of genetically superior offspring (Fesseha & Degu, 2020; Ribeiro et al., 2023). In communal farming areas, where herd sizes are small and financial resources are limited the cost of applying these technologies to individual animals may discourage adoption (Elmetwally et al., 2021).

The inclusion of Estradiol Cypionate (ECP) into FTAI protocols offers a practical way to reduce costs because it eliminates additional animal handling lowering labour requirements and minimizing stress-related losses. Group-based synchronization and insemination strategies allow fixed costs to be distributed across a larger number of animals enhancing overall economic efficiency (Kolachi et al., 2025). Consequently, the development and validation of cost-effective, locally adapted FTAI protocols are essential for promoting wider adoption of reproductive technologies in smallholder production systems (Mawadri et al., 2025).

2.14 Research Gap

Although Estradiol Cypionate has been reported to improve estrus expression and conception rates in fixed-timed artificial insemination (FTAI) programs, limited information exists regarding its effectiveness across different cattle breeds managed under extensive production systems. Previous studies conducted under controlled commercial conditions demonstrated

improved pregnancy outcomes following the use of ECP-based synchronization protocols (Pfeifer et al., 2020). However, reproductive responses may differ between breeds due to physiological and endocrine differences between Bos Taurus and Bos indicus cattle (Sartori et al., 2010). Breeds commonly reared in Zimbabwe are exposed to diverse environmental and nutritional challenges characteristic to extensive grazing systems, yet there is limited local evidence to their response to ECP synchronization remains limited. This leaves farmers and livestock practitioners without sufficient information to guide reproductive management and technology adoption.

Parity is another important factor influencing reproductive performance in cattle. Variations in hormonal activity, metabolic demands and postpartum recovery between primiparous and multiparous cows may influence estrus expression, conception success and subsequent calving performance (Fodor et al., 2019; Catalano et al., 2025). Although previous studies have investigated parity and reproductive performance separately, a limited number have examined its effect on both conception and calving percentages. Calving percentage is a recognized indicator of reproductive efficiency and herd productivity (Changule, 2022), limited information is available on parity-specific have linked parity-specific calving outcomes under Zimbabwe field conditions.

This study was therefore conducted to assess the reproductive performance of Boran, Angus and Red Dane cattle from different parity groups following Estradiol Cypionate synchronization under local extensive production systems. It aimed to produce practical, evidence based findings that could help farmers improve reproductive management where resources are limited.

CHAPTER 3: METHODOLOGY

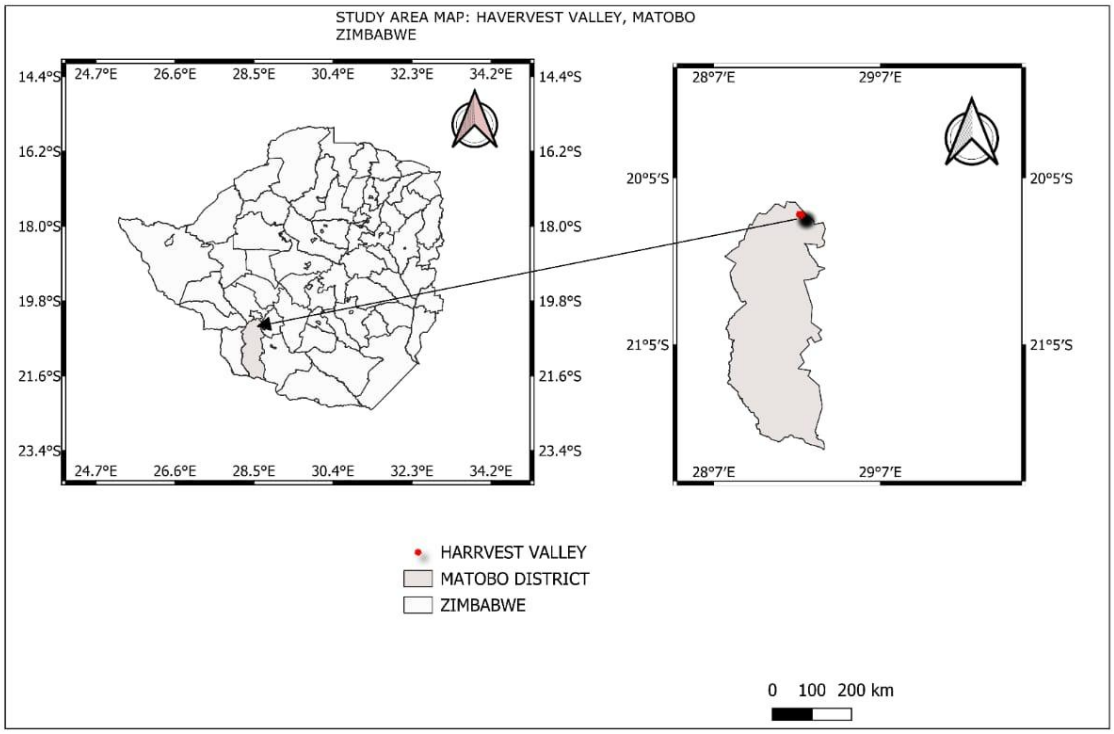
3.1 STUDY SITE

The study was conducted at Harvest Valley Farm in Matobo district (28°38'59" E, 20° 17'32" S).The farm lies within Natural region IV characterized by semi-arid climatic conditions with annual rainfall ranging between 450 and 650mm.Rainfall season is unimodal and begins in November/December and ends in March/April. The long term average rainfall is 590mm.

