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Advancing Livestock Reproductive Performance through Artificial Intelligence: A Systematic Literature Review

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ABSTRACT

Artificial intelligence (AI) is revolutionising livestock farming by improving reproductive efficiency through predictive modelling, automated monitoring, and data-driven decision-making. This systematic literature review synthesises findings from over 20 peer-reviewed studies to assess the contributions of AI technologies—such as machine learning, deep learning, computer vision, robotics, and precision learning—to reproductive management in livestock. Key applications identified include oestrus detection, fertility monitoring, embryonic sex determination, heat stress tracking, and automated disease detection and treatment. These AI-driven solutions enhance productivity, reduce labour demands, and promote animal welfare. Despite these benefits, existing research is largely centred on dairy cattle and pigs, with limited attention given to other economically important species such as sheep, goats, poultry, and rabbits. The review also highlights persistent challenges, including high implementation costs, insufficient data quality, lack of system integration, and limited real-world deployment. These issues underscore the urgent need for more inclusive, scalable, and practical AI solutions across a broader range of livestock species and farming systems. This study aims to: present an overview and historical background of artificial intelligence; identify AI technologies used in animal agriculture; examine their contributions to reproductive management in livestock; and synthesise recommendations for enhancing reproductive efficiency through AI. In conclusion, while AI shows strong potential for transforming reproductive practices in livestock farming, there is need for future research to address current gaps to enable broader adoption. A more diverse and integrative approach will be key to meeting the growing global demand for animal products while safeguarding animal welfare, environmental sustainability, and public health.

Keywords: *Artificial intelligence, Fertility, Machine learning, Oestrus detection, Precision learning farming, Reproductive efficiency.*

1 INTRODUCTION

Animal agriculture is currently experiencing a paradigm shift driven by the integration of artificial intelligence (AI). Increasingly, AI technologies are being deployed across livestock and poultry farms to facilitate data collection and analysis, support decision-making, and enhance overall farm operations. This shift is occurring against the backdrop of significant global challenges, including climate change, food insecurity, threats to peace, evolving production systems, and growing demands for quality assurance, all of which underscore the urgent need for more innovative and efficient agricultural practices (Rojas-Downing et al., 2017). The growing complexity of farm operations, coupled with expanding herd sizes and diminishing interest in agriculture among younger generations, has rendered traditional labour methods insufficient (Aydan, 2019). In response, farmers are increasingly adopting advanced technologies to sustainably meet the rising global demand for animal products (Bouhali et al., 2022; Congdon et al., 2022).

AI-based technologies have found applications across multiple agricultural domains, including disease control, sustainable resource management, animal welfare, and planning (Viego et al., 2022). The integration of robotics, drones, sensors, and intelligent monitoring systems is revolutionising animal agriculture by enabling precise and real-time evaluation of animal behaviour, health status, reproductive metrics, and productivity indicators. Through early disease detection, optimised feeding strategies, and efficient resource use, these systems contribute to improved animal welfare, operational efficiency, and cost-effectiveness (Henna et al., 2024). AI technologies such as machine learning, deep learning, precision learning, robotics, and computer vision have shown great promise in enhancing the reproductive efficiency of farm animals. Their applications span oestrus detection, fertility rate monitoring, embryonic sex determination (e.g., in chicks), mastitis detection, automated milking, identification of live embryos in eggs, heat stress monitoring, and robotic vaccine or medication delivery systems (Awoke et al., 2024). Despite these advancements, existing research remains disproportionately focused on a narrow range of species,

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particularly dairy cattle and pigs. There is a notable lack of comprehensive studies examining the application of AI in reproductive management for other economically important species such as sheep, goats, rabbits, and poultry. Additionally, persistent limitations across studies such as high implementation costs, inconsistent data quality, lack of system integration, and minimal real-world deployment continue to hinder the full potential of AI in livestock reproduction.

