Scientific Electronic Archives
Issue ID: Vol.19 (3), May/Jun 2026, p. 1-6
DOI: http://dx.doi.org/10.36560/19320262247
+ Corresponding author*:* rodolfo.berber@ufr.edu.br
ISSN 2316-9281

Timed artificial insemination in cattle: advances, impacts, and future perspectives

Eloa Lima de Oliveira Portela, Júlia Silva de Oliveira, Isabela Correa da Costa Marques, Raynara De Lima Goi, Julia Mello Wesz, Enzo Pugliese, Maria Eduarda dos Santos Silva Lopes, Sophia Marques Miranda, Yasmim Eduarda Venturini dos Santos, Rodolfo Cassimiro de Araujo Berber +

Universidade Federal de Rondonópolis

Abstract. Timed artificial insemination (TAI) has consolidated itself as one of the main reproductive biotechnologies in Brazilian cattle production, promoting significant advances in the productive, genetic, and economic indices of herds. In recent decades, especially between 2020 and 2025, there has been expressive growth in the use of this technique in Brazil, making the country the world leader in the number of protocols performed. Recent scientific advances have contributed to the improvement of hormonal protocols, with emphasis on the simplification of management, strategic use of hormones such as progesterone, estradiol, prostaglandin F2α, and eCG, in addition to the development of specific programs for challenging categories, such as anestrous cows and super precocious heifers. Studies demonstrate that TAI provides higher pregnancy rates, anticipation of conception, accelerated genetic improvement, and greater productive efficiency when compared to traditional reproductive methods. Furthermore, the association of the technique with technological tools, such as sex-sorted semen, resynchronization, genomic evaluation, and digital monitoring systems, has further expanded its efficiency and applicability in modern production systems.
Keywords: TAI. Ovulation synchronization. Precision livestock farming. Pregnancy rate. Animal biotechnology.

Contextualization and analysis

Reproductive efficiency constitutes one of the fundamental pillars for cattle productivity, directly affecting the profitability of meat and milk production systems. In this context, Timed Artificial Insemination (TAI) has emerged as the most impactful reproductive biotechnology in Brazilian cattle production in recent decades (Sales et al., 2024). TAI is a technique that combines traditional artificial insemination with hormonal protocols capable of synchronizing ovulation in bovine females, eliminating the need for estrus detection and allowing an entire batch of cows to be inseminated on a pre-established date (Jesus & Meneguelli, 2025). This represents a significant logistical advance, especially in large-scale operations, where individual estrus detection would be impractical.

Brazil stands out globally in the use of this technology. In a survey conducted by Monteiro et al. (2023), which analyzed 228 manuscripts published between 1995 and 2021 totaling 272,668 TAIs, it was found that the majority of studies originated from Brazil and the United States, followed by Canada, Argentina, Uruguay, and Australia. This scenario highlights the country's leading position in the development and application of the technique.

National and Global TAI Scenario

The growth of TAI in Brazil in recent decades is notable. According to Sales et al. (2024), the evolution of ovulation synchronization protocols in the country has allowed pregnancy rates to vary according to animal category and the management employed. The technique has consolidated itself as an indispensable tool for genetic improvement and increasing herd productivity.

Globally, Monteiro et al. (2023) identified that two main types of TAI protocols are used worldwide: GnRH-based protocols and estradiol/progesterone (E2/P4)-based protocols. This distinction is fundamental for understanding regional differences in the application of the technology.

Most Used Hormonal Protocols for Dairy and Beef Cows

Hormonal protocols constitute the basis of TAI and remain an object of intense scientific investigation. It is essential to distinguish the strategies employed for dairy and beef cows, since the physiological bases and management objectives differ substantially between these production systems.

For dairy cows, especially high-producing ones, the central challenge is to overcome the negative effects of negative energy balance and metabolic stress on estrus expression and fertility. In this context, the Ovsynch protocol and its variations, such as Double-Ovsynch, are widely adopted. Double-Ovsynch consists of two cycles of GnRH and prostaglandin (PGF2α) before TAI, aiming to increase ovulation synchronization and pregnancy rates. Studies demonstrate that lactating Jersey cows submitted to Double-Ovsynch had pregnancy rates of 64.2% when inseminated with conventional beef semen, superior to those obtained with insemination after estrus detection (56.3%) (Lauber & Fricke, 2024). Also in dairy cows, Ambrose, Colazo, and Gobikrushanth (2025) demonstrated that the Ovsynch protocol with or without a progesterone device (PRID) resulted in pregnancy rates ranging from 37% to 45% in Holstein cows with ovarian cysts.