Figure 3.1: showing location of Harvest Valley Farm

3.2 POPULATION SIZE

This study employed a purposive stratified sampling design with 45 cattle comprising three breeds: Angus (n=15), Red Dane (n=15) and Boran (n=15) subjected to an Estradiol Cypionate synchronization protocol. Within each breed, cows were further grouped based on parity into two categories: parity (0-1) representing low parity and high parity (2-4) representing multiparous cows.



3.3 DATA COLLECTION

The following baseline data was recorded for each animal at study commencement: animal identity number, body condition score (BCS; assessed on a 1–5 scale following Edmonson et al., 1989), breed, date of birth, date of last calving, stage of parity and lactation status. The data was captured in Microsoft Excel spreadsheets for analysis.

Visual observations for signs of estrus were conducted and the proportion of cows showing standing estrus (primary sign) was recorded during the protocol period. Pregnancy diagnosis via rectal palpation was conducted to confirm non-pregnancy at the beginning of the study

and again three months post-insemination to determine conception status. Conception rate was calculated as:

Conception Rate (%) = (Number of cows diagnosed pregnant ÷Total number inseminated) × 100

Calving data was subsequently collected to compute calving percentage:

Calving Percentage (%) = (Number of calves born ÷ Total number inseminated) × 100

3.4 ESTRADIOL CYPIONATE SYNCHRONIZATION PROTOCOL

The study utilized a standardized Estradiol Cypionate based Fixed Time Artificial Insemination protocol. Controlled Internal Drug Release (CIDR®) loops were inserted intravaginally on day 0 to deliver a continuous dose of progesterone that maintained a pseudo-luteal phase, suppressing estrus and preventing premature follicular development. This was followed by administration of 2 ml Estradiol Benzoate and 1ml of Prostaglandins Estrumate , to induce the emergence of a new follicular wave. On day 7, the CIDR® loops were removed and there was administration of 1 ml of Estradiol Cypionate and 1 ml of Prostaglandins (Estrumate) injections. Timed artificial insemination (TAI) was conducted on day 9.

Figure 3.2 showing the ECP protocol administration

Day	Procedure	Products Administered
Day 0	CIDR®insertion+ injections	CIDR(progesterone device), 2ml Estradiol Benzoate, 1ml Prostaglandins Estrumate

Day 7	CIDR®removal+injections	1ml Estradiol Cypionate, 1ml Prostaglandins Estrumate
Day 9	Timed Artificial Insemination	FTAI performed 48-56 hours post-CIDR removal
Day 97(3 months)	Pregnancy Diagnosis	Rectal palpation
~Day 280	Calving records	Date and outcomes of parturition recorded

3.5 ETHICAL CONSIDERATIONS

This study was conducted in strict compliance with the ethical standards governing animal research as set out in Veterinary Act (Chapter 19:01) of Zimbabwe. All 45 animals used in this study were handled in accordance with acceptable animal welfare standards.

3.6 DATA ANALYSIS

Data on reproductive performance was analyzed using SAS Version 9.4. Descriptive statistics were used to summarize conception rates and calving percentages as proportions and percentages. Breed differences in conception and calving outcomes were assessed using the Chi-square test (χ^2). Fisher's Exact Test was used where expected cell differences were less than five.

To determine the effect of breed and parity on reproductive performance, binary logistic regression analysis was performed separately for conception and calving outcomes. The dependent variables were conception status and calving status coded as 1 for success and 0 for failure. Breed and parity were included in the model as explanatory variables.

Logistic regression analysis was used to evaluate the influence of parity (0-1) and (2-4) on conception rates and calving percentages. The statistical model used was:

$$Iog\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1(Breed) + \beta_2(Parity)$$

Where:

p = probability of conception or calving success

β_0 = intercept

β_1 and β_2 = regression coefficients for breed and parity, respectively

Results were presented as odd ratios with 95% confidence intervals. Statistical significance was declared at $P < 0.05$

CHAPTER 4: RESULTS

4.1 Overall Reproductive Performance

Table 4.1: Overall conception rate and calving percentage following ECP-based FTAI

Parameter	Total inseminated	Number	Percentage (%)
Confirmed pregnant	45	27	60.0
Empty	45	18	40.0
Calved	45	23	51.1

Did not calve	45	22	48.9

Overall, a conception rate of 60.0% was recorded following ECP-based FTAI. Twenty-three (23) subsequently calved out of the 27 confirmed pregnant cows yielding an overall percentage of 53.1%. The difference between conception rate and calving percentage reflects embryonic and foetal losses that occurred during the gestation period.

4.2 Breed-specific Conception rates and Calving percentages

Table 4.2: Conception and calving percentages by breed following ECP-based FTAI

Breed	N	Conceived(n)	Conception rate(n)	Calved(n)	Calving%(n)	P-value^{+}
Boran	15	10	66.7	8	53.3	—
Angus	15	8	53.3	7	46.7	—
Red Dane	15	9	60.0	8	53.3	—
Overall	45	27	60.0	23	51.1	—
χ^2 (P-value)			0.56		0.18	NS

Boran cows recorded the highest conception rate of 66.7%, followed by Red Dane at 60.0% and Angus at 53.3%. With respect to calving percentage, Boran and Red Dane were equal at 53.3% while the Angus recorded the lowest calving percentage at 46.7%. Chi-square analysis revealed no statistically significant difference in conception rates (χ^2 =0.56, df =2, p > 0.05) or calving percentages (χ^2 = 0.18, df = 2, p > 0.05) among the three breeds, indicating that breed alone was not a significant determinant of reproductive performance under the conditions of this study.

