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Review Article

Hormonal Estrus Synchronization in Dairy Cattle in Ethiopia: Opportunities, Constraints and Strategies for Improved Reproductive Efficiency: Review

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Abstract

Hormonal estrus synchronization has emerged as a central reproductive technology in Ethiopia's dairy sector, chiefly in the context of rapid growth in urban and peri-urban dairying and the national push toward genetic improvement through artificial insemination (AI). The technology enables strategic control of the estrous cycle, improves breeding efficiency, enhances the use of superior breeds and increases calving rates in smallholder and commercial dairy systems. Despite its potential, adoption remains low and performance inconsistent due to management, technical, infrastructural, and socio-economic challenges. Several synchronization protocols including Prostaglandin F2α (PGF2α) based programs, progesterone-releasing devices, Ovsynch and its modifications and combined hormonal regimens have been implemented in national programs such as Growth and Transformation Plan (GTP), the National Artificial Insemination Program, the OIE/FAO-supported projects, and regional extension packages. However, conception rates are highly variable, ranging from 20–55%, largely influenced by body condition, nutrition, heat detection efficiency, protocol adherence, AI technician skill, breed differences, season, and postpartum reproductive disorders. The opportunities created by increasing demand for dairy products, improved extension platforms and expanding private veterinary services contrast sharply with challenges such as inadequate awareness, drug shortages, limited technical capacity and the absence of structured monitoring systems. This review synthesizes existing evidence on hormonal estrus synchronization in Ethiopian dairy cattle, highlighting protocols used, success rates, constraints, opportunities and strategic recommendations for enhanced adoption and performance. Such understanding is crucial for designing sustainable reproductive interventions and strengthening Ethiopia's dairy value chain.

Keywords

Estrus Synchronization, Dairy Cattle, Ethiopia, Hormonal Protocols, Progesterone, Prostaglandin, Reproductive Technology

1. Introduction

Dairy cattle production is a rapidly growing component of Ethiopia's livestock sector, driven by rising urban demand for milk, expanding commercial dairies, and ongoing genetic improvement initiatives. Ethiopia hosts one of the largest cattle populations in Africa, with an estimated 13–15 million cows kept under smallholder mixed crop-livestock systems, peri-urban farms, and emerging commercial operations [4, 8, 28]. Most smallholder dairy production relies on indigenous zebu cattle, which are characterized by low milk yields, long postpartum anestrus and poor reproductive efficiency. Cross-

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breeding with Bos taurus dairy breeds, supported through artificial insemination (AI) programs, is increasingly promoted to improve milk productivity [9]. However, reproductive inefficiencies remain a major bottleneck in dairy development, underscoring the importance of reproductive technologies such as hormonal estrus synchronization.

Hormonal estrus synchronization is used to induce or synchronize estrus in a group of cows, allowing timed breeding and facilitating efficient use of AI services and superior genetics. Synchronization enables fixed-time AI (FTAI), which reduces reliance on traditional heat detection that is often inaccurate or labor-intensive in Ethiopia's smallholder systems [6, 20]. It also shortens calving intervals, improves reproductive management and enhances precision breeding in commercial dairies. Programs such as Ovsynch, Cosynch, PGF2α injections, progesterone devices like Controlled Internal Drug Release and estrogen-based regimens have been evaluated in Ethiopia with varying levels of success depending on management, breed type, nutritional status and technician skill [22, 30]. Despite these advantages, synchronization uptake remains modest, especially among rural smallholders, due to poor extension capacity, inconsistent hormone supply, and limited technical competence in AI service provision.

The national government and development partners have implemented several reproductive intervention programs aimed at improving dairy productivity through synchronization. Notable examples include the national estrus synchronization and mass insemination campaign (ES-MAI), the Ethiopian Livestock Master Plan (2015–2020), the second Growth and Transformation Plan (GTP II) and various NGO-supported projects including those by ILRI, SNV, Land O'Lakes, and Heifer International [12, 18, 21]. These programs have created unprecedented opportunities to expand AI services, improve the dairy genetic base and train technicians. However, inconsistent conception rates, inadequate monitoring mechanisms and seasonal fluctuations in feed supply impede the effectiveness of synchronization interventions.