For beef cows, especially in Brazil, where the majority of herds are composed of *Bos indicus* (Nelore) animals under grazing systems, the most widespread protocols are based on the association of progesterone (P4) and estradiol (E2) (Baruselli et al., 2017). These protocols are particularly effective for synchronizing the emergence of a new follicular wave and inducing ovulation in a large number of females, even in the presence of postpartum anestrus. A study conducted by Oliveira et al. (2025) compared the use of eCG and rbST in *Bos indicus* cows with low body condition score (mean BCS = 2.3). The results demonstrated that the group treated with eCG achieved a pregnancy rate of 43.4%, significantly higher than the groups treated with rbST (16.1% to 19.4%) and the control group (30.9%) (Oliveira et al., 2025). This finding reinforces the importance of eCG in protocols for challenging categories.

Table 1. Hormonal TAI protocols, pregnancy rates, and sources.

Category	Hormonal Protocol	Conception Rate (Pregnancy/AI)	Source (Author, year)
Dairy Cows (Jersey)	Double-Ovsynch + beef semen	64.2% - 65.5%	Lauber & Fricke, 2024
Dairy Cows (Holstein)	Ovsynch + PRID	37% - 45%	Ambrose, Colazo & Gobikrushanth, 2025
Beef Cows (Nelore - low BCS)	E2/P4 + eCG	43.4%	Oliveira et al., 2025
Beef Cows (Nelore - low BCS)	E2/P4 + rbST	16.1% - 19.4%	Oliveira et al., 2025
Beef Cows (Nelore - low BCS)	E2/P4 (control)	30.9%	Oliveira et al., 2025

Source: Elaborated by the authors based on the reviewed literature.

Regional Differences in TAI Protocols: South America vs. North America

A fundamentally important aspect in understanding TAI is the recognition that there is no single, universally applicable protocol**.** Hormonal strategies vary significantly between countries and regions, reflecting differences in production systems, animal genetics, environmental conditions, and, crucially, in regulations concerning hormone use.

Monteiro et al. (2023), in their comprehensive 27-year review of TAI research for beef cattle, clearly identified these two distinct approaches. The authors report that GnRH-based protocols are predominant in North America (United States and Canada), while estradiol and progesterone (E2/P4)-based protocols are widely used in South America(Brazil, Argentina, and Uruguay).

This regional divergence has historical and practical reasons. North American protocols (GnRH-based) were primarily developed for high-producing *Bos taurus* dairy cows, in which GnRH is effective for inducing ovulation and synchronizing follicular emergence (Ayantoye et al., 2025). On the other hand, South American protocols (E2/P4-based) have proven more effective for *Bos indicus* beef cows and *Bos indicus* × *Bos taurus* crossbreds, which present particular physiological characteristics, such as a higher incidence of prolonged postpartum anestrus (Baruselli et al., 2017; Sales et al., 2024).

An additional crucial difference lies in regulatory restrictions**.** The use of estradiol in TAI protocols is prohibited or severely restricted in the European Union and other markets, which limits the acceptance of animal products originating from herds subjected to such protocols. This regulatory pressure has driven research into efficient protocols that do not use E2, an area of intense investigation both in South America and North America.

From an efficacy standpoint, Monteiro et al. (2023) performed an important comparative analysis. The authors evaluated the effect of adding GnRH at the time of TAI in E2/P4-based protocols. The results demonstrated that GnRH use at TAI increased pregnancy rates in beef cows from 54.7% to 59.2%, but no detectable increase was observed in heifers (Monteiro et al., 2023). This finding suggests that integration between the two protocol philosophies may be beneficial, paving the way for hybrid protocols that combine the best of both approaches.

Advances in Hormonal Protocols and Associated Technologies

The role of estradiol has been widely discussed in the literature. Studies demonstrate that protocols containing estradiol have robust reproductive performance in *Bos indicus* (Baruselli et al., 2017). However, regulatory restrictions in international markets have driven the search for alternatives.

Equine chorionic gonadotropin (eCG) remains a strategic hormone in contemporary TAI protocols, especially in categories that present greater reproductive challenges. Oliveira et al. (2025) demonstrated that the use of eCG in *Bos indicus* cows with low body condition score resulted in a larger dominant follicle diameter (11.2 mm vs. 9.6-10.1 mm in the other groups) and a higher follicular growth rate (2.20 mm/day vs. 0.93-1.17 mm/day in the other groups). These results corroborate the recommendation of eCG use in cows with low BCS.