4.3 Influence of Parity on Conception Rates and Calving Percentages

Table 4.3: Influence of parity on conception rates and calving percentages in cattle subjected to an ECP based synchronization protocol

Parity group	N	Conceived (n)	Conception rate (%)	Calved (n)	Calving (%)	P-value

Low parity (0-1)	19	10	52.6	9	47.4	—
High parity (2-4)	26	17	65.4	14	53.8	—
χ^2 (P-value)			0.74		0.18	NS

NS = Not significant

High parity cows (parity 2 to 4) recorded a conception rate of 65.4%, compared to 52.6% for low parity animals. High parity also achieved a higher calving percentage of 53.8% compared to 47.4% for low parity animals. These differences were not statistically significant at the $P < 0.05$ level ($\chi^2 = 0.74$, df = 1, $p > 0.05$ for conception; $\chi^2 = 0.18$, df = 1, $p > 0.05$ for calving) suggesting that while multiparous cows tended to perform better numerically the effect of parity was not statistically significant in this sample.

4.4 Breed by parity interaction on Conception Rates and Calving percentage

Table 4.4: Conception rates by breed and parity group

Breed	Low Parity (0-1)		High Parity (2-4)		Overall Breed	
	Conception rate (%)	N	Conception rate (%)	N	Conception rate (%)	N
Boran	57.1	4/7	75.0	6/8	66.7	10/15
Angus	50.0	3/6	55.6	5/9	53.3	8/15
Red Dane	50.0	3/6	66.7	6/9	60.0	9/15
Overall	52.6	10/19	65.4	17/26	60.0	27/45

Table 4.5: Calving percentages by breed and parity group

Breed	Low Parity (0-1)		High Parity (2-4)		Overall Breed	
	Calving % (%)	N	Calving % (%)	N	Calving % (%)	N
Boran	57.1	4/7	50.0	4/8	53.3	8/15
Angus	33.3	2/6	55.6	5/9	46.7	7/15
Red Dane	50.0	3/6	55.6	5/9	53.3	8/15
Overall	47.4	9/19	53.8	14/26	51.1	23/45

High parity cows recorded superior conception rates compared to low parity animals across all breeds. The most pronounced within- breed parity effect on conception was observed in Boran (75% FOR high parity versus 57.1 for low parity) and Red Dane (66.7% versus 50.0%). Angus showed the smallest within- breed parity differential (55.6% versus 50.0%). For calving, high parity Angus cows (55.6%) outperformed low parity Angus cows (33.3%), representing the widest calving differential among the three breeds. Boran low parity cows recorded a higher calving percentage (57.1%) than Boran high parity cows (50.0%) which was the only instance in which low parity animals outperformed high parity animals on calving.

4.5 Influence of parity on conception rate and calving percentage

Table 4.6: Logistic regression analysis for Conception Rate (n=45)

Fixed Effect	B	SE	Wald χ^2	P-value	OR	95% Cl
Intercept (β_0)	-0.037	0.582	0.004	0.949	0.964	0.31-3.02
Boran vs Angus (β_1)	0.341	0.712	0.230	0.632	1.407	0.35-5.68

Red Dane vs Angus (β_1)	0.120	0.796	0.023	0.880	1.128	0.24-5.37
Parity 2-4 vs 0-1 (β_2)	0.560	0.620	0.817	0.366	1.751	0.52-5.90

OR = odds ratio: Cl = confidence interval: SE =standard error

The logistic regression analysis revealed no statistically significant effects of breed or parity on conception rates (all P >0.05). However, the odd ratios indicate directional trends:

Boran vs Angus: Boran cattle had 1.41 times the odds of conception compared to Angus (OR = 1.41, 95% Cl: 0.35, P = 0.632). This suggests a numerical advantage for Boran though not statistically significant.

Red Dane vs Angus OR = 1.13 (95%Cl O.24-5.37), P = 0.880) : Red Dane showed minimal difference from Angus with an odds ratio of conception compared to low parity animals (parity 0-1), with OR =1.75 (95% Cl: 0.52 – 5.90, P = 0.366). This represents the strongest effect observed even though statistical significance was not achieved.

Table 4.7: Logistic regression analysis for Calving Percentage (n=45)

Fixed Effect	B	SE	Wald χ^2	P-value	OR	95% Cl
Intercept (β_0)	-0.174	0.557	0.091	0.764	0.841	0.27-2.61
Boran vs Angus (β_1)	0.105	0.687	0.023	0.879	1.110	0.29-4.27
Red Dane vs Angus (β_1)	0.008	0.780	0.000	0.992	1.008	0.22-4.65

Parity 0-2 vs 0-1 (β_2)	0.327	0.604	0.293	0.588	1.387	0.42-4.53

OR = odds ratio: Cl = confidence interval: SE =standard error

For calving outcomes, the logistic regression confirmed no statistically breed or parity effects (all P > 0.05):

Boran vs Angus: Boran cattle showed minimal advantage with OR = 1.11 (95% Cl: 0.29-4.27, P = 0.879). Red Dane vs Angus: Red Dane exhibited nearly identical calving odds to Angus (OR = 1.01, 95% Cl: 0.22-4.65, P = 0.992). Multiparous cows demonstrated 1.39 times the odds of successful calving compared to primiparous/heifer groups (OR = 1.39, 95% Cl: 0.42-4.53, P = 0.558). This difference was not statistically significant.

