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Review of artificial intelligence in dairy farming: A comprehensive perspective with emphasis on parasitology

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Abstract
Artificial Intelligence (AI) is increasingly redefining modern dairy farming by enabling precision livestock management, early disease detection, and data-driven decision-making. While AI applications in dairy production and general animal health monitoring have expanded rapidly, their targeted use in veterinary parasitology remains comparatively underexplored. Parasitic diseases continue to impose substantial economic losses, compromise animal welfare, and contribute to antimicrobial and anthelmintic resistance in dairy systems. This review critically examines current and emerging applications of AI in dairy farming, with particular emphasis on parasitological diagnostics, surveillance, and control strategies. The integration of machine learning, deep learning, computer vision, and Internet of Things (IoT) technologies is discussed alongside existing challenges and future research directions. The review highlights AI's potential to transform parasitic disease management from reactive treatment to predictive and precision-based control.

Keywords: Artificial intelligence, dairy farming, parasitology, precision livestock farming, machine learning

Introduction
The global dairy sector is undergoing rapid technological transformation driven by the need for sustainable production, improved animal welfare, and reduced economic losses from disease (Antognoli *et al*., 2025; Maheshwari *et al*., 2025) [2, 5]. Artificial Intelligence (AI), encompassing Machine Learning (ML), Deep Learning (DL), and computer vision, has emerged as a cornerstone of precision livestock farming. These technologies allow continuous monitoring, real-time analysis, and automated decision support based on large and complex datasets (Menezes, 2025) [6].

Parasitic diseases caused by helminths, protozoa, and arthropod vectors remain among the most persistent constraints in dairy farming, particularly in tropical and subtropical regions (Chamuah *et al*., 2025) [3]. Conventional parasitological diagnostics rely heavily on microscopy and expert interpretation, which are time-consuming, labour-intensive, and often unavailable in resource-limited settings. AI-based systems offer a promising alternative by enabling rapid, scalable, and objective detection of parasitic infections, thereby supporting timely interventions and sustainable parasite control (Chamuah *et al*., 2025; AlZubi, 2024) [3, 1].

AI technologies relevant to dairy farming
Machine learning and deep learning
Machine learning algorithms identify patterns and relationships within large datasets derived from animal health records, production parameters, and environmental variables (Menezes, 2025) [6]. Deep learning, particularly neural networks, enhances predictive accuracy by automatically extracting high-level features from raw data. In dairy farming, these approaches support early disease prediction, risk stratification, and automated health alerts, forming the backbone of intelligent decision-support systems (Chamuah *et al*., 2025) [3].

Computer Vision

Computer vision enables automated interpretation of visual data obtained from cameras and imaging devices. In parasitology, Convolutional Neural Networks (CNNs) have demonstrated high accuracy in identifying parasite eggs, oocysts, and larvae from fecal microscopy images (Chamuah *et al*., 2025; Antognoli *et al*., 2025) [3, 2]. This approach minimizes observer bias and reduces dependence on skilled parasitologists, facilitating large-scale screening in dairy herds.

Internet of Things (IoT)

Internet of Things (IoT) systems integrates wearable sensors, smart collars, and environmental monitoring devices to collect continuous, real-time data on animal behavior, physiological parameters, and housing conditions. When combined with AI algorithms, IoT-derived data can provide indirect indicators of parasitic burden, such as altered feeding patterns, reduced activity, or changes in milk yield and quality (Maheshwari *et al*., 2025; Menezes, 2025) [5, 6]. This integration allows for non-invasive, automated surveillance of herd health, complementing direct parasitological diagnostics.

