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Review Article

Effectiveness of progestagen-based artificial insemination protocols in cows under tropical production systems: a systematic review

Eficacia de los protocolos de inseminación artificial basados en progestágenos en vacas bajo sistemas de producción tropical: una revisión sistemática

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Abstract

This study examined the impact of progestagen-based estrus synchronization protocols on pregnancy rates in cows under tropical production systems. A systematic review of 44 scientific articles published between 2000 and 2025 was conducted using the Scopus, ScienceDirect, PubMed, and Google Scholar databases. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] guidelines to ensure a rigorous study selection process. The results showed that progestagen-based protocols are an effective tool for improving reproductive efficiency in cattle, achieving pregnancy rates ranging from 30% to 60%, depending on the design of the protocol, the hormonal combination used, and the physiological status of the animals. In this context, short-term protocols (6 to 7 days) demonstrated superior performance, particularly when combined with GnRH, $PGF_{2}\alpha$, or eCG. These protocols promote better estrous cycle synchronization and higher pregnancy rates. The J-Synch protocol and P4 + GnRH-based schemes stood out among these, achieving pregnancy rates close to 55–60%, especially, in anestrous cows. Conversely, conventional P4 + estradiol-based protocols showed greater variability in outcomes, influenced by factors such as body condition, management practices, and production conditions. Overall, the available evidence supports the use of progestagen-based protocols as an effective strategy for optimizing reproductive performance in tropical cattle production systems.

Keywords: anestrus, artificial insemination, intravaginal device, progestagens.

Resumen

El presente trabajo tuvo como objetivo analizar el impacto de los protocolos de sincronización del celo basados en progestágenos sobre la tasa de preñez en vacas bajo sistemas de producción tropical. Para ello, se realizó una revisión sistemática de 44 artículos científicos publicados entre los años 2000 y 2025, recopilados en las bases de datos Scopus, ScienceDirect, PubMed y Google Scholar, siguiendo los lineamientos del modelo *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* [PRISMA] para garantizar una selección rigurosa de los estudios. Los resultados evidenciaron que los protocolos basados en progestágenos constituyen una herramienta eficaz para mejorar la eficiencia reproductiva en bovinos, alcanzando tasas de preñez entre el 30 y el 60%, dependiendo del diseño del protocolo, la combinación hormonal empleada y el estado fisiológico de los animales. En este contexto, los protoco-

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los de corta duración (6 a 7 días) mostraron un desempeño superior, especialmente cuando se combinaron con GnRH, $PGF_{2}\alpha$ o eCG, favoreciendo una mejor sincronización del ciclo estral y mayores tasas de preñez. Entre ellos, el protocolo J-Synch y los esquemas basados en P4 + GnRH destacaron por alcanzar tasas cercanas al 55–60%, particularmente en vacas en anestro. En contraste, los protocolos convencionales basados en P4 + estradiol presentaron una mayor variabilidad en los resultados, influenciada por factores como la condición corporal, el manejo y las condiciones productivas. En conjunto, la evidencia disponible respalda el uso de protocolos con progestágenos como una estrategia eficiente para optimizar el desempeño reproductivo en sistemas bovinos tropicales.

Palabras clave: anestro, dispositivo intravaginal, inseminación artificial, progestágenos.

1. Introduction

Cattle farming in tropical regions faces reproductive challenges due to high temperatures and forage scarcity during the dry season, leading to heat stress, sperm mortality, and early embryonic loss (Pedroso Sosa et al., 2024). These conditions reduce reproductive efficiency, prolong the calving-to-conception interval, and decrease the number of weaned calves, directly affecting livestock profitability (Botelho-Gomes & Narváez, 2021). In this context, fixed-time artificial insemination has become a key reproductive tool, as it optimizes reproduction without relying on estrus detection, improving production efficiency and accelerating genetic progress in beef, dairy, and dual-purpose systems (Marcondes Seneda et al., 2022).

In tropical production systems, the most common strategy for addressing prolonged postpartum anestrus and synchronizing estrus is the use of hormonal treatments (Bó et al., 2018; García-Díaz et al., 2017). These protocols are based on the administration of hormones that simulate the natural estrous cycle, allowing the reactivation of ovarian activity, control of follicular development, and synchronization of ovulation (Bó et al., 2018).