Furthermore, estrus synchronization in dairy cattle is deeply influenced by Ethiopia's diverse agro-ecological zones, which affect feed resources, heat stress exposure, disease prevalence and management intensity [17, 36]. In many smallholder systems, poor nutrition, postpartum reproductive disorders and low body condition scores significantly reduce synchronization success [19]. Commercial dairies, although better resourced, still face challenges related to skilled AI technicians, timely hormone administration and record-keeping and reproductive disorder diagnosis.

Given the growing importance of reproductive efficiency in meeting Ethiopia's dairy development goals, a comprehensive review of hormonal estrus synchronization protocols, opportunities and constraints is essential. Existing studies are fragmented, region-specific, or limited to small sample sizes, making it difficult to draw national-level conclusions. This review therefore aims to synthesize scientific evidence on major protocols, their performance, adoption levels, constraints and opportunities for scaling. It underscores the need for integrated reproductive management, efficient extension services, and supportive policy frameworks to fully harness synchronization technology for dairy development.

Objective

1) To examine hormonal estrus synchronization protocols in dairy cattle in Ethiopia and assess their effectiveness.
2) To evaluate the adoption of different methods, including GnRH, prostaglandin and CIDR (Controlled Internal Drug Release) based protocols.
3) To identify socio-economic and management factors affecting successful implementation.

2. Literature Review

2.1. Physiology of the Bovine Estrous Cycle and Its Relevance to Hormonal Synchronization

The bovine estrous cycle is a complex, hormonally coordinated process that averages 21 days and encompasses four stages: proestrus, estrus, metestrus, and diestrus. These stages are regulated by the hypothalamic pituitary ovarian (HPO) axis, which orchestrates interactions among gonadotropin releasing hormone (GnRH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), estradiol (E2) and progesterone (P4). Understanding this physiology is essential for the development and successful application of estrus synchronization protocols. GnRH secreted in pulses from the hypothalamus stimulates the anterior pituitary to release FSH and LH, driving follicular growth and ovulation. Estradiol produced by the dominant follicle triggers behavioral estrus and positive feedback to induce the pre-ovulatory LH surge [11, 15, 16]. Estrus synchronization protocols rely on manipulating these hormonal events to control follicle wave emergence, regression of the corpus luteum (CL), and timing of ovulation.

Follicular development occurs in waves, typically two or three per cycle, with each wave consisting of recruitment, selection, dominance and atresia or ovulation. The dominant follicle suppresses subordinate follicles through estradiol and inhibin, ensuring single ovulation in Bos taurus and most Bos indicus cattle [38]. For synchronization to be effective, protocols must control follicular waves so that cows ovulate at a predictable time. Progesterone plays a central role because high circulating progesterone concentrations inhibit LH pulse frequency, preventing premature ovulation and allowing controlled follicular turnover. Manipulating P4 through exogenous sources such as CIDR devices or intravaginal sponges allows synchronization of follicular waves and ensures that cows enter estrus simultaneously when progesterone is withdrawn [25, 27, 37].

Regression of the corpus luteum is another foundational element of estrus synchronization. Prostaglandin F2α

(PGF2α) is the natural luteolysin secreted by the uterus during late diestrus, initiating CL regression and reducing progesterone levels. PGF2α-based synchronization protocols mimic this physiological process, inducing luteolysis in cows with functional CLs, thereby triggering follicular growth and estrus expression within 48–96 hours. However, PGF2α is ineffective in cows lacking a functional CL, making its application dependent on ovarian status during administration [24, 26, 29]. Understanding these physiological mechanisms is crucial for designing and adapting synchronization strategies suited to Ethiopian dairy systems, where animals often show nutritional and postpartum variability affecting ovarian cyclicity.