These research gaps highlight the need for broader, more inclusive investigations into AI applications across diverse livestock species. There is a growing need for solutions that are not only technologically sound but also scalable, reproducible, and practically implementable in real-world farming environments. As such, this review aims to synthesise and analyse existing literature on the contributions of AI technology to the improvement of reproductive efficiency in livestock. The review focuses on the effectiveness of AI tools in improving the reproductivity of farm animals, addressing various animal welfare concerns, as well as their roles in ensuring that environmental sustainability and public health are not compromised, as mankind strives to meet the ever-increasing demands for animal products as a result of the exponential increase in human population. Thus, this study aims to: present an overview and historical background of artificial intelligence; identify AI technologies used in animal agriculture; examine their contributions to reproductive management in livestock; and synthesise recommendations from previous studies for enhancing reproductive efficiency through AI.

2 LITERATURE REVIEW/RELATED WORK

A study titled *"Invited Review: Examples and Opportunities for Artificial Intelligence (AI) in Dairy Farms"* by De Vries et al. (2023) focuses specifically on the applications of machine learning (ML) and deep learning in dairy farming. The authors detail various problem types where AI outperforms classical statistical approaches and identify areas where these advanced tools fall short. Drawing from existing literature, the study presents practical examples illustrating the scope of AI use in dairy farms—spanning disease detection, reproduction prediction, milk yield forecasting, and feed intake estimation while also discussing limitations such as poor data quality, missing data, and lack of system integration.

One key contribution of this review is its synthesis of findings from five recent systematic reviews, providing a consolidated understanding of AI applications in areas like animal health, reproduction, and productivity. The methodology was based on an unstructured literature review, supplemented by the authors' hands-on experience with AI systems in dairy operations. Notably, the study critiques the limited interpretability of AI models compared to classical methods like logistic regression and highlights a concerning gap many studies fail to benchmark AI performance against traditional models. In terms of global contributions, China leads in AI research output, followed by growing activity in the U.S. However, most studies are published in engineering or data science journals rather than core dairy science literature, limiting accessibility for animal scientists. Furthermore, practical deployment remains rare due to challenges with data accessibility, software usability, and real-world validation. While the study focuses on dairy cattle, it notes a gap in AI applications for other livestock species such as sheep, goats, poultry, and micro-livestock species such as rabbit.

Complementing this, *Dilaver and Dilaver (2024)* in their study *"Robotic Systems and Artificial Intelligence Applications in Livestock Farming"* explore the integration of machine learning, deep learning, and fuzzy logic within robotic systems to improve livestock productivity, welfare, and operational efficiency. Adopting a narrative literature review approach, they examined a variety of AI implementations such as image processing, IoT integration, autonomous systems, and sensor-based monitoring. The authors presented multiple case studies, evaluating models like ResNet18, SVM, Random Forest, and Gradient Boosted Trees, all of which achieved high accuracy in tasks like disease prediction and animal classification.

They also highlighted how robotic systems automate crucial tasks such as milking, feeding, facial recognition, oestrus detection, and behavioural monitoring, effectively reducing human error and labour costs. Moreover, fuzzy logic-based decision systems were noted for their role in feed optimisation and health monitoring. However, the study acknowledges significant limitations, including high investment costs, variable model performance (especially in fuzzy systems), lack of data standardisation, and societal hesitance toward full automation. Importantly, the paper did not delve into the applications of other key AI technologies such as computer vision and precision learning.

Expanding the scope further, *Melak et al. (2024)* in their paper *"The Influence of Artificial Intelligence Technology on the Management of Livestock Farms"* provide a broad overview of AI's impact on livestock management. Through a literature review of 128 publications, the authors assessed how AI, along with emerging technologies like augmented reality (AR), virtual reality (VR), drones, IoT, and blockchain, are transforming livestock farming. The study underscores AI's role in automating tasks such as milking, feeding, and weighing; tracking animal behaviour; detecting diseases and heat stress; and enhancing traceability through blockchain.