Progestagen-based hormonal treatments have become a key tool for improving fertility, especially in anestrous cows, as they promote oocyte maturation and increase conception rates (Arndt et al., 2009; Botelho-Gomes & Narváez, 2021; Lonergan & Sánchez, 2020). However, pregnancy rates remain variable, a situation associated with factors such as breed, body condition, and the interaction between hormonal protocols and estrus expression (Delgado-Piloso et al., 2024).

Synchronization protocols combining progesterone [P4] and estradiol [E2], such as J-Synch, have proven effective in inducing ovulation in anestrous *Bos indicus* cows by regulating follicular dynamics and reducing treatment duration (Carvalho et al., 2023; De la Mata & Bó, 2012). Research continues to evaluate alternative methods of P4 administration to improve reproductive efficiency in tropical production systems (EL-Sherry et al., 2010).

Although previous reviews have addressed fixed-time artificial insemination [FTAI] programs in cattle, most have focused on general synchronization protocols or specific production systems. Limited evidence comparatively synthesizes progestagen-based protocols under tropical conditions while considering treatment duration, ovulation inducers, and the physiological characteristics of the animals. Therefore, this review aims to update and synthesize the available evidence published between 2000 and 2025.

This review aimed to analyze the impact of progestagen-based estrus synchronization protocols on pregnancy rates in cows managed under tropical production systems. Specifically, it evaluated the effects of these protocols according to intravaginal device removal time, ovulation inducer, and the inclusion or exclusion of estradiol. Pregnancy rate was selected as the primary outcome because it is a direct indicator of reproductive efficiency in livestock systems. The analysis focused on dual-purpose cows (beef and dairy) to assess the influence of these protocols on reproductive performance under tropical conditions.

Based on the available evidence, progestagen-based synchronization protocols appear to be a reliable alternative for inducing ovulation and improving pregnancy rates, thereby contributing to greater reproductive efficiency in tropical cattle production systems.

2. Materials and Methods

This research was conducted as a qualitative systematic review. Due to the heterogeneity of hormonal protocols, animal categories, production systems, and reproductive variables reported by the included studies, a meta-analysis or a formal quantitative synthesis was not possible. Consequently, the evidence was integrated through a descriptive and comparative analysis of the available results.

To this end, a comprehensive search of scientific literature published between 2000 and 2025 was performed in the ScienceDirect, Scopus, PubMed, and

Google Scholar databases. The process of identifying, selecting, determining eligibility, and including studies followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] statement. Initially, 90 potentially relevant records were identified, of which, after applying the inclusion and exclusion criteria, 44 scientific articles were selected for the systematic review (Figure 1). Of these studies, 14 presented detailed information on estrus synchronization protocols, hormonal treatments used, and pregnancy rates obtained; these were summarized and compared in Table 3.

The search strategy included Spanish and English terms related to artificial insemination in cows, the use of progestogens, hormonal protocols, anestrus, intravaginal devices, and pregnancy rates. Boolean operators (AND, OR) were also used to optimize information retrieval and ensure appropriate selection of studies included in the review.

In the PubMed database, the search strategy was structured using MeSH terms combined with Boolean operators as follows: ("Cattle" OR "Cows") AND ("Artificial Insemination") AND ("Progestins" OR "Progesterone") AND ("Anestrus" OR "Postpartum Anestrus") AND ("Intravaginal Devices" OR "CIDR") AND ("Pregnancy Rate" OR "Fertility").

In Scopus, search fields were used in the title, abstract, and keywords (TITLE-ABS-KEY), combining terms using Boolean operators: (TITLE-ABS-KEY ("cattle" OR "cow*")) AND (TITLE-ABS-KEY ("artificial insemination")) AND (TITLE-ABS-KEY ("progestogen*" OR "progesterone")) AND (TITLE-ABS-KEY ("anestrus" OR "postpartum anestrus")) AND (TITLE-ABS-KEY ("intravaginal device*" OR "CIDR")) AND (TITLE-ABS-KEY ("pregnancy rate" OR "fertility")).