2.2. Major Hormonal Estrus Synchronization Protocols Used in Ethiopia

A wide array of hormonal protocols has been used in Ethiopian dairy cattle, ranging from simple PGF2α programs to advanced multi-hormonal fixed-time artificial insemination (FTAI) protocols. The most common protocols include PGF2α-based regimens, progesterone-based systems using controlled internal drug release (CIDR) devices, GnRH-based protocols such as Ovsynch and Cosynch, and combined protocols integrating progesterone, GnRH, and PGF2α.

2.2.1. PGF2α (Prostaglandin $F_2\alpha$) Based Protocols

PGF2α and its synthetic analogues (Cloprostenol) are widely used due to affordability, availability, and simplicity. Single-injection PGF2α protocols induce luteolysis only in cows with a mature CL (≥5 days old), making estrus expression unreliable when ovarian status is unknown. To mitigate this, double PGF2α injections spaced 11–14 days apart are employed, ensuring that cows without a CL at first injection will generally be responsive at the second. Ethiopian studies report conception rates ranging from 28–50% with double-injection PGF2α programs, depending on breed type, nutrition, technician skill, and postpartum interval [2, 13, 35]. However, heat detection challenges in smallholder systems often reduce effectiveness despite acceptable ovarian response rates.

2.2.2. Progesterone-based Protocols (CIDR/Progesterone Sponges)

Progesterone-releasing intravaginal devices such as CIDR are used to mimic the luteal phase and suppress estrus until device removal. Ethiopian trials using CIDR for 7–10 days in combination with equine chorionic gonadotropin (eCG) and PGF2α have achieved response rates above 80% and conception rates of 35–55% [6, 20, 31]. Progesterone-based methods are particularly advantageous for anestrous cows, which are common in Ethiopia because of poor nutrition and prolonged postpartum intervals. Despite their effectiveness, the high cost and limited rural availability of CIDR devices constrain widespread uptake.

2.2.3. Gonadotropin-releasing Hormone Based Protocols (Ovsynch, Cosynch, Pre-synch)

The Ovsynch protocol GnRH on day 0, PGF2α on day 7, second GnRH on day 9, and FTAI 16–24 hours later is among the most scientifically robust synchronization methods. Ovsynch controls both the luteal and follicular phases and allows AI without heat detection. Different research reports conception rates of 30–45% with Ovsynch, with improvements when pre-synchronization methods such as Presynch (two PGF2α injections before Ovsynch) are used [1, 10, 33]. Cosynch variants (in which the second GnRH is administered at AI) reduce handling frequency and have shown comparable performance in Ethiopian crossbred dairy cows.

2.3. Performance of Synchronization Protocols Under Ethiopian Dairy Conditions

The performance of synchronization protocols in Ethiopia exhibits considerable variability due to differences in breed, management, nutritional status, and agro-ecological conditions. Crossbred dairy cows (Holstein × Zebu) generally exhibit higher synchronization responses and conception rates than indigenous zebu breeds, reflecting their more predictable ovarian physiology and stronger estrus expression [3, 14, 30]. However, Bos indicus cattle display slower follicular turnover, smaller dominant follicles, and weaker estrus signs, all of which can affect hormonal synchronization outcomes and timing of ovulation [5, 16, 27]. This highlights the importance of protocol adaptation for zebu and zebu-cross dairy cows in Ethiopia.

Environmental and nutritional factors significantly influence protocol success. Ethiopia's smallholder dairy cattle often exhibit low body condition scores (BCS), extended postpartum anestrus, and poor ovarian activity due to feed scarcity, especially during the dry season. Such conditions limit responsiveness to PGF2α and GnRH-based protocols because cows without a functional CL or with inactive ovaries cannot mount an appropriate hormonal response [2, 19, 23]. In contrast, commercial dairy farms with improved feeding systems report higher estrus expression, ovulation rates, and conception outcomes, demonstrating the strong influence of management on synchronization effectiveness. Ethiopian research consistently emphasizes that nutritional supplementation before synchronization significantly improves follicular growth and conception rates.

