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Artificial Insemination (AI) in Goats and Sheep

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Abstract

Artificial insemination (AI) is a strategic reproductive biotechnology that enhances genetic progress and reproductive efficiency in sheep and goats. Its success, however, is highly dependent on multiple interrelated factors, including animal selection, semen type and handling, insemination technique, and synchronization protocols. While laparoscopic AI remains the gold standard in sheep due to cervical anatomical limitations, transcervical AI has become increasingly effective in goats, especially with the development of specialized tools and field-adapted protocols. The use of cervical mucus evaluation and flexible-time AI (FxTAI) has improved insemination accuracy, allowing better alignment with ovulation resulting in high pregnancy rates. Data from the Brazilian CapraGene® program demonstrate the potential of AI in dairy goat production, with pregnancy rates ranging from 45% to nearly 90%. Despite anatomical and logistical challenges, AI has proven to be a cost-effective and impactful tool for genetic improvement, especially when implemented with precision and physiological understanding. This review highlights the physiological basis, practical considerations, and field-level results of AI in small ruminants, supporting its broader adoption in commercial production systems.

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Artificial insemination (AI) is one of the most impactful reproductive biotechnologies used in sheep and goat production systems. Its proper implementation can enhance reproductive efficiency, accelerate genetic progress, and optimize the use of superior sires, especially in isolated or resource-limited production environments. Despite its advantages, the adoption and success rates of AI remain uneven across regions and production systems due to physiological constraints, logistical challenges, and variability in reproductive management protocols. In goats, estrus is generally easier to detect due to overt behavioral signs and the social structure of the herd, where dominant animals enter estrus earlier. In sheep, however, estrus detection is often more subtle, and AI success is more closely linked to the insemination technique, the timing of ovulation, and anatomical limitations such as the complexity of the cervix.

Achieving high pregnancy rates through AI requires attention to multiple factors. Female selection is crucial and must consider reproductive health and body condition score (BCS). According to Fonseca and Alvim, optimal AI results are associated with BCS values between 2.75 and 3.5 on a five-point scale. Animals with poor condition or prior reproductive failures have significantly lower pregnancy rates. Capgenes (2025) reported that goats failing to conceive in a previous AI attempt had only half the probability of success in the following cycle. Age and breed also influence the outcome. Specialized dairy breeds such as Saanen and Alpine tend to respond better to synchronization protocols and AI than indigenous or meat breeds. Multiparous animals typically have superior conception rates than primiparous or nulliparous females, likely due to more consistent endocrine responses and uterine receptivity (Capgenes, 2025).

The choice and handling of semen are equally critical. Semen can be used fresh, cooled, or frozen-thawed. Each form differs in its viability window, capacitation dynamics, and sensitivity to thermal shock. Frozen semen requires precise timing and high technical accuracy, while fresh semen allows for a broader insemination window but is less practical in large-scale operations. The use of tested semen from progeny-evaluated males is recommended to ensure both fertility and genetic merit, with doses containing 75 to 150 million progressively motile spermatozoa depending on the route of administration .

Several AI techniques are available, and their efficacy varies depending on the species and anatomical accessibility. Intra-vaginal insemination, although the simplest method, has limited success due to poor semen deposition site and lower fertilization rates. Cervical insemination is more common in sheep but presents challenges due to the narrow, convoluted cervical canal. Penetration of the cervix in sheep is achieved in only 6% of cases using standard applicators, compared to 60% in goats (Fonseca and Simplício, 2008). Transcervical insemination, which requires immobilization of the cervix and specialized tools such as the Embrapa forceps and speculum, is widely used in goats and has been reported to result in intrauterine semen deposition in over 90% of cases when performed correctly . Laparoscopic insemination remains the gold standard for sheep due to its ability to deliver semen directly into the uterine horns, circumventing the cervical barrier. It consistently produces the highest conception rates but requires surgical facilities and trained personnel, making it less accessible for field use .