In ScienceDirect, the search equation was constructed using general keywords combined with Boolean operators: ("cattle" OR "cows") AND ("artificial insemination") AND ("progestogens" OR "progesterone") AND ("anestrus") AND ("intravaginal device" OR "CIDR") AND ("pregnancy rate" OR "fertility").

In Google Scholar, a more flexible search strategy was applied, using Boolean operators to combine the main terms: ("progestogens" OR "progesterone") AND ("artificial insemination") AND ("cows" OR "cattle") AND ("anestrus") AND ("intravaginal device" OR "CIDR") AND ("pregnancy rate").

Finally, for regional databases and Spanish-language literature, the following search equation based on MeSH terms was used: ("bovinos" OR "vacas") AND ("inseminación artificial") AND ("progestágenos" OR "progesterona") AND ("anestro") AND ("dispositivo intravaginal" OR "CIDR") AND ("tasa de preñez" OR "fertilidad").

The selection criteria considered original articles, systematic reviews, and meta-analyses published from 2000 onward, written in Spanish or English, and with full text available. Priority was given to studies that specifically analyzed artificial insemination protocols in cows incorporating progestogens into the hormonal treatment. Conversely, studies in other species, non-scientific publications, duplicate articles, or those that did not provide relevant data on reproductive efficacy were excluded. This process ensured a rigorous, coherent review focused on evaluating the effectiveness of hormonal protocols used in bovine reproduction.

The PRISMA flow diagram, adapted to the approach of this study on the effectiveness of artificial insemination protocols using progestogens in cows, is presented below. This model, based on the proposal by Page et al. (2021), allowed for the clear organization and visualization of each stage of the information search, evaluation, and selection process. As a result of this procedure, the available evidence was identified and refined, yielding a total of 44 articles that were included in the systematic review. Figure 1 is shown below.

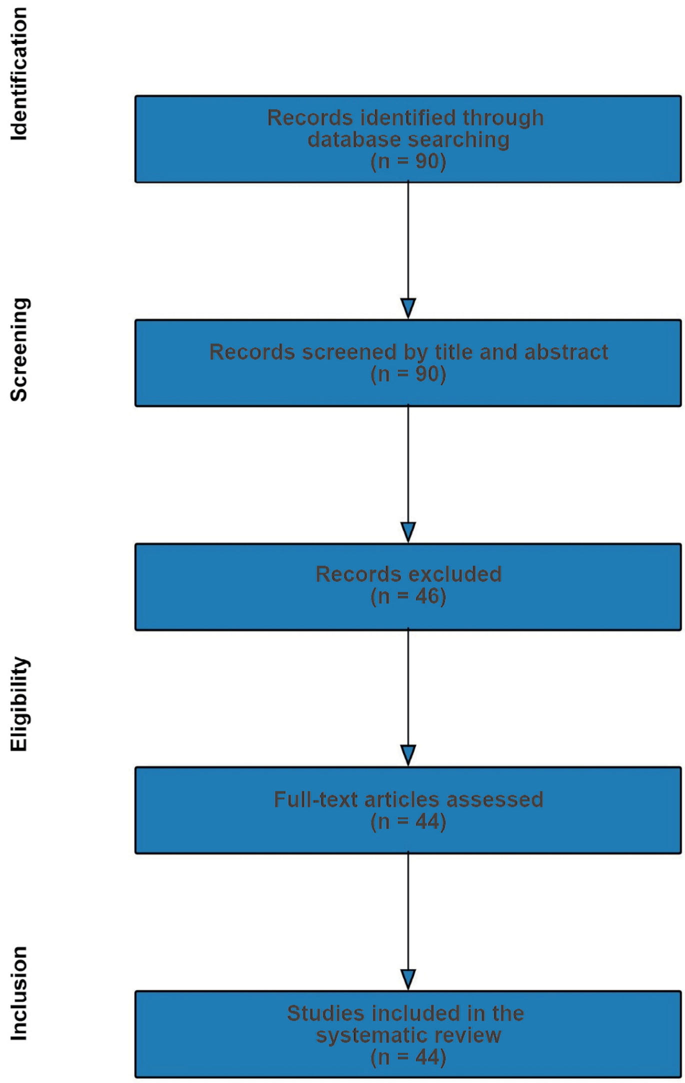
The methodological quality of the included studies was assessed using validated tools to ensure the reliability and validity of the systematic review. The risk of bias was evaluated based on criteria including randomization, blinding, allocation concealment, and completeness of reported data, following recommendations from the scientific literature. The Jadad scale was used to assess clinical trials, whereas the Grading of Recommendations Assessment, Development and Evaluation [GRADE] approach was applied to classify the overall quality of evidence as high, moderate, low, or very low. This assessment is essential in systematic reviews because it identifies potential sources of bias and evaluates the internal validity of the included studies, thereby reducing the risk of overestimating reported effects (Hartling et al., 2009).