CHAPTER 5: DISCUSSION

5.1 Overall Reproductive Performance

The findings demonstrated a moderate overall conception rate of 60% and a calving percentage of 51.1% indicating that the protocol is effective under low-input conditions. These outcomes are consistent with previously reported results from estradiol based fixed time artificial insemination programs which have shown that hormonal synchronization can

improve reproductive performance (Pfeifer et al., 2020) and align with the 55–65% conception rates documented by Sales et al., (2023) in cows managed under semi-intensive and extensive systems with variable body condition scores. Colazo et al., 2003 conducted four experiments in CIDR-based FTAI programs in beef heifers and established ECP administered at CIDR removal or 24 hours later produced comparable pregnancy rates of 44 - 59%. Bó et al., (2018) reported conception rates ranging from 40% to 60% in suckled beef cows subjected to progesterone and estradiol- based FTAI protocols in South American Extensive systems.

The 8.9 percentage point gap reflects embryonic mortality, foetal losses and calving complications that are characteristic to extensive production environments, where nutritional and climatic stressors cannot be fully controlled. D'Occhio et al. (2019) confirmed that negative energy balance and suboptimal body condition at the time of insemination increase the risk of early embryonic death in beef cows, and this physiological vulnerability is intensified under the semi-arid grazing conditions of the study site. Similarly pregnancy loss patterns following FTAI have been documented by Bosolasco et al. (2021), who noted that ECP administered at CIDR removal improved post-ovulatory luteal function and uterine environment, thereby partially reducing embryonic mortality relative to protocols lacking ECP treatment.

The 60% conception rate also compares favourably with findings from Carvalho et al., (2020) who demonstrated that ECP treatment at progesterone device removal reduced the number of animal handling times without compromising pregnancy rates in timed artificial insemination programs. Pfeifer et al. (2020) similarly showed that ECP significantly enhanced estrus expression and pregnancy rates in timed artificially inseminated beef cows, supporting the moderate to good conception rates recorded in the study.

5.2 Breed- Specific Conception Rates

Boran cows recorded the numerically highest conception rate (66.7%)in this study, a finding consistent with the adaptive reproductive capacity that Bos indicus derived breeds exhibit under resource- constrained extensive systems. According to Sartori et al. (2016), Bos indicus breeds maintain higher circulating concentrations of reproductive hormones including progesterone and estradiol compared with Bos Taurus cattle which may improve follicular development and corpus luteum function after hormonal synchronization. The numerically

lover conception rate in Angus (53.3%) relative to Boran may reflect breed-specific differences in follicular dynamics and responsiveness to the ECP protocol, as reported by Baldrighi et al. (2022). Red Dane cows achieved an intermediate conception rate of 60%, suggesting moderate responsiveness to the ECP protocol consistent with their Bos Taurus heritage under semi-arid extensive conditions of the study site. The absence of statistically significant differences is likely due to the limited sample size which restricts statistical power to detect moderate effect sizes. The uniform body condition score (predominantly 2.5 on a 1 to 5 scale) recorded across the herd in this study likely reduced breed-related fertility differences that might otherwise emerge under more variable nutritional conditions.

5.3 Breed-Specific calving percentages

Calving percentages for Boran (53.3%) and Red Dane (53.3%) were identical and numerically superior to Angus (46.7%). The lower calving percentage in Angus may reflect a higher incidence of foetal losses or calving complications in this breed under semi-arid conditions of Matobo District. Bahrami- Yekdangi et al. (2022) identified blood macro-mineral imbalances such as specifically hypocalcemia) at parturition as risk factors associated with the incidence of dystocia and stillbirths in Holstein dairy cows.

5.4 Influence of parity on Conception Rates

High parity cows (2-4) recorded a numerically superior conception rate (65.4%) compared to low parity animals (52.6%) with and odds ratio of 1.75 in favour of high parity animals. These findings are consistent with established literature on parity-related reproductive constrains. Sales et al. (2023) showed that increasing ECP dose improves pregnancy rates only in low-body condition animals and that higher Estradiol Cypionate or equine chorionic gonadotrophin (eCG) supplementation could enhance reproductive outcomes in this subgroup.

5.5 Influence of parity on Calving Percentage

High parity cows achieved a calving percentage of 53.8% compared to 47.4% for low parity animals (odds ratio = 1.39). This numerical advantage is consistent with findings by Sa Filho et al. (2015) who reported that primiparous cows submitted to large scale resynchronization FTAI programmes achieved lower pregnancy rates than multiparous cows, reflecting the combined effect of reduced estrus expression, smaller ovulatory follicles, and greater susceptibility to early embryonic loss. Boran low parity cows recorded a higher calving percentage (57.1%) than Boran high parity cows (50%).

CHAPTER 6

6.1 CONCLUSION

The ECP-based FTAI protocol yielded a satisfactory overall conception rate of 60% and a calving percentage of 51.1% under extensive production conditions, demonstrating the viability of ECP-based synchronization as a practical reproductive technology for communal and smallholder cattle production systems in Zimbabwe.

Numerically, Boran cows achieved the highest conception rate (66.7%) and Angus cows achieved the lowest (53.3%), while Boran and Red Dane tied for the highest calving percentage (53.3% each). However, breed differences in both conception rate and calving percentage were not statistically significant, indicating that under comparable management and nutritional conditions, ECP-based FTAI can deliver broadly equivalent fertility outcomes across diverse cattle breeds.