The use of cervical mucus as an indicator of insemination timing has been well established. Aisen et al. (1994) showed that crystalline cervical mucus correlates with the highest fertility outcomes, while striated and caseous mucus are associated with lower pregnancy rates. Therefore, cervical mucus evaluation is a practical and non-invasive tool to guide insemination timing, especially in protocols involving flexible-time AI.

Flexible-Time Artificial Insemination (FxTAI) has emerged as a promising approach that adjusts insemination based on individual estrus manifestation and cervical mucus type rather than a rigid fixed schedule. Fonseca (2021) and Cortat et al. (2022) demonstrated that FxTAI allows for improved fertility outcomes compared to traditional Fixed-Time AI (FTAI), particularly in field conditions where estrus onset varies considerably among animals. The use of FxTAI protocols offers important benefits for the reproductive management of dairy goats. Bonato et al. (2019) demonstrated that two administrations of d-cloprostenol at a 7.5-day interval resulted in a high estrous response (90.0%) and a pregnancy rate of 80.0%, with greater synchrony of estrus onset occurring between 36 and 48 hours after the second prostaglandin administration. Notably, goats subjected to the 7.5-day interval exhibited shorter intervals to estrus (40.1 ± 1.5 h) and achieved higher conception rates following intrauterine insemination compared to those receiving an 11.5-day protocol. Furthermore, the flexible insemination strategy based on the detection of estrus symptoms allowed inseminations to be timed according to optimal cervical mucus characteristics, achieving conception rates of up to 88.9% in goats expressing estrus 24-36 hours after treatment. These findings underscore the efficiency and practicality of FxTAI protocols, facilitating high pregnancy rates while reducing the need for rigid fixed-time inseminations and intensive labor .

Studies conducted under the CapraGene® program in Brazil provide robust evidence supporting AI's effectiveness in dairy goats. Pregnancy rates varied between 45.8% and 89.7% depending on breed, semen type, and insemination strategy. Notable results include 66.7% conception in Alpine and Saanen goats using transcervical AI and 73.8% in a large sample of 290 goats . These findings underscore the potential of AI not only to improve reproductive efficiency but also to implement genetic selection programs aimed at enhancing milk yield and other economically relevant traits.

Proper semen handling is critical to preserving sperm viability. Semen must be stored in liquid nitrogen at -196°C and handled with care to avoid temperature fluctuations. The thawing process must follow strict protocols, including water bath temperatures and exposure times. Any deviation can lead to sperm membrane damage and reduced motility. Additionally, AI technicians must be trained to minimize stress on animals during the procedure and ensure hygienic conditions to avoid post-insemination infections.

Economically, AI enables the dissemination of elite genetics across distant regions without the need for live animal transport, thereby reducing costs and biosecurity risks. Genetic progress is also accelerated by concentrating reproductive effort on females with high potential and using semen from sires with proven performance. In dairy goat systems, the benefits are particularly significant. Despite these advantages, challenges remain. In sheep, the anatomical structure of the cervix still limits the use of non-invasive AI techniques. Research into pharmacological softening of the cervix or mechanical innovations may help overcome this barrier in the future. Additionally, the widespread implementation of AI in smallholder systems requires capacity building, government or cooperative support, and the availability of reliable synchronization products and semen storage infrastructure.

To fully harness the benefits of AI in goats and sheep, it is essential to integrate scientific knowledge with practical field strategies. Selection of suitable animals, strict protocol adherence, and monitoring of ovulation markers such as cervical mucus and behavioral estrus are key to maximizing outcomes. Future research should focus on refining synchronization protocols, improving semen extenders for tropical conditions, and developing cost-effective, user-friendly AI kits for field use.

In conclusion, artificial insemination is a transformative tool for improving reproductive performance and genetic quality in small ruminant production. Its success depends on a combination of technical precision, physiological understanding, and adaptive management strategies. When implemented with attention to critical details, such as semen quality, timing, technique, and female selection, AI can deliver high pregnancy rates, better herd genetics, and significant productivity gains. As more producers adopt FxTAI and invest in technician training, the potential for AI to revolutionize goat and sheep breeding systems becomes increasingly achievable.

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