Another remarkable advance is the convergence between TAI and digital technologies applied to precision livestock farming. Ayantoye et al. (2025) highlight that the integration of "omic" technologies (genomics, transcriptomics, proteomics, and metabolomics) into TAI protocols will allow for treatment personalization. The objective is to identify molecular biomarkers that indicate the genetic, metabolic, and physiological profile of each animal, allowing fine adjustments in hormonal protocols to maximize individual fertility, a concept known as "precision reproductive medicine" (Ayantoye et al., 2025).

Productive, Economic, and Environmental Impacts

Pregnancy rate remains the main indicator for evaluating TAI programs, and recent data confirm the superiority of this technique when compared to natural service and conventional artificial insemination with estrus detection. Lauber and Fricke (2024) demonstrated that submitting lactating Jersey dairy cows to the Double-Ovsynch protocol for first insemination resulted in increased insemination rate and fertility, regardless of semen type (conventional or sex-sorted) and estrus expression. This effect was particularly pronounced in cows with excessive postpartum body condition score loss, in which Double-Ovsynch resulted in a higher pregnancy rate (54.1%) than insemination after estrus detection (36.1%) (Lauber & Fricke, 2024).

In addition to pregnancy rates, TAI provides anticipation of conception within the breeding season, reducing the calving interval and contributing to earlier births. Consequently, calves born early in the season have higher weaning weights and greater productive performance.

From an economic perspective, TAI remains one of the most impactful technologies in Brazilian cattle production. Batch standardization, birth concentration, improved sanitary and nutritional planning, and greater commercial valorization of the produced animals are additional benefits that contribute to a highly favorable financial return.

The environmental dimension of TAI has also gained increasing prominence in recent literature. Systems that use this technology present greater productive efficiency and lower greenhouse gas emissions per unit produced. By increasing pregnancy rates and reducing the calving interval, the technique allows for producing more meat or milk with less need for herd expansion, favoring the sustainability of production systems (sustainable intensification).

Future Perspectives for TAI

The perspectives for TAI in the coming years are promising and aligned with the concept of "Livestock 4.0". The main trends, based on recent literature, include:

- ✓ *Integration with "Omic" Technologies***:** Ayantoye et al. (2025) propose a framework for future research to refine TAI protocols to address genetic variability and apply omic technologies to identify validated biomarkers for early pregnancy detection. This represents a significant shift from reproductive management based on standardized protocols ("blanket synchronization") to personalized approaches.

- ✓ *Estradiol-Free Protocols***:** Regulatory pressure to eliminate estradiol from TAI protocols will continue to drive research. The development of new long-acting GnRH formulations and the use of recombinant hormones are areas of intense investigation.

- ✓ *Digital Tools and Artificial Intelligence***:** Monitoring sensors, management software, and artificial intelligence algorithms will be increasingly used to predict the ideal AI moment, monitor animal welfare, and automate data collection.

- ✓ Integration with Other Biotechnologies**:** The combination of resynchronization programs and TAI, associated in some systems with in vitro embryo production (IVEP), represents an important technological frontier. Baruselli et al. (2017) highlight that resynchronization allows for reducing the interval between services, increasing the number of inseminations within the breeding season, and maximizing calf production.

Final Considerations

Timed artificial insemination represents an important technological milestone for cattle production, bringing together reproductive, genetic, economic, and environmental benefits. The advances observed in recent years demonstrate the constant evolution of hormonal protocols, management strategies, and associated technologies. However, it is essential to recognize that there is no single, universally applicable protocol, and adaptation of strategies to local conditions, production systems, and, crucially, to the regulations in force in each country or consumer market is essential.

The consolidation of TAI in Brazil highlights its strategic relevance for the sustainable development of cattle production. Despite the positive results, challenges related to implementation costs, need for qualified labor, and correct execution of protocols still exist. Thus, continued investment in research, technical training, and knowledge dissemination is fundamental to expand access to the technology and optimize its results in different production systems.

Therefore, it is concluded that TAI will continue to play an essential role in the modernization of Brazilian cattle production, being an indispensable tool for the productive, genetic, and sustainable advancement of the activity.

References

AGROADVANCE. IATF: inseminação artificial em tempo fixo e a biotecnologia. Disponível em: https://agroadvance.com.br/blog-iatf-pecuaria-de-corte/. Acesso em: 27 abr. 2025.

AMBROSE, D.; COLAZO, M.; GOBIKRUSHANTH, M. Fate of cystic ovarian follicles, clinical responses, and pregnancy in dairy cows subjected to Ovsynch and timed artificial insemination, with or without an intravaginal progesterone device. Clinical Theriogenology, v. 17, 2025. DOI: 10.58292/CT.v17.12189.