A meta-analysis was not performed because of the substantial heterogeneity among the included studies, including differences in hormonal protocols, production systems, cattle breeds, environmental conditions, and reproductive outcomes. Therefore, the evidence was synthesized through a qualitative and comparative analysis of the available studies.

3. Results

The methodological evaluation using the Jadad scale showed that most of the included studies had

Figure 1. Flowchart for item selection (PRISMA)



moderate methodological quality, achieving scores of three points (Table 1). Overall, the reviewed studies adequately described the randomization procedures and reported losses or exclusions during the experimental period. However, none of the studies implemented blinding of operators or evaluators, a common limitation in reproductive research conducted under field conditions because of the nature of the hormonal treatments. Despite this limitation, the studies presented consistent experimental designs and sufficient methodological detail, supporting the reliability of the reported findings.

The GRADE assessment showed that the available evidence on progestagen-based protocols was of moderate to high quality (Table 2). Short-term protocols, such as J-Synch, and those focused on ovulation synchronization demonstrated the highest level of evidence. In contrast, evidence regarding pregnancy rate and reproductive response in anestrous cows was rated as moderate because of variability in hormonal protocols, animal characteristics, and management conditions. Overall, these findings support the effectiveness of progestagen-based protocols for improving reproductive performance in cattle.

3.1. Main progestagen-based protocols used in cows

The main progestagen-based protocols used in cows under tropical production systems, together with their variations in ovulation inducers, production system, hormonal components, duration of intravaginal device insertion, and reported pregnancy rates, are summarized in Table 3.

The included studies presented differences in breed, productive category, physiological status, environmental conditions, and experimental design. Due to this heterogeneity, pregnancy rates were interpreted in a comparative and descriptive manner, avoiding direct quantitative inferences between protocols.

Table 1. Methodological Assessment of the Included Studies According to the Jadad Scale.

Research	Randomization	Appropriate method	Reported losses	Blinding	Score
Alonso Alanuza et al. (2009)	Yes	Yes	Yes	No	3
Botelho-Gomes & Narváez (2021)	Yes	Yes	Yes	No	3
De la Mata & Bó (2012)	Yes	Yes	No	No	2
Garcia-Ispierto et al. (2013)	Yes	Yes	Yes	No	3
Simões et al. (2018)	Yes	Yes	Yes	No	3
Mion et al. (2019)	Yes	Yes	Yes	No	3
Espinoza-Villavicencio et al. (2021)	Yes	Yes	Yes	No	3
Yánez-Avalos et al. (2021)	Yes	Yes	Yes	No	3
Pilla-Campaña et al. (2022)	Yes	Yes	Yes	No	3
Diaz-Quevedo et al. (2023)	Yes	Yes	Yes	No	3
Carballo-Guerrero et al. (2023)	Yes	Yes	Yes	No	3
López Parra et al. (2024)	Yes	Yes	Yes	No	3
Guillen-Alvarado et al. (2025)	Yes	Yes	Yes	No	3
Vásquez-Tarrillo et al. (2025)	Yes	Yes	Yes	No	3

Note: Due to the nature of the reproductive protocols evaluated in cattle, none of the included studies implemented blinding of operators or evaluators; therefore, the maximum Jadad score obtained was 3 points.

Table 2. Quality of evidence assessment using the GRADE approach.

Outcome	Studies included (n)	Quality of evidence	Consistency	Final quality
Pregnancy rate	14	High	Moderate	Moderate
Ovulation synchronization	12	High	High	High
Estrus expression	10	Moderate	Moderate	Moderate
Fertility in anestrous cows	9	Moderate	Moderate	Moderate
Effect of eCG on pregnancy rate	5	Moderate	High	Moderate
Short-duration protocols (J-Synch)	6	High	High	High

Note: The quality of the evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation [GRADE] approach, considering the risk of bias, consistency of results, precision of the estimates, and applicability of the evidence.