Current applications of AI in dairy health management

Behaviour and health monitoring

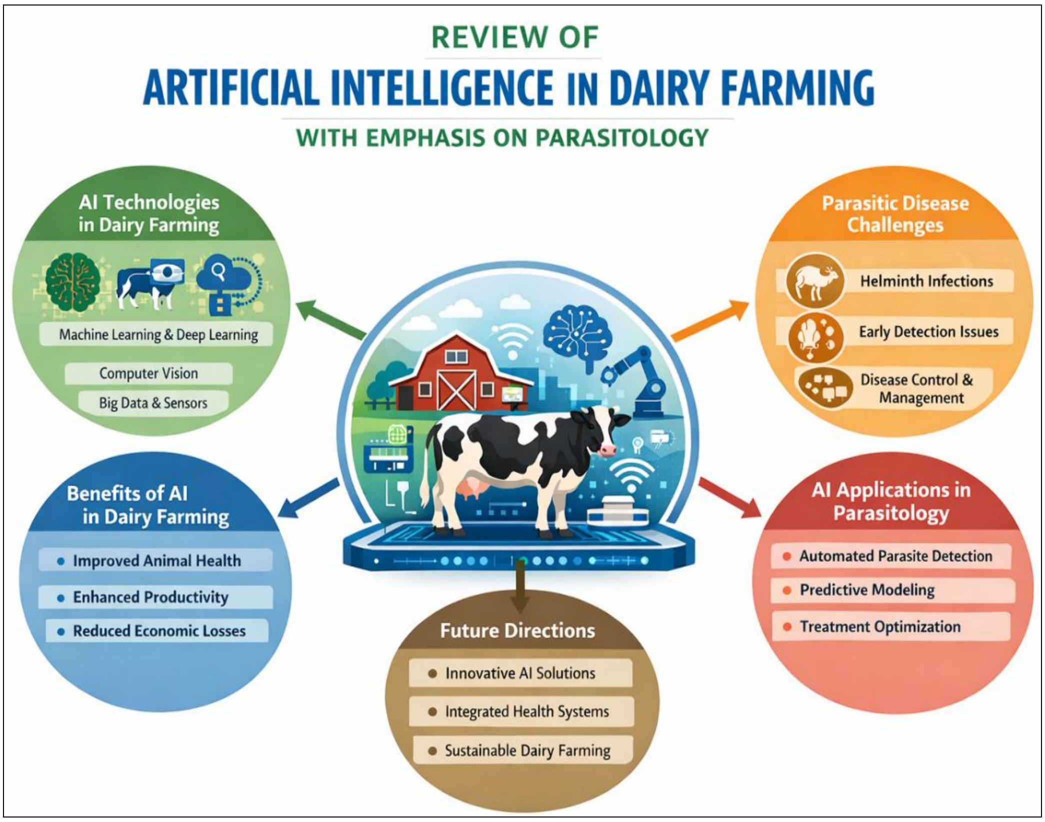
AI-driven behavioural analysis systems enable continuous monitoring of feeding, rumination, locomotion, and social interactions in dairy cattle (Menezes, 2025) [6]. Deviations from established baseline patterns can signal underlying health issues, including subclinical parasitic infections, often before overt clinical signs appear. Early detection is critical for preventing production losses, reducing disease transmission, and supporting timely interventions that improve animal welfare and herd productivity (Maheshwari *et al*., 2025; Chamuah *et al*., 2025) [5, 3].

Predictive disease surveillance

Predictive analytics leverage historical farm records alongside climatic and environmental data to forecast disease risk. Since parasite prevalence and vector abundance are strongly influenced by temperature, humidity, and rainfall, AI-based models can anticipate seasonal parasite outbreaks and guide preventive interventions at both herd and regional levels (Antognoli *et al*., 2025; Menezes, 2025) [2, 6]. These predictive capabilities enable proactive management strategies, minimizing the impact of parasitic diseases on dairy production.

Milk quality and production analytics

Alterations in milk yield, composition, and somatic cell counts can serve as indirect indicators of parasitic stress (Chamuah *et al*., 2025) [3]. AI models that integrate production data with health records can identify associations between parasitism and productivity, supporting targeted diagnostic testing and evidence-based treatment decisions. Such analytics enhance the efficiency of herd management and contribute to sustainable dairy production by linking animal health with economic outcomes (Maheshwari *et al*., 2025) [5].



AI in parasitology: Diagnosis and classification

AI-assisted parasitological diagnostics primarily focus on automated fecal egg detection and classification. CNN-based models have shown promising results in identifying helminth eggs in bovine fecal samples with accuracy comparable to expert microscopists (Chamuah *et al*., 2025) [3]. Similar successes in human medical parasitology demonstrate the broader applicability of AI-based image analysis for parasite identification.