While AI is credited with improving productivity, sustainability, and welfare, several limitations were highlighted. These include high infrastructure costs, lack of

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technical expertise in rural areas, concerns about job displacement, cybersecurity risks, and ethical dilemmas around surveillance. Another critical shortcoming of the study is its limited focus on reproductive applications and its omission of small ruminants (e.g., sheep, goats) and micro-livestock (e.g., rabbits, bees), which are essential for diversified livestock production systems.

The concept of "innovative livestock" is explored by *Mijwil et al. (2023)* in their study *"Innovative Livestock: A Survey of Artificial Intelligence Techniques in Livestock Farming Management."* The authors review the application of machine learning (e.g., CNN, YOLO), computer vision, and natural language processing in monitoring animal health, productivity, and behaviour. Case studies include using AI for facial recognition to detect emotional states, predicting milk yield and disease via artificial neural networks (ANNs), and integrating wearable devices and drones for real-time monitoring.

The study demonstrates how AI contributes to early disease detection, improved feeding regimens, waste reduction, and welfare enhancement. Yet, limitations such as high cost, limited access for smallholders, and ethical concerns regarding labour replacement were discussed. Moreover, while the study broadly covers health, behaviour, and productivity, it does not specifically address reproductive efficiency, leaving a critical area underexplored.

Another notable study by *Neethirajan (2022)*, titled *"Affective State Recognition in Livestock—Artificial Intelligence Approaches,"* investigates how biometric sensors and AI can quantify emotional states in cows and pigs. The study introduces digital twins and multimodal sensor fusion (e.g., facial recognition, thermal imaging, vocalisation analysis) for non-invasive welfare monitoring. Using supervised learning models like CNNs and SVMs, as well as unsupervised learning and social network analysis, the study demonstrates AI's ability to accurately detect emotional cues and link them to physiological indicators such as heart rate variability and cortisol levels.

Despite promising results in real-time welfare tracking, the study suffers from limitations including small sample sizes, incomplete datasets, sensor fragility, and lack of species diversity—it primarily focuses on pigs and cows, leaving out other economically significant species. Moreover, reproductive monitoring was not within the scope of this research.

Finally, *Wang et al. (2022)* in their review *"The Research Progress of Vision-Based Artificial Intelligence in Smart Pig Farming"* focus on computer vision and sound analysis for pig detection, behaviour monitoring, and disease diagnosis. They propose a Precision Pig Farming (PPF) framework with integrated IoT equipment, data modules, AI decision systems, and visualisation interfaces. AI tools like YOLOv4 and Faster RCNN achieved over 90% accuracy in detecting behaviours like aggression and oestrus, while sound analysis was used effectively for diagnosing respiratory illnesses.

While the study provides a robust technical foundation for vision-based AI in pig farming, it is limited by the availability of quality datasets and hardware durability in harsh farm environments. Real-time processing challenges and high training costs further restrict broader adoption. Moreover, the study focuses exclusively on pigs and neglects reproductive management, an area critical for farm productivity.

In summary, these studies collectively highlight the diverse and growing role of artificial intelligence in livestock farming ranging from health and behavioural monitoring to automation and welfare enhancement. While most research focuses on dairy cattle and pigs, there is a significant gap in the application of AI to reproductive efficiency across a broader range of livestock species. Moreover, common limitations persist across studies, including high costs, data quality concerns, lack of integration, and limited real-world implementation. These gaps underscore the need for future research to explore more inclusive, scalable, and reproducible AI solutions that address species diversity and prioritise reproductive performance alongside animal welfare and productivity.

3 METHODOLOGY

This review systematically gathered and analysed over 30 scholarly articles sourced from a combination of published literature and unpublished materials relevant to artificial intelligence (AI) applications in livestock farming. The selection process involved a strategic deployment of targeted keywords related to AI and livestock reproduction, with Google Scholar serving as the secondary search engine. The search aimed to capture a broad spectrum of studies addressing the role and impact of AI technologies in enhancing reproductive performance across farm animal species. Relevant identified articles were subjected to a rigorous, unbiased summary process, ensuring an equitable appraisal of their contributions. Inclusion criteria prioritized research that explicitly focused on the utilization of AI to advance reproductive management and efficiency in livestock systems. Studies spanning theoretical frameworks, empirical investigations, and technological reviews were incorporated to provide a comprehensive understanding of AI's multifaceted roles in this domain. The review process emphasized the collation of evidence pertaining to various AI-driven approaches—including machine learning, sensor technology, computer vision, and robotics—as they relate to key reproductive parameters such as oestrus detection, fertility monitoring, and breeding optimization. Data from these sources were synthesized to identify prevailing trends, challenges, and opportunities for AI integration in reproductive technologies within animal agriculture.