Table 3. Main progestogen-based synchronization protocols used in cows in tropical systems, with different intravaginal device removal times and their effect on pregnancy rates.

Authors of reviewed studies	Protocol	Ovulation inducers	Type of production	Sample size	Main components*	Intravaginal device removal time (days)	Pregnancy rate (%)
Alonso Alanuza et al. (2009)	Conventional protocol P4 + E2	Not applicable	Meat production	144	Day 0: P4 (CIDR/DIV) + EB; Day 7: device removal + $PGF_2\alpha$; estrus detection; FTAI according to estrus intensity (~12 h after estrus)	7	45%
Carballo-Guerrero et al. (2023)	Conventional protocol P4 + E2	Estradiol cypionate [ECP]	Dual-purpose	188	Day 0: 0.6 g of progesterone [P4] + 2 mg of estradiol benzoate [EB] IM; Day 8: Device removal + 1 mg of ECP IM + 0.150 mg of d-cloprostenol IM + 400 IU of eCG; FTAI at 50 h after device removal	8	50–55%
De la Mata & Bó (2012)	J-Synch conventional	GnRH	Meat production	28	P4 (DIV/CIDR) + EB; removal on day 6; GnRH + FTAI -72 h after removal	6	60%
Diaz-Quevedo et al. (2023)	Modified Ovsynch + intravaginal progesterone (P4) device	GnRH	Dairy production	45	P4 (CIDR/DIV) + GnRH (day 0); $PGF_2\alpha$ (day 7); device removal + EB (day 8); GnRH (day 9); FTAI ~48–56 h after removal	7	40–60%
Espinoza-Villavicencio et al. (2021)	Estradiol–progesterone protocol [CIDR/DIV + EB] + eCG	ECP	Dual-purpose	110	Day 0: P4 (DIV/CIDR) + EB; day 7: device removal + $PGF_2\alpha$ + ECP ± eCG; FTAI at 48–54 h after removal	7	51–59%
Garcia-Ispierto et al. (2013)	Estradiol–progesterone protocol [CIDR + EB]	GnRH	Dairy production	249	Estradiol–progesterone protocol with P4 device (CIDR/DIV + EB at the beginning)	7	30–40%
Botelho-Gomes & Narváez (2021)	P4 presynchronization protocol	Not applicable	Meat production	74	Day 0: P4 (CIDR/DIV); device removal (day 7) + $PGF_2\alpha$; subsequent synchronization with estradiol–progesterone protocol + FTAI	7	30–40%
Guillen-Alvarado et al. (2025)	P4 + E2 protocol (with/without ECP)	Estradiol cypionate [ECP]	Meat production	60	Day 0: P4 (CIDR/DIV) + EB; day 7: device removal + $PGF_2\alpha$ ± ECP; FTAI at 48–54 h after removal	7	With ECP: 50–55% Without ECP: 40–45%