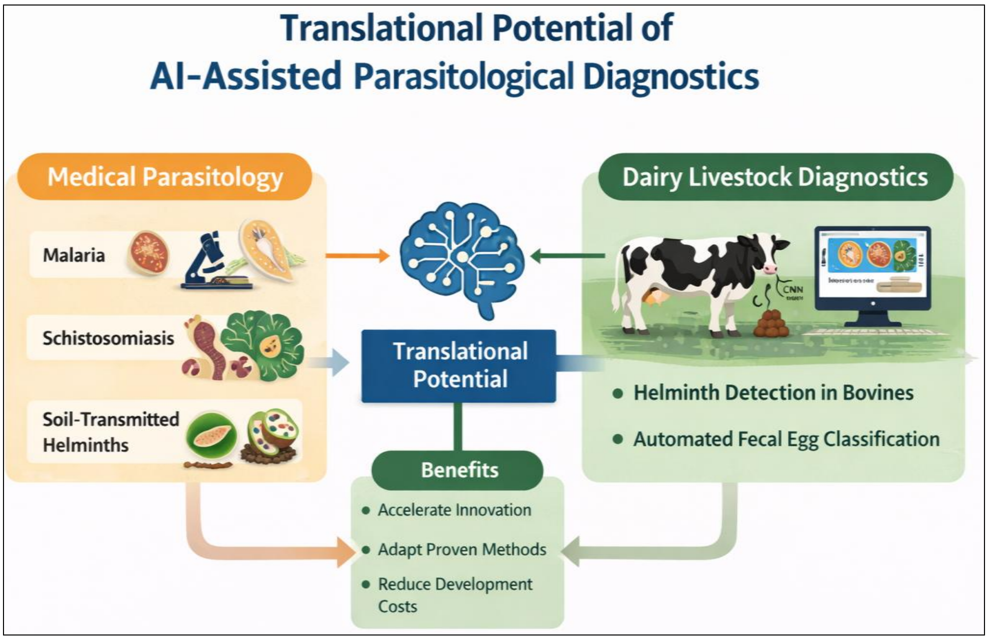
- A recent study used convolutional neural networks for diagnosing helminth infections in bovines using image data, providing rapid and accurate classification (Chamuah *et al*., 2025) [3].

Beyond livestock, AI has been reviewed extensively in human medical parasitology, demonstrating the ability of neural networks to classify parasite species in microscopy images with high accuracy and speed (Eissa *et al*., 2023) [4].

Translational potential from medical parasitology

Advances in AI-enabled diagnostics for human parasitic diseases provide a valuable framework for veterinary applications. Techniques developed for malaria, schistosomiasis, and soil transmitted helminths can be adapted to dairy parasitology, accelerating innovation and reducing development costs.

These advances illustrate the potential to translate AI techniques from medical parasitology into dairy livestock diagnostics (Eissa *et al*., 2023) [4].



Key advantages

- **Early detection of parasite burden**

AI enables detection of subtle health changes linked to parasitic infections, including behavioural shifts and weight changes, improving prognosis through earlier intervention.

- **High-throughput diagnostics**

Automated microscopic image analysis reduces dependence on expert parasitologists and accelerates diagnosis.

- **Precision management**

AI empowers precision parasitic control programs - targeting treatments based on individual or herd risk, thereby reducing drug use and resistance.

Challenges in implementation

Despite its promise, several challenges impede AI adoption in parasitology:

- **Data quality & availability:** Effective AI models require large, labelled datasets of parasitic images and health indicators, which are limited in veterinary contexts.
- **Integration complexity:** Combining molecular, behavioural, and sensor data into cohesive AI models is technically demanding.
- **Infrastructure needs:** Rural farms may lack the computational and network resources for advanced AI deployment.
- **Model interpretability:** Black-box nature of deep learning complicates trust and adoption by veterinarians and farmers.

Future prospects

- **Enhanced dataset development**

Creation of open repositories of parasite images from cattle, goats, and buffalo will be critical.

- **Explainable AI**

Developing transparent AI frameworks will assist clinical decision support and farmer adoption.

- **Integration with Molecular Diagnostics**

AI could integrate PCR, qPCR, and sequencing data with phenotypic health data to improve accuracy in *Theileria*, *Anaplasma*, *Babesia* and other parasitic diagnoses.

- **Mobile Apps for Field Deployment**

Smartphone-based imaging tools with integrated AI could democratize parasitology diagnosis in low-resource settings.

Future research should prioritize the development of open-access parasitological image databases, explainable AI models, and integration of molecular diagnostics such as PCR and sequencing data. Smartphone-based AI applications hold particular promise for field-level diagnosis and extension services in developing regions. Collaborative efforts between veterinarians, data scientists, and farmers will be essential for translating AI innovations into practical dairy parasite control strategies.

Conclusion

Artificial intelligence has already demonstrated significant value in dairy farming through enhanced monitoring, prediction, and management of animal health. Its application in parasitology, though still evolving, offers transformative potential for early diagnosis, precision treatment, and sustainable parasite control. Continued interdisciplinary research, data sharing, and technology adaptation will be crucial to fully harness AI's role in improving dairy herd health and productivity.

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