Overall, this study provides preliminary evidence supporting the adoption of ECP-based FTAI as an economically feasible and practically implementable reproductive management tool in Zimbabwe's extensive cattle production systems. The protocol's capacity to reduce animal handling while maintaining competitive pregnancy rates makes it particularly suitable for resource limited communal farming environments.

The current study suggests that Estradiol Cypionate based FTAI protocols are suitable for Zimbabwe's extensive production systems, demonstrating overall conception and calving rates of 60.0% and 51.1%. The results show that the protocol works consistently across breeds, but parity is a key factor influencing success. Multiparous cows had significantly higher reproductive performance. Targeted use of the protocol and improved management for low-parity animals may be needed to achieve better outcomes.

6.2 RECOMMENDATIONS

Future studies should use multi-site, multi-season trials to fully separate the contributions of breed, parity, nutritional status, and environmental variability to Estradiol Cypionate (ECP) protocol efficacy across Zimbabwe's diverse agro-ecological zones and production systems. Larger breed-specific samples of at least 30 to 50 animals per group, or a minimum of 30 animals per breed-parity subgroup, are recommended to achieve adequate statistical power for detecting moderate effect sizes in conception and calving outcomes as well as for formal interaction testing. Future studies should also monitor and control body condition score (BCS) more rigorously by deliberately including cows with a wider range of BCS values to allow evaluation of the interaction between nutritional status, breed, parity, and response to ECP-based synchronization. In addition, strategic pre-mating supplementation of low BCS cows combined with ECP-based fixed-time artificial insemination (FTAI) warrants further evaluation under Zimbabwe's seasonal extensive systems, as this may substantially improve conception and calving outcomes. Future research should further investigate the causes of pregnancy loss between conception and calving through incorporation of mid-gestation pregnancy diagnosis and postpartum health records to better characterize the stage and causes of foetal attrition. Economic cost-benefit analysis comparing Estradiol Cypionate-based fixed-time artificial insemination to alternative reproductive technologies such as natural mating, conventional synchronization methods, and GnRH-based protocols is also needed to guide adoption decisions for communal farmers and extension services across Zimbabwe's diverse agro-ecological zones.

REFERENCES

Andrade, J. P. N., Domingues, R. R., Carvalho, B. P., Gomez-Leon, V., Prata, A. B., Sartori, R., & Wiltbank, M. C. (2024). Optimizing ReBreed21 I: Evaluation of endocrine and ovarian dynamics in non-bred Bos indicus heifers. Theriogenology, 220, 77–83.

Arya, D., Goswami, R., & Sharma, M. (2023). Estrous synchronization in cattle, sheep and goat. Multidisciplinary Reviews, 6(1), e2023001.

Ayantoye, J. O., Kolachi, H. A., Zhang, X., Shahzad, M., Kandil, O. M. T., Wan, P., & Zhao, X. (2025). Advances in Timed Artificial Insemination: Integrating Omics Technologies for Enhanced Reproductive Efficiency in Dairy Cattle. *Animals*, *15*(6), 816.

Bahrami-Yekdangi, M. & Ghorbani, Gholam & Sadeghi-Sefidmazgi, Ali & Mahnani, Abolfazl & Drackley, James & Hosseini Ghaffari, Morteza. (2022). Identification of cow-level risk factors and associations of selected blood macro-minerals at parturition with dystocia and stillbirth in Holstein dairy cows. Scientific Reports. 12. 10.1038/s41598-022-09928-w.

Bahrami-Yekdangi, M., Ghorbani, G. R., Sadeghi-Sefidmazgi, A., Mahnani, A., Drackley, J. K., & Ghaffari, M. H. (2022). Identification of cow-level risk factors and associations of

selected blood macro-minerals at parturition with dystocia and stillbirth in Holstein dairy cows. Scientific Reports, 12, 5929.

Baldrighi, J. M., Sá Filho, M. F., Siqueira, A. F., Visintin, J. A., Baruselli, P. S., & Assumpção, M. E. O. A. (2022). Temporal evaluation of follicular dynamics and endocrine patterns of Holstein (Bos taurus), Gir (Bos indicus), and Murrah (Bubalus bubalis) heifers kept under the same nutritional, management and environmental conditions. *Theriogenology*, *190*.

Berean, D. I., Bogdan, L. M., & Cimpean, R. (2025). Comparative evaluation of Ovsynch and Double Ovsynch protocols with single and double insemination in Holstein dairy cows: Reproductive performance and cost analysis. Animals, 15(16), 2380.

Bihon, A., & Assefa, A. (2021). Prostaglandin based estrus synchronization in cattle: A review. *Cogent Food & Agriculture*, *7*(1).

Biswas, S., Swarna, M., Biswas, D., & Paul, A. (2023). Management of pregnancy failure in cows with vaginal stimulation and hormone therapy. *Bangladesh Veterinarian*, *39*(1–2)

Bó, G. A., & Cedeño, A. (2018). Expression of estrus as a relevant factor in fixed-time embryo transfer programs using estradiol/progesterone-based protocols in cattle. *Animal reproduction*, *15*(3), 224–230.

Bó, G. A., Huguenine, E., de la Mata, J. J., Núñez-Olivera, R., Baruselli, P. S., & Menchaca, A. (2018). Programs for fixed-time artificial insemination in South American beef cattle. *Animal reproduction*, *15*(Suppl 1), 952–962.

Bó, G.A., Menchaca, A. (2023) Prohibition of hormones in animal reproduction: what to expect and what to do? Animal Reproduction, 20 (2), e20230067.