The timing and skill of AI technicians play a crucial role in determining synchronization outcomes. Studies in Oromia, Amhara, and Tigray regions indicate that conception rates vary widely ranging from 20% to more than 50%—depending on the technician's ability to properly administer hormones, diagnose reproductive status, and perform AI at the correct time relative to ovulation [6, 32, 34]. Poor heat detection accuracy further reduces success in protocols that require visual estrus identification, whereas FTAI-based systems such as Ovsynch reduce this dependency but demand strict adherence to timing. National campaigns have reported lower conception rates because of inconsistency in hormone administration, limited follow-up, and inadequate farmer preparation of animals before synchronization.

2.4. Factors Affecting Conception Rates in Estrus Synchronization Programs

Conception rates following hormonal estrus synchronization depend on a complex interaction of physiological, environmental, nutritional, managerial, and genetic factors. One of the most critical determinants is the ovarian cyclicity status at the initiation of synchronization. Cows in anestrus particularly postpartum anestrus common in Ethiopian dairy systems exhibit weak or absent responses to PGF2α because a functional corpus luteum is absent [7, 19, 23]. In GnRH-based protocols like Ovsynch, cyclic cows respond optimally by forming ovulatory follicles, whereas non-cyclic cows often form suboptimal follicles or fail to ovulate following the first GnRH. The physiological differences between Bos taurus and Bos indicus breeds also influence conception success, as zebu cattle typically have slower follicular growth rates, smaller pre-ovulatory follicles, and lower circulating estradiol concentrations, all of which can reduce the synchrony between ovulation and insemination [5, 16, 27].

Nutritional status plays an equally important role in determining synchronization outcomes. Body condition score (BCS) is strongly associated with follicular dynamics, ovarian cyclicity, and systemic concentrations of reproductive hormones. Cows with low BCS often experience suppressed GnRH and LH secretion, leading to delayed dominant follicle emergence and impaired ovulation, which negatively affects the success of protocols relying on timed ovulation [30, 32, 34]. In Ethiopian smallholder systems, seasonal feed scarcity often results in negative energy balance (NEB), reducing synchronization responses because cows are less able to support estrus expression and embryo survival. Supplementary feeding with energy and protein concentrates before synchronization enhances follicular growth, increases estradiol secretion, and improves uterine environment, leading to higher conception rates [3, 6, 20].

Management practices, including timing of artificial insemination, technician competency, and handling stress, significantly influence conception outcomes. In programs requiring heat detection, incorrect identification of estrus or delayed insemination greatly lowers fertility because AI timing must align with ovulation. This is a major issue in Ethiopia due to limited farmer knowledge, labor constraints, and low estrus expression in zebu-influenced cattle [1, 2, 33]. In FTAI protocols, the precision of hormone administration timing is critical; deviations of even 6–12 hours may reduce synchronization precision and conception rate. Stress caused by poor handling or transportation before or after synchronization increases cortisol secretion, which negatively affects LH surge and ovulation [15, 24, 29]. The cumulative effect of these physiological and managerial factors explains much of the variation observed in conception rates across Ethiopian dairy herds.

2.5. Opportunities for Expansion of Estrus Synchronization in Ethiopia

Ethiopia possesses several structural, economic and policy-driven opportunities that support the wider adoption of hormonal estrus synchronization. The rapid growth of the dairy industry, driven by urbanization and demand for milk and milk products, has encouraged the expansion of crossbred dairy cattle in peri-urban and urban production clusters. Productivity gaps in smallholder systems create an urgent need for reproductive technologies that accelerate genetic improvement, shorten calving intervals, and increase milk yields [4, 17, 28]. Estrus synchronization offers a scalable pathway to meet these production demands by facilitating planned breeding seasons, coordinated AI, and improved reproductive efficiency. These opportunities align with national livestock transformation objectives and donor-supported modernization initiatives.

