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Control of Ovarian Function in Dairy Cattle: The Role of Machine Learning in Reproductive Management

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Abstract: *Control of ovarian function in dairy cattle is a central component of reproductive management, directly influencing fertility, calving interval, and overall herd profitability. Conventional hormonal protocols have significantly improved synchronization of estrus and ovulation; however, reproductive performance remains highly variable due to individual differences in metabolic status, physiological condition, and environmental influences. Machine learning (ML) has emerged as a promising approach for integrating large and heterogeneous datasets to support advanced reproductive decision-making. By combining activity monitoring, milk production, body condition, progesterone profiles, rumination behavior, and farm management records, ML models can enhance estrus detection, improve ovulation timing estimation, and predict pregnancy outcomes. These tools also enable early identification of cows at risk of postpartum anovulation or luteal dysfunction, facilitating timely hormonal interventions. Despite its potential, practical implementation remains constrained by data quality, model interpretability, and herd-to-herd variability.*

• Introduction

Reproductive efficiency is one of the most economically significant determinants of profitability in dairy farming. Ovarian function plays a central role in bovine reproductive physiology, with the resumption of cyclic activity after parturition being essential for the restoration of fertility. In high-yielding dairy cows, the transition period is characterized by negative energy balance, immunosuppression, and metabolic stress, all of which can delay the first postpartum ovulation and impair follicular development. Machine learning (ML) offers a powerful framework for extracting practical information from complex, multidimensional datasets — capable of identifying non-linear interactions among variables, handling missing data, and adapting to herd-specific patterns.

• Objectives and Approach

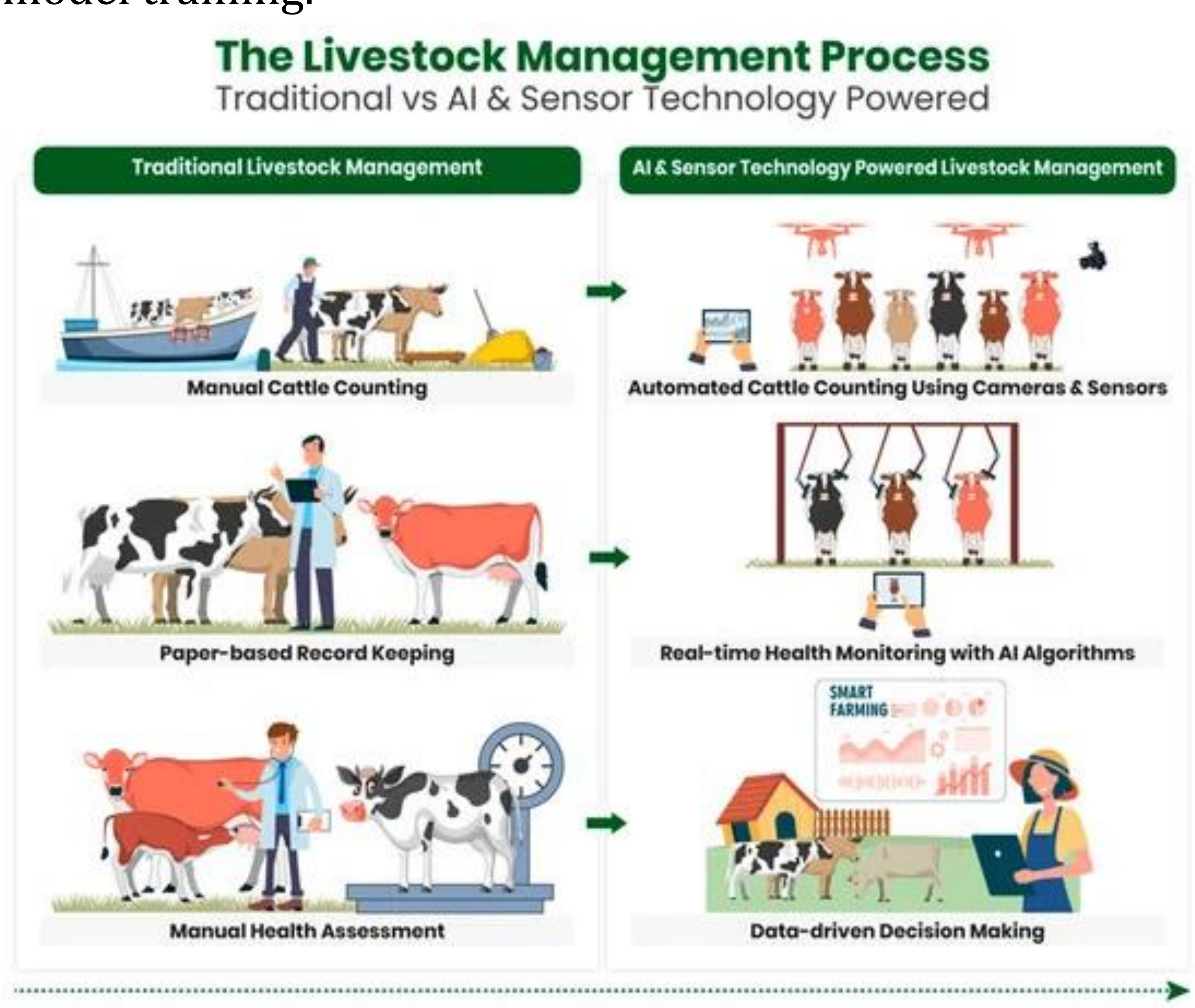
This review evaluates the role of ML in controlling ovarian function in dairy cattle. Evidence was synthesized from published studies addressing estrus and ovulation detection, conception outcome prediction, progesterone profile monitoring, and early identification of postpartum reproductive disorders, integrating findings from wearable sensors, inline milk analyzers, and farm management systems.

• Results and discussions

ML models consistently outperform threshold-based commercial systems for estrus detection, particularly for silent estrus. Deep learning approaches using video analysis achieved mounting detection accuracy above 99%. For conception prediction, random forest algorithms captured complex interactions among parity, health status, and energy balance more effectively than conventional methods. Inline milk progesterone sensors combined with ML enable near real-time detection of luteolysis, while milk mid-infrared spectra allow simultaneous assessment of metabolic and reproductive status. Early postpartum anovulation and ovarian cysts can also be identified using ML — without repeated veterinary examinations.

• Conclusions

ML can genuinely improve how ovarian function is monitored and managed in dairy cows, particularly when integrating multiple data sources — behavior, milk parameters, and farm records. Models combining multiple data streams consistently outperform single-indicator approaches across all reproductive applications. The evidence supports a clear shift from standardized herd-level hormonal protocols toward individualized, data-driven reproductive decisions. Key barriers remain: incomplete farm data, limited model interpretability, herd-to-herd variability, and poor integration with existing farm software. Future directions include combining genomic data with real-time sensors and developing federated learning frameworks for multi-farm model training.



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