Bosolasco, D., Nuñez-Olivera, R., de Brun, V., Meikle, A., & Menchaca, A. (2021). Estradiol cypionate administered at the end of a progesterone-based protocol for FTAI induces ovulation and improves postovulatory luteal function and uterine environment in anestrous beef cows. *Theriogenology*, 162, 74–83.

Carvalho, N. A. T., Carvalho, J. G. S., Sales, J. N. S., Guerreiro, B. M., Freitas, B. G., D'Occhio, M. J., & Baruselli, P. S. (2020). Treatment with estradiol cypionate at

progesterone withdrawal reduces handling without compromising pregnancy rate to timed artificial insemination. Theriogenology, 157, 498–502.

Catalano, D., et al. (2025). Relationship between estrus and reactivity on the reproductive performance of beef cows. Applied Animal Behaviour Science, 288, 106679.

Changule, A. P. (2022). Maximizing the reproductive efficiency of cattle: A review benefits of sexual puberty induction in heifers through hormonal protocols. International Journal of Innovative Science and Research Technology, 7(11), 2062–2066.

Chawala, A. R., Sanchez-Molano, E., Dewhurst, R. J., Peters, A., Chagunda, M. G. G., & Banos, G. (2021). Breeding strategies for improving smallholder dairy cattle productivity in Sub-Saharan Africa. *Journal of Animal Breeding and Genetics*, *138*(6).

Christenson, D. M., Thomas, J. M., Kelly, D. J., & Funston, R. N. (2022). Extending melengestrol acetate feeding from 14 to 18 days during an estrus synchronization and artificial insemination protocol for March-calving beef heifers. Applied Animal Science, 38(5), 499–504.

Colazo, M. G., Kastelic, J. P., & Mapletoft, R. J. (2003). Effects of estradiol cypionate (ECP) on ovarian follicular dynamics, synchrony of ovulation, and fertility in CIDR-based, fixed-time AI programs in beef heifers. Theriogenology, 60(5), 855–865.

Corpron, M. R., Zoca, S. M., Reynolds, M., Carnahan, K., Hall, J. B., & Ahmadzadeh, A. (2019). Evaluating the effects of a high-concentration dose of prostaglandin F2α in a 5-d CO-Synch + controlled internal drug release protocol on fertility in beef cows. Translational Animal Science, 3, 1754–1757.

D'Occhio, M. J., Baruselli, P. S., & Campanile, G. (2019). Influence of nutrition, body condition, and metabolic status on reproduction in female beef cattle: A review. Theriogenology, 125, 277–284.

Dias, S., Carvalho, J., Várzea Rodrigues, J., &Martins, M.V. (2020). Fixed-time artificial insemination in extensive cattle. *Millenium – Journal of Education, Technologies, and Health*, 2(13), 23-28.

Dodicho, A. A., Gebeyehu, S. T., & Kidane, Z. Y. (2024). Evaluating single and double doses of prostaglandin (PGF2α) injection on estrus induction and conception rate in Boran cattle breed in Southwestern Ethiopia. _Cogent Food & Agriculture, 10(1), 2420851.

Doležalová, M., et al. (2024). Interval from oestrus to ovulation in dairy cows: A key factor for insemination timing. Veterinary Sciences, 11(4), 152.

Dzivakwi Rashidi, R., Makuza, S.M., & Murungweni, C. (2024). Natural mating versus artificial insemination on reproductive performance of cattle in Zimbabwe's smallholder sector: A review. *Journal of Technological Sciences*, 1(2), 15-32.

Edmonson, A.J., Lean I.J., Weaver L.D., Farver T., Webster G., (1989). "A body condition scoring chart for holstein dairy cows". *Journal of Dairy Sciences,* 72: 68-78. 72: 68-78.

Elmetwally, M. A., Hussien, A., Sharawy, H., Mostagir, A., Risha, E., et al. (2021). A review of attempts to improve cow fertility through reproductive management: Estrous synchronisation. Journal of Veterinary Healthcare, 2(4), 1–25.

Ferré, L. B., Cerviño, M. N., Jaeschke, J., Itterman, M., McLean, J., Aragon, A., Fernández, M., Villa, M., Formia, N., Jaureguiberry, M., Rearte, R., Kjelland, M. E., Colazo, M. G., Thomas, J. M., & de la Sota, R. L. (2025). Evaluation of GnRH- versus estradiol-based protocols for ovulation synchronization in postpartum Bos taurus grazing beef cows submitted to fixed-time artificial insemination. Theriogenology, 233, 1–7.

Fesseha, H., & Degu, T. (2020). Estrus detection, estrus synchronization in cattle and its economic importance. *International Journal of Veterinary Research*, *3*(1), 1–7.

Fodor, I., Gábor, G., Lang, Z., Abonyi-Tóth, Z., & Ózsvári, L. (2019). Relationship between reproductive management practices and fertility in primiparous and multiparous dairy cows. Canadian Journal of Veterinary Research, 83(3), 218-227

Food and Agriculture Organization of the United Nations. (2020). Zimbabwe at a glance. Rome, Italy: FAO.

Hasbi, H., & Gustina, S. (2020). Comparative monitoring of the estrus cycle in livestock: Hormonal features and ultrasound. Jurnal Ilmu-Ilmu Peternakan, 30(1), 10–18.