Authors of reviewed studies	Protocol	Ovulation inducers	Type of production	Sample size	Main components*	Intravaginal device removal time (days)	Pregnancy rate (%)
López-Parra et al. (2024)	Conventional	Estradiol cypionate (ECP)	Dual-purpose	301	Day 0: P4 device + 2 mg EB IM. Day 7: device removal + 500 µg PGF2α + 0.5 mg ECP IM. Day 9: FTAI 48–54 h after device removal. Short proestrus, ovulation induced by ECP	7	51–59%
Mion et al. (2019)	Conventional with estradiol + cypionate (ECP)	ECP	Meat production	296	Day 0: used DIV (1 g P4) + 2 mg EB. Day 7: PGF2α. Day 9: DIV removal + 1 mg of ECP + 250 IU eCG. Estrus detection; those showing estrus are inseminated 12 h later; those not showing estrus are inseminated 48 h after removal (FTAI)	9	45%
Pilla-Campaña et al. (2022)	J-Synch (short duration)	J-Synch: GnRH	Dual-purpose	100	J-Synch: Day 0: P4 (CIDR/DIV) + EB; day 6: removal + PG-$F_2\alpha$; GnRH; FTAI ~72 h after removal	6	J-Synch 53%
	Conventional protocol with progesterone (P4 + estradiol)	Conventional: ECP			Conventional: Day 0: P4 (CIDR/DIV) + EB; day 7: removal + $PGF_2\alpha$ + ECP; FTAI 48–54 h after removal	7	Conventional 47%
Simões et al. (2018)	Modified Ovsynch with progesterone (P4)	GnRH	Meat production	431	P4 (CIDR) prior to the protocol; GnRH (day 0); $PGF_2\alpha$ (day 7); GnRH (day 9); FTAI ~16–24 h after the final GnRH	0	With previous exposure to progesterone (P4): 55% Without previous exposure to progesterone: 50%
Vásquez-Tarrillo et al. (2025)	Estradiol–progesterone protocol (CIDR/DIV + EB)	ECP	Dairy production	159	Day 0: P4 (CIDR/DIV) + EB; day 7: device removal + $PGF_2\alpha$ + ECP; FTAI 48–54 h after removal	7	40–48%
Yánez-Avalos et al. (2021)	J-Synch (6 days) with and without eCG.	GnRH.	Dual-purpose	448	Day 0: P4 (CIDR/DIV) + EB; day 6: device removal + $PGF_2\alpha$; day 6: eCG (according to treatment); GnRH; FTAI ~72 h after removal	6	With eCG 55% Without eCG:45%

*GnRH = Gonadotropin-releasing hormone, $PGF_2\alpha$ = Prostaglandin F2 alpha, CIDR® = Progesterone-releasing intravaginal device, IATF = Fixed-time artificial insemination (FTAI), EB = Estradiol benzoate, P4 = Progesterone, ECP = Estradiol cypionate, eCG = Equine chorionic gonadotropin.

4. Discussion

The integrated analysis of the studies presented in Table 3 confirms that synchronization protocols based on intravaginal progesterone (P4) devices constitute the central axis of reproductive control in cattle, particularly in tropical systems where ovarian cyclicity is often irregular. As indicated by Andersen et al. (2021) and Pessoa et al. (2025), the incorporation of P4 allows regulation of the endocrine environment, synchronizing follicular development and facilitating the implementation of FTAI, regardless of estrus detection. This operational advantage is clearly reflected in the table, where most protocols include CIDR® or similar devices as a base component.

However, when critically analyzing the results, it becomes evident that progesterone alone does not guarantee high levels of reproductive efficiency; rather, its success depends on the appropriate combination with ovulation inducers and the physiological context of the animal. For example, conventional P4 + estradiol protocols show variable rates (30–55%), as observed in studies such as Garcia-Ispierto et al. (2013) and Alonso Alanuza et al. (2009), suggesting a strong dependence on factors such as body condition, cyclicity, and management. This variability supports the findings reported by Mercadante et al. (2024), who highlight that the interaction between progestogens, GnRH, and $PGF_2\alpha$ is decisive for inducing cyclicity in anestrous cows and improving fertility.

In tropical systems, the available evidence indicates that the most efficient protocols are those that combine intravaginal progesterone (P4) devices with GnRH and, in certain cases, eCG, because progesterone allows regulation of the endocrine environment and synchronization of follicular development, while GnRH ensures a more precise and synchronized ovulation, reducing variability in reproductive response (Hernández-Coronado et al., 2023; Mohammed et al., 2021). Likewise, the inclusion of eCG has proven particularly useful in cows with low ovarian activity or anestrus, increasing pregnancy rates, as demonstrated by Yánez-Avalos et al. (2021), who reported improvements of 55% compared with 45%.

On the other hand, short-duration synchronization protocols, such as J-Synch (6 days), have shown favorable reproductive results compared with conventional 7-day protocols. This is attributed to the fact that a shorter exposure to progesterone, together with the extension of proestrus, promotes a more physiological ovulation and improves oocyte quality, favoring the establishment of pregnancy (De la Mata & Bó, 2012). In dual-purpose cows under adequate productive conditions, it has been observed that the use of GnRH, EB, or ECP as ovulation inducers, combined with progesterone devices, generates similar reproductive results, with pregnancy rates ranging between 51% and 59% (López Parra et al., 2024).