Institutionally, Ethiopia's livestock sector benefits from ongoing government and NGO interventions that promote AI and reproductive technologies. Programs such as the Livestock Master Plan (LMP), the Growth and Transformation Plans (GTP I and II), the National Artificial Insemination Strategy, and development projects by ILRI, FAO, SNV, and USAID have established frameworks to expand synchronization-based breeding [12, 18]. These interventions have increased the availability of trained AI technicians, extension personnel, and veterinary paraprofessionals. They also promote capacity-building initiatives, mobile AI services, and community-based breeding strategies. Such institutional investments significantly enhance the potential for synchronization technology to scale in both rural and peri-urban dairy sectors [21]. Moreover, emerging private veterinary service providers and pharmaceutical distributors improve access to drugs, semen, and synchronization kits.

Technological advances further expand opportunities. New progesterone-releasing devices, low-cost PGF2α analogues, long-acting GnRH formulations, and robust FTAI protocols adapted for Bos indicus cattle have increased the reliability of synchronization programs. Studies in Ethiopia show improved conception rates when protocols are combined with nutritional supplementation or modified according to ovarian status [6, 33]. Digital breeding records, mobile extension tools, and herd management software offer additional prospects for modernizing reproductive management. When integrated with cooperative dairy production systems and improved feed value chains, estrus synchronization can drive significant gains in milk productivity, household income, and commercialization of the dairy sector [20].

2.6. Constraints and Challenges in the Use of Hormonal Estrus Synchronization

Despite its potential, estrus synchronization in Ethiopia faces substantial constraints. One of the most persistent challenges is the low level of awareness and understanding among smallholder dairy farmers regarding the principles of synchronization, the importance of heat detection, and proper animal preparation [22]. Many farmers do not understand the need for timely insemination, appropriate nutrition, or postpartum recovery, leading to poor conception outcomes even when hormonal protocols are correctly administered [34, 19]. Misconceptions about the technology, fear of hormonal drugs, and inconsistent extension messaging further reduce uptake among rural households. Limited record-keeping also prevents evaluation of reproductive performance and hinders long-term planning.

Input supply challenges significantly constrain synchronization performance. Hormonal drugs including PGF2α, GnRH analogues, and CIDR devices are often expensive, counterfeit, poorly stored, or unavailable in rural markets. Irregular supply chains and inadequate cold storage compromise drug potency, leading to inconsistent results [1, 31]. Similarly, variable semen quality, shortages of liquid nitrogen, and inadequate AI delivery infrastructure reduce the effectiveness of breeding interventions [33]. Transport challenges and the lack of service fee standardization further limit access, especially in pastoral and remote highland areas.

Managerial and environmental constraints are equally significant. Most smallholder dairy cows face nutritional stress, especially during dry seasons, resulting in poor ovarian activity, low BCS, and weak estrus expression. Diseases such as mastitis, metritis, retained placenta, brucellosis, and reproductive tract infections impair conception following synchronization [3, 30]. Additionally, heat stress in lowland areas suppresses reproductive hormone secretion, reduces oocyte quality, and negatively affects early embryo survival. The lack of skilled AI technicians, poor supervision of national synchronization campaigns, and absence of systematic monitoring and evaluation further limit success [32]. These constraints demonstrate that hormonal synchronization must be integrated with holistic improvements in nutrition, health, and reproductive management to achieve sustainable outcomes.