Hassanein, E. M., Szelényi, Z., & Szenci, O. (2024). Gonadotropin-Releasing Hormone (GnRH) and Its Agonists in Bovine Reproduction I: Structure, Biosynthesis, Physiological Effects, and Its Role in Estrous Synchronization. Animals : an open access journal from MDPI, 14(10), 1473.

Huruba, R. (2026). Improving rural livelihoods through optimisation of beef cattle production and marketing by smallholder farmers in Zimbabwe.

Kasimanickam, R., & Kasimanickam, V. (2026). Impact of nutrition on embryo production in cattle: Mechanistic insights. Animals, 16(6), 892.

Kolachi, H. A., Zhang, X., Rahimoon, M. M., Shahzad, M., Oluwaseun, A. J., Panhwar, M. I., Hassan, M. F., Kandil, O. M. T., Wan, P., & Zhao, X. (2025). Fixed-time artificial insemination technology in buffaloes: A review. Frontiers in Veterinary Science, 12, Article 1586609.

Lemos, L. A., Carvalho, L. R., Vicente, M. P., Souza Simões, L. M., Fernandes do Vale, L. S., de Souza, J. C., & de Sousa Sales, J. N. (2026). Reproductive efficiency of Bos indicus cows under different estradiol-free ovulation synchronization protocols. Theriogenology, 254, 117830.

Magwede, C. D., Chatiza, F. P., & Makuza, S. M. (2025). Evaluation of synchronization protocols and semen quality characteristics on reproductive efficiency and fertility outcomes in Zimbabwean dairy cattle production. Journal of Technological Sciences (JTS), 2(1), 103.

Mawadri, P., Balemwa, T., Mugizi, D. R., et al. (2025). Ovarian follicular responses to estrus and ovulation synchronization protocols in East African Shorthorn Zebu cattle. Acta Veterinaria Scandinavica, 67, 37.

Menchaca, A., Bosolasco, D., Núñez-Olivera, R., Cuadro, F., Speciale, C. J. M., & Perez-Wallace, S. (2021). Estradiol cypionate treatment in suckling/weaning and estrous cycling/anestrous beef cows subjected to fixed-time artificial insemination. *Animal Reproduction Science, 233*.

Ministry of Finance, Economic Development and Investment Promotion. (2025). 2024 annual economic and fiscal review. Government of Zimbabwe.

Moniruzzaman, M., Roy, B. C., Arafath, M. S., Alam, M. H., Bari, J., Deb, G. K., & Juyena, N. S. (2024). Efficacies of PGF2α, Ovsynch, and CIDR protocols on synchronization of estrus in buffaloes: A comparative study. _Journal of Buffalo Science, 14, 123–130.

Monn, R. E., Poole, R. K., Mackey, J. C., Mayberry, K. J., Dudley, H. B., Alley, M., & Poole, D. H. (2019). A two-injection prostaglandin F2α presynchronization treatment decreases pregnancy rates of cycling replacement beef heifers. Translational Animal Science, 3, 456–463.

Moorey, S. E., & Biase, F. H. (2020). Beef heifer fertility: Importance of management practices and technological advancements. Journal of Animal Science and Biotechnology, 11, 97.

Muteyo, E., Chomuzinda , G., & Chikumba, N. (2025). Analysis of Smallholder Farmers' Contributions to the Beef Value Chain in Two Zimbabwean Localities (Gokwe South and Mount Darwin). *Journal of Animal Science and Applied Biology*, *1*(1), 8–16.

Nogueira, E., Silva, M. R., Silva, J. C. B., Abreu, U. P. G., Anache, N. A., Silva, K. C., Cardoso, C. J. T., Sutovsky, P., & Rodrigues, W. B. (2019). Timed artificial insemination plus heat I: Effect of estrus expression scores on pregnancy of cows subjected to progesterone-estradiol-based protocols. *Animal*, *13*(10), 2305–2312.

Okada, M. S. D., Silenciato, L. N., Bonamichi do Couto, S. R., Ferreira, J. E., & de Mello, M. R. B. (2025). Efficacy of short-term timed artificial insemination protocols with estradiol esters and $PGF_2\alpha$ in Girolando cows. Reproduction in Domestic Animals, 60(5), e70076.

Pal, P., & Dar, M. R. (2020). Induction and synchronization of estrus. In Animal reproduction in veterinary medicine. IntechOpen.

Parker, E. L., Kemp, B., & Blake, C. (2024). Seasonal anestrus and its management in beef cattle. *Journal of Animal Science*, 102(4), 487–498.

Pfeifer, L. F. M., Moreira, E. M., Silva, G. M., Souza, V. L., Nunes, V. R. R., Andrade, J. S., Neves, P. M. A., & Ferreira, R. (2020). Effect of estradiol cypionate on estrus expression and pregnancy in timed artificially inseminated beef cows. *Livestock Science, 231,* 103886.

Reese, S. T., et al. (2022). Influence of estrus activity and reproductive tract characteristics on fertility in beef cows undergoing fixed-time artificial insemination. Journal of Animal Science, 98(6).

Ribeiro, J. B., et al. (2023). Comparison of reproductive management strategies combining estrus detection and fixed-time artificial insemination in dairy cows. *Animal Reproduction Science, 248*, 107331.

Sa Filho, O. G., Torres-Júnior, J. R. S., Penteado, L., Gimenes, L. U., Ferreira, R. M., Ayres, H., Castro e Paula, L. A., Sales, J. N. S., & Baruselli, P. S. (2015). Influence of category heifers, primiparous and multiparous lactating cows in a large-scale resynchronization fixed-time artificial insemination program. Journal of Veterinary Science, 16(3), 367–373.