In contrast, in postpartum Bos indicus cows, the use of GnRH has proven superior to ECP, increasing the pregnancy rate from 26% to 41%, which highlights its importance under conditions of greater physiological restriction in tropical systems (Hernández-Coronado et al., 2023). Overall, these findings allow concluding that, in tropical systems characterized by high environmental variability and nutritional challenges, protocols based on P4 + GnRH, with eCG support in anestrous animals, represent the most robust and adaptable strategy to optimize reproductive efficiency, although their implementation should be adjusted to the specific conditions of each production system (Mercadante et al., 2024).

One of the main factors that conditions the effectiveness of progestogen protocols is the reproductive status of the cow at the beginning of treatment. In postpartum anestrous animals, with low ovarian activity or not cycling, the insertion of a progesterone device usually requires the support of other hormones to induce a quality follicular wave (Mínguez & Calvo, 2020). Several studies indicate that the presence of the calf, poor nutrition, and lack of cyclicity reduce the response to P4 and estradiol protocols (Sales et al., 2019). Likewise, Ari et al. (2017) reported that cows with better body condition (≥ 2.5) achieved higher pregnancy rates (59.2% vs 36.8%) when PRID was included in the protocol. Overall, these findings confirm that cyclicity, body condition, and postpartum status are decisive factors for the success of progestogen treatments.

Another determining factor in the effectiveness of progestogen protocols is follicular dynamics, which are influenced by the size of the dominant follicle at the time of induction, the phase of the follicular cycle at the beginning of treatment, and the lysis of the previous corpus luteum. Several studies indicate that, although prostaglandin $F_2\alpha$ ($PGF_2\alpha$)-induced luteolysis does not show significant differences between days 6 and 17 of the cycle in crossbred cows, plasma progesterone concentrations and the effectiveness of luteal regression are critical factors for achieving adequate ovarian synchronization (Umaña Sedó et al., 2022; Wiltbank, 2014). This demonstrates that hormonal control must ensure both complete luteolysis and a favorable endocrine environment for the development of a functional dominant follicle, optimizing the response to intravaginal progesterone devices (Couto et al., 2023).

Environmental and metabolic stress decisively influence the effectiveness of progestogen protocols. In a study conducted in Gyr cows under tropical conditions in Peru, it was observed that estrus expression was higher when animals remained for a longer time with a temperature-humidity index [THI] below 72, whereas values above 83 significantly reduced its expression (Vásquez-Tarrillo et al., 2025). This confirms that, even in breeds adapted to tropical conditions, heat and humidity can compromise ovarian response. In turn, recent reviews indicate that factors such as lactation, energy balance, and peak production also modulate the action of progestogens on the ovary (Julanov et al., 2024), highlighting the need to consider environmental and metabolic conditions in reproductive planning.

Body Condition Score [BCS] and nutritional status are controllable but decisive factors for the success of hormonal protocols. The study by Ari et al. (2017) demonstrated that the incorporation of PRID into the Ovsynch protocol in lactating dairy cows significantly improved the pregnancy rate in animals with better BCS, demonstrating the direct influence of body condition on the response to treatment. Similarly, recent reviews indicate that cows with low body condition scores have a lower probability of cycling, longer postpartum intervals, and lower conception rates, even under synchronization (Sales et al., 2019). In this context, ensuring adequate nutrition and body condition before initiating a progestogen protocol is essential to optimize fertility and the reproductive efficiency of the herd.

The effectiveness of progestogen protocols depends directly on their hormonal design, including the duration of the device, the type of progestagen, the timing of application, and its combination with GnRH, $PGF_2\alpha$, or estradiol. Wiltbank et al. (2014) pointed out that the reproductive response varies according to the individual production and metabolism of progesterone, factors that determine the effectiveness of the treatment. Likewise, Hernández-Coronado et al. (2023) highlighted that synchronization should be adjusted to the reproductive status of each cow: in cyclic animals, the results are usually more predictable, whereas in anestrous cows, longer-duration devices or additional strategies, such as temporary calf separation, may be required to reactivate ovarian activity.