ANDRADE, G. G. et al. Desempenho reprodutivo de vacas de corte submetidas à IATF com diferentes protocolos hormonais. Research, Society and Development, v.12, n. 4, 2023. DOI: https://doi.org/10.33448/rsd-v12i4.32688

AYANTOYE, J. O. et al. Advances in Timed Artificial Insemination: Integrating Omics Technologies for Enhanced Reproductive Efficiency in Dairy Cattle. Animals, v. 15, n. 6, p. 816, 2025. DOI: 10.3390/ani15060816.

BARBOSA, Carla Neves et al. Gestational losses after innovating with two embryos in a fixed-time embryo transfer program. Scientific Electronic Archives, v. 14, n. 10, 2021.

BARUSELLI, P. S. et al. Evolução e perspectivas da inseminação artificial em bovinos. Boletim Eletrônico do Departamento de Reprodução Animal/FMVZ/USP, 6ª ed., 2022. Disponível em: https://agroadvance.com.br/blog-iatf-pecuaria-de-corte/

BARUSELLI, P. S. et al. Mitos e realidades sobre a inseminação artificial em tempo fixo (IATF) em bovinos de corte. Revista Brasileira de Reprodução Animal, v. 45, n. 4, p. 625-646, out./dez. 2021. DOI: 10.21451/1809-3000.RBRA2021.083. Disponível em: http://www.cbra.org.br/portal/downloads/publicacoes/rbra/v45/n4/p.625-646.pdf. Acesso em: 27 abr. 2025.

BARUSELLI, P. S. et al. Timed artificial insemination: current challenges and recent advances in reproductive efficiency in beef and dairy herds in Brazil. Animal Reproduction, v. 14, n. 3, p. 558-571, 2017.

BOLETIM ELETRÔNICO – Departamento de Reprodução Animal/FMVZ/USP, ed. 8, fev. 2024. Indicadores de mercado de IATF no Brasil – 2023. Disponível em: http://www.assessoriaagropecuaria.com.br/noticia/2024/03/12/usp-boletim-dereproducao-animal-indica-91-de-iatf-em-2023

CAMARGO, I. R. S. Uso de programas de inseminação artificial em tempo fixo (IATF) em vacas de corte. 2025. Trabalho de Conclusão de Curso (Graduação em Medicina Veterinária) – Centro Universitário Fama. Disponível em: https://repositorio.faculdadefama.edu.br/xmlui/handle/123456789/348. Acesso em: 27 abr. 2025.

CONFEDERAÇÃO DA AGRICULTURA E PECUÁRIA DO BRASIL (CNA). Melhoramento genético e eficiência reprodutiva: a influência da IATF no sucesso da pecuária. Disponível em: https://www.cnabrasil.org.br/publicacoes/melhorame

ntogenetico-e-eficiencia-reprodutiva-a-influencia-da-iatf-no-sucesso-da-pecuaria. Acesso em: 27 abr. 2025.

COSTA, N. A. et al. Impactos ambientais da eficiência reprodutiva em bovinos de corte: relação entre IATF, produtividade e emissões. Acta Scientiae Veterinariae, v.50, 2022. DOI: https://doi.org/10.22456/1679-9216.118061

FERREIRA, R. M.; NOGUEIRA, G. P. Fatores que afetam a resposta a protocolos de IATF: escore corporal, anestro e ambiente. Arquivos de Medicina Veterinária e Zootecnia, v. 75, 2023.

FIRMO FERREIRA, L. et al. Sêmen sexado: conhecendo melhor as técnicas e os avanços. Revista Brasileira de Reprodução Animal (RBRA), v. 48, n. 1, p. 77–87. Disponível em: http://www.cbra.org.br/portal/downloads/publicacoes/rbra/v48/n1/RB1129%20Firmo%20Ferreira%20p.77-87.pdf

GIMENES, L. U. et al. Estresse térmico e sua interferência no desempenho reprodutivo de vacas submetidas à IATF. Revista Eletrônica Científica da UFLA, v. 20, n. 3, p. 89–102, 2024

JAGUSZEKI, M. Z. et al. Transition and postpartum period in bovine female: review of literature. Scientific Electronic Archives, v. 11, n. 6, p. 131-138, 2018.

JESUS, E. R. B.; MENEGUELLI, M. Reprodução animal com ênfase na Inseminação Artificial em Tempo Fixo (IATF). Research, Society and Development, v. 14, n. 6, e7214649071, 2025. DOI: http://dx.doi.org/10.33448/rsd-v14i6.49071. Disponível em: https://rsdjournal.org/rsd/article/download/49071/38433 . Acesso em: 27 abr. 2025.