2.7. Comparative Evaluation of Major Synchronization Protocols in Ethiopia

Comparisons among synchronization protocols reveal that no single method is universally superior; rather, effectiveness depends on ovarian status, breed composition, management intensity, and cost considerations. PGF2α-based protocols remain popular due to their low cost and simplicity but are limited by their requirement for a functional CL and their dependence on accurate heat detection [39]. As a result, conception rates vary widely among Ethiopian smallholders. Progesterone-based protocols, such as CIDR, provide greater control over follicular dynamics and are effective in both cyclic and anestrous cows. They also minimize the need for heat detection. However, their higher cost and limited availability restrict widespread adoption.

GnRH-based protocols such as Ovsynch and Cosynch offer the advantage of FTAI without estrus detection, making them suitable for commercial dairies and smallholders with limited labor capacity. Ethiopian studies suggest that Ovsynch combined with presynchronization (Presynch-Ovsynch) improves conception by ensuring cows begin the protocol at an optimal stage of their cycle [10, 33]. Nonetheless, these protocols require high precision in timing and trained personnel, which can be challenging in large-scale national programs. In general, integrating synchronization protocols with improved nutrition, heat stress mitigation, postpartum management, and skilled AI service delivery yields the best reproductive outcomes [23].

3. Conclusion and Recommendations

3.1. Conclusion

Hormonal estrus synchronization remains a cornerstone reproductive technology with significant potential to improve Ethiopia's dairy sector. Protocols such as PGF2α, CIDR-based systems, and GnRH-based programs like Ovsynch have proven effective under controlled conditions, enabling timed breeding, efficient use of artificial insemination, and accelerated genetic improvement. However, success in Ethiopia is often limited by variable ovarian cyclicity, breed differences, nutritional constraints, poor heat detection, and technician skill, which affect conception rates and overall herd productivity.

Despite these challenges, opportunities exist to scale and optimize synchronization through expanding urban and peri-urban dairy systems, improving nutrition and animal health, strengthening extension support, and enhancing AI services. Sustainable adoption requires addressing technical capacity, hormone and semen supply, farmer awareness, and monitoring systems, particularly in smallholder farms. With coordinated efforts from government, researchers, development organizations, and the private sector, estrus synchronization can significantly enhance reproductive efficiency, dairy productivity, farm profitability, and national food security in Ethiopia.

3.2. Recommendation

To improve the success of hormonal estrus synchronization in dairy cattle in Ethiopia, it is recommended to enhance farmer awareness and training on reproductive management and synchronization protocols. Strengthening veterinary service delivery and ensuring the availability of hormones and synchronization tools at affordable costs are essential. Farmers should adopt appropriate protocols based on herd management, breed type, and production system, while extension services and research institutions provide continuous technical support. Additionally, integrating reproductive management with overall herd nutrition and health programs can optimize conception rates, improve milk production, and promote sustainable dairy farming practices across different agro-ecological zones.

Abbreviations

AI	Artificial Insemination
BCS	Body Condition Score
CIDR	Controlled Internal Drug Release
CL	Corpus Luteum
Cosynch	Controlled Synchronization Protocol
CSA	Central Statistical Agency of Ethiopia
E2	Estradiol
eCG	Equine Chorionic Gonadotropin
ES-MAI	Estrus Synchronization and Mass Artificial Insemination
FAO	Food and Agriculture Organization of the United Nations
FSH	Follicle-Stimulating Hormone
FTAI	Fixed-Time Artificial Insemination
GnRH	Gonadotropin-Releasing Hormone
GTP	Growth and Transformation Plan
HPO axis	Hypothalamic–Pituitary–Ovarian axis
ILRI	International Livestock Research Institute
LH	Luteinizing Hormone
LMP	Livestock Master Plan
MOA	Ministry of Agriculture
NEB	Negative Energy Balance
NGO	Non-Governmental Organization
OIE	World Organisation for Animal Health
Ovsynch	Ovulation Synchronization Protocol
P4	Progesterone
PGF2α	Prostaglandin F2 Alpha
Presynch	Pre-synchronization Protocol
SNV	Netherlands Development Organisation
USAID	United States Agency for International Development

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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