Overall, the reviewed evidence demonstrates that progestagen-based protocols constitute an effective tool for improving reproductive efficiency in cattle under tropical conditions. However, the magnitude of the reproductive response depends on factors such as the physiological status of the cows, body condition, heat stress, and the specific design of the hormonal protocol used. The best results were observed in short-duration protocols associated with GnRH and, in anestrous cows, with the inclusion of eCG.

4.1 Future perspectives and limitations in the use of progestogens

The use of progesterone-releasing intravaginal devices, such as CIDR and PRID, has become established as a fundamental tool in synchronization and fixed-time artificial insemination programs. However, their effectiveness is not uniform, as it varies according to the protocol used, the animal category, and herd management conditions. Hölper et al. (2023) reported that the incorporation of the PRID device into a 7-day Ovsynch protocol increased pregnancy rates in dairy cows, although this effect depended on the production context. Similarly, Arkose and Uslu (2022) observed improvements when comparing the use of PRID or CIDR, although with inconsistent results among studies and production systems. In addition, Stevenson and Lamb (2016) highlighted that the physiological differences between beef and dairy cattle influence postpartum progesterone concentrations, thereby affecting the response to hormonal treatments.

Recent studies have demonstrated that P4 regulates gene expression in the endometrium and modulates the embryonic signals necessary for the establishment of pregnancy (Lonergan & Sánchez, 2020). However, the direct relationship between higher P4 concentrations and higher pregnancy rates is not always consistent. Interventions aimed at increasing its levels, such as the administration of hCG on day 2 of the cycle, have shown overall positive results, although these vary according to the stage of lactation and the physiological status of the cows (Cuevas-Gómez et al., 2025; Michelena et al., 2025; Shafi et al., 2025).

In the case of repeat breeder cows, progesterone administration may favor the early events of pregnancy, but it does not necessarily correct the underlying causes, such as lack of endometrial receptivity, subclinical inflammation, or heat stress. Recent studies using sustained-release P4 formulations have demonstrated beneficial molecular effects, highlighting the potential of new formulations, although the clinical results remain inconsistent (Modaresi et al., 2024). Likewise, reviews of therapies for repeat breeder females suggest that the combination of GnRH, P4, and anti-inflammatory agents may improve the response in certain subgroups, provided that an accurate diagnosis is available to allow treatment to be individualized (Carbonari et al., 2024). There are also practical limitations in the use of these devices. Although the reuse of CIDRs may appear to be an economical option, studies have demonstrated the presence of bacterial contamination even after disinfection, representing a risk to biosecurity and reproductive efficiency (Perry et al., 2024; Talsma et al., 2020; Yessa et al., 2024).

Ultimately, progesterone will continue to be an essential cornerstone of synchronization programs, although its use will tend to become more selective, quantifiable, and traceable, being incorporated into decisions supported by rational management policies.

5. Conclusions

The analyzed evidence confirms that progestagen-based artificial insemination protocols constitute a key tool for improving reproductive efficiency in cattle, especially in tropical systems where environmental and physiological conditions limit ovarian cyclicity. Their effectiveness lies not only in the use of progesterone as the central component but also in its appropriate combination with other hormones such as GnRH, $PGF_2\alpha$, or eCG. In this context, short-duration protocols (6 to 7 days) proved to be the most efficient, with the J-Synch protocol and P4 + GnRH-based schemes standing out, achieving the highest pregnancy rates, close to 55–60%, especially when supplemented with eCG in anestrous cows. These protocols promote better follicular synchronization, more precise ovulation, and higher pregnancy rates. In contrast, prolonged treatments or the reuse of devices may compromise fertility due to hormonal alterations and health risks.

From a practical perspective, it is recommended to prioritize short-duration protocols based on progestogens combined with GnRH, especially in cows managed under tropical conditions. Likewise, future research should comparatively evaluate the economic efficiency of these protocols, the use of biodegradable devices, and the integration of precision livestock farming tools to optimize reproductive decision-making.

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Author Contributions

Bridget Maldonado: conceptualization, investigation, methodology, resources, software, and writing – original draft.
Edwin Velásquez: validation, writing – review & editing.

Data Availability

The data used are from previously published studies.

Artificial Intelligence Use Declaration

The authors declare that Artificial Intelligence has not been used in the preparation of the manuscript.

Ethical Implications

The authors declare that there are no ethical implications.

Conflict of Interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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