LAUBER, M. R.; FRICKE, P. M. Effect of postpartum body condition score change on the pregnancy outcomes of lactating Jersey cows inseminated at first service with sexed Jersey or conventional beef semen after a synchronized estrus versus a synchronized ovulation. Journal of Dairy Science, v. 107, n. 4, p. 2524-2542, 2024. DOI: 10.3168/jds.2023-23892.

LOBÊ, G. C. P.; FONSECA, C. W.; PINTO, E. V. Manejo reprodutivo em bovinos: os impactos positivos da IATF nas propriedades rurais no Brasil. Revista IberoAmericana de Humanidades, Ciências e Educação (REASE), v. 11, n. 12, dez. 2025. DOI: https://doi.org/10.51891/rease.v11i12.23126

MARINHO, A. L. M. et al. Ovarian cysts in domestic animals: etiopathogenesis and treatments. Scientific Electronic Archives, v. 9, n. 2, p. 108-113, 2015.

MARINHO, AL M. et al. Artificial insemination in bovine. Scientific Electronic Archives, v. 9, n. 1, p. 50-55, 2016.

MICHETTI, M. et al. Seasonal variation of price and milk production in Mato Grosso. Scientific Electronic Archives, v. 7, p. 67-76, 2020.

MONTEIRO, P. L. J. et al. Research on timed AI in beef cattle: Past, present and future, a 27-year perspective. Theriogenology, v. 211, p. 161-171, 2023. DOI: 10.1016/j.theriogenology.2023.07.022.

MOREIRA, P. S. A.; PALHARI, C.; BERBER, R. C. A. Dietary chromium and growth performance animals: a review. Scientific Electronic Archives, v. 13, n. 7, p. 59-66, 2020.

OLIVEIRA, R. C. et al. Comparison between recombinant bovine somatotropin and equine chorionic gonadotropin in timed artificial insemination protocols in Bos indicus cows with low body condition score. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, v. 77, n. 2, 2025. DOI: 10.1590/1678-4162-13256.

PONTA AGRO. IATF – O que é inseminação artificial em tempo fixo? Disponível em: https://pontaagro.com/o-que-e-inseminacao-artificial-em-tempo-fixo/ . Acesso em: 27 abr. 2025.

RODRIGUES, C. A. et al. Tendências tecnológicas na reprodução bovina: IATF, ressincronização e integração com seleção genômica. Revista Acadêmica de Medicina Veterinária, v. 32, n. 1, p. 55–68, 2024.

SÁ FILHO, M. F.; BARUSELLI, P. S.; MARQUES, M. O. Impacto da IATF na produtividade de rebanhos de corte e leite. Revista Brasileira de Reprodução Animal, v. 35, n. 2, p. 141–150, 2011.

SALES, J. N. S. et al. Evolution over the last 40 years of the assisted reproduction technologies in cattle – the Brazilian perspective I – timed artificial insemination. Animal Reproduction, v. 21, n. 3, e20240034, 2024. Disponível em: https://periodicos.newsciencepubl.com/arace/article/view/12809 . Acesso em: 27 abr. 2025.

SANTOS, R. M.; VASCONCELOS, J. L. M. Inseminação Artificial em Tempo Fixo (IATF) em bovinos: o que é e que cuidados devem ser tomados? MilkPoint, fev. 2021. Disponível em: https://www.milkpoint.com.br/colunas/jose-luiz-moraesvasconcelos-ricarda-santos/iatf-quais-cuidados-devem-ser-tomados-para-execucao-224071/

SARTORI, R. et al. Manipulation of follicle development to improve fertility of cattle in timed-artificial insemination programs. Animal, v. 17, p. 100769, 2023.

SCORSATTO, A. C. S.; ALVES, M. S.; UBIRAJARA FILHO, C. R. C. Desafios e soluções na inseminação artificial de bovinos. ARACÊ, 2025. Disponível em: https://periodicos.newsciencepubl.com/arace/article/view/12809 . Acesso em: 27 abr. 2025.

VASCONCELOS, J. L. M.; SANTOS, R. IATF: quais cuidados devem ser tomados para execução? MilkPoint, 2023. Disponível em: https://www.milkpoint.com.br/colunas/jose-luiz-moraes-vasconcelos-ricardasantos/iatf-quais-cuidados-devem-ser-tomados-para-execucao-224071/. Acesso em: 27 abr. 2025.