Sales, A., Cappellozza, B. I., Vilela, E., Claro Júnior, I., Sá Filho, O. G., & Vasconcelos, J. L. M. (2023). Effects of estradiol cypionate dosage and body condition on reproductive performance of Nellore cattle synchronized for timed artificial insemination. Theriogenology, 210, 207–213.

Sales, J. N. S. (2024). Exposure to progesterone before an ovulation synchronization protocol increases the follicular diameter and fertility of multiparous suckled Bos taurus cows. Theriogenology, 218, 239–243. https://doi.org/10.1016/j.theriogenology.2024.01.031

Sales, J. N. S., Carvalho, L. R., Simões, L. M. S., Lemos, L. A., Vicente, M. P., Silva, R. R. R., Orlandi, L. O., Baruselli, P. S., & Souza, J. C. (2025). New perspectives and evolution of ovulation synchronization protocols in bovine females. *Animal Reproduction, 22*(3), e20250048.

Salverson, R., & Perry, G. (2020). *Understanding estrus synchronization in cattle*. South Dakota State University, Animal Science Department

Samkange, A. (2019).Conception rates and calving intervals of different beef breeds at a farm in the semi-arid region of Namibia', *Tropical Animal Health and Production*, 51(7), pp. 1829–1837.

Sartori, R., Bastos, M. R., Baruselli, P. S., Gimenes, L. U., Ereno, R. L., & Barros, C. M. (2010). Physiological differences and implications to reproductive management of Bos

Taurus and Bos indicus cattle in a tropical environment. Society of Reproduction and Fertility supplement, 67, 357-375.

Sartori, R., Gimenes, L. U., Monteiro, P. L., Jr, Melo, L. F., Baruselli, P. S., & Bastos, M. R. (2016). Metabolic and endocrine differences between Bos taurus and Bos indicus females that impact the interaction of nutrition with reproduction. *Theriogenology*, *86*(1), 32–40.

Sartori, R., Monteiro Jr., P. L. J., & Wiltbank, M. C. (2016). Endocrine and metabolic differences between Bos taurus and Bos indicus cows and implications for reproductive management. Animal Reproduction, 18(2), 1–10.

Sharma, A., Singh, M. M., Sharma, A., & Kumar, P. (2018). Prostaglandin F2α administration on day 8 postpartum leads to early resumption of ovarian cyclic activity in dairy cattle. *Indian Journal of Animal Reproduction, 39*(1), 38–40.

Silper, B., J.M. Madureira, L. B. Polsky, S. Soraino,A. F . Sica, J. L. M.Vasconcelos, and R. L. A Cerri. (2017). Daily lying behavior of lactating Holstein cows during an estrus synchronization protocol and its associations with fertility. J Dairy Sci.87:85-94

S

Silva, M. A. V., Santos, C. S., França, I. G., Pereira, H. G., Sá Filho, M. F., Freitas, B. G., Guerreiro, B. M., Faquim, A., Baruselli, P. S., & Torres-Júnior, J. R. S. (2018). Hormonal strategy to reduce suckled beef cow handling for timed artificial insemination with sex-sorted semen. *Theriogenology, 114*.

Simões, L. M. S., Lima, E. A., Carvalho, L. R., Martínez, M. B. P., Zanatta, G. M., Santos, M. F. O., Machado, A. B., Dias, M. M., Guerreiro, B. M., Freitas, B. G., Bastos, M. R., &

Taghizadeh, E., Barati, F., Fallah, A. A., Hemmatzadeh-Dastgerdi, M., & Nejabati, M. S. (2024). Estrogens improve the pregnancy rate in cattle: A review and meta-analysis. In *Theriogenology* (Vol. 220).

Temesgen, M. Y., Assen, A. A., Gizaw, T. T., Minalu, B. A., & Mersha, A. Y. (2022). Factors affecting calving to conception interval (days open) in dairy cows located at Dessie and Kombolcha towns, Ethiopia. PLOS ONE, 17(2), e0264029.

Tsaousioti, A., Basioura, A., Praxitelous, A., & Tsousis, G. (2024). Dystocia in dairy cows and heifers: A review with a focus on future perspectives. Dairy, 5(4), 655–671.

Vasconcelos, J. L. M., Carvalho, R., Peres, R. F. G., Rodrigues, A. D. P., Claro Júnior, I., Meneghetti, M., et al. (2017). Reproductive programs for beef cattle: incorporating management and reproductive techniques for better fertility. *Animal Reproduction*, 17(3), 547–557.

Washaya, S., P. Mudzengi, C., Gobvu, V., Mafigu, T., & Mutore, R. (2025). Postpartum Anoestrus in Extensively Managed Beef Cows. In Veterinary Medicine and Science. IntechOpen.

Wiltbank, M. C., & Sartori, R. (2021). Factors that optimize reproductive efficiency in dairy herds with an emphasis on timed artificial insemination programs. *Animals (Basel)*, 11(2), 301.

Zeng, W., An, L., Wang, Y., Gu, X., Qin, Y., & Tian, J. (2024). The effect of different doses of estradiol benzoate on follicle development and twin birth in beef cattle with induced superovulation. *Archives Animal Breeding*, *67*(4).

Zuidema, D., Kerns, K., &Sutovsky, P. (2021). An exploration of current and persperctive semen analysis and sperm selection for livestock artificial insemination. *Animals, 11*(12), Article 3563.