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By consolidating insights from a diverse range of credible sources, this study aims to deliver an objective and thorough evaluation of current advancements, thereby informing future research and practical applications in precision livestock reproduction. This section outlines the systematic process used in identifying, selecting, reviewing, and synthesizing literature to assess the contributions of artificial intelligence (AI) to reproductive efficiency in animal agriculture.

3.1 RESEARCH DESIGN

A qualitative, systematic literature review (SLR) approach was adopted to critically evaluate existing academic and grey literature related to AI applications in livestock reproductive management. The review follows a narrative synthesis method to summarise diverse types of AI tools, their functionality, and impact on animal reproduction.

3.2 SEARCH STRATEGY

The search strategy involved querying multiple reputable databases including Google Scholar, ScienceDirect, Scopus, PubMed, and various institutional repositories. Keywords such as "Artificial Intelligence in Animal Agriculture," "AI in Livestock Reproduction," "Machine Learning in Farm Animal Breeding," "Robotics in Dairy Farming," "Precision Livestock Farming," and "Animal Reproduction and Artificial Intelligence" were employed. Boolean operators like AND and OR were applied to refine and optimize search results.

3.3 INCLUSION CRITERIA

Articles were included in the review based on specific criteria: the focus had to be on the application of AI in animal agriculture, particularly livestock reproduction. Only peer-reviewed articles, conference papers, or grey literature published between 2000 and 2024 were considered. The studies had to discuss technologies such as machine learning, deep learning, computer vision, robotics, or sensor-based systems in livestock. Additionally, only literature published in English that provided empirical data, theoretical discussion, or comprehensive reviews was selected.

3.4 EXCLUSION CRITERIA

Exclusion criteria were applied to filter out articles unrelated to animal reproduction or livestock farming, duplicated sources across databases, studies focusing solely on plant agriculture or AI applications in companion or pet animals, and publications without full-text access or lacking rigorous peer review.

3.5 DATA EXTRACTION SYNTHESIS

Data extraction and synthesis were conducted by manually screening over 30 articles. A structured matrix captured key information such as author(s), publication year, AI technology employed, species studied, purpose of AI application, and key findings. Thematic synthesis organized the data into categories including AI technologies in animal agriculture, specific AI applications in reproduction (such as oestrus detection, sex determination, and fertility monitoring), and the advantages and limitations of AI in this context. Narrative summaries were then developed based on the evidence gathered from the selected studies.

3.6 QUALITY ASSESSMENT CRITERIA

Quality assessment was performed by evaluating the relevance, credibility, and recency of each source using adapted criteria from the Critical Appraisal Skills Programme (CASP). Particular attention was given to the validity of methodologies used in primary studies, the applicability of findings to the livestock sector, and the technological innovation and impact reported.

3.7 ETHICAL CONSIDERATIONS

As this review only involved secondary data collection from published and publicly accessible materials, no ethical approval was required

4 RESULTS AND DISCUSSION

In this section, an overview and historical background of artificial intelligence; a summary of some AI technologies used in animal agriculture; an examination of their contributions to reproductive management in livestock; and synthesis of recommendations from previous studies for enhancing reproductive efficiency through AI was conducted.

4.1 OVERVIEW AND HISTORICAL BACKGROUND OF ARTIFICIAL INTELLIGENCE

Despite decades of study, artificial intelligence (AI) continues to be one of the most elusive subdisciplines in computer science (Wang *et al.*, 2022). Artificial intelligence is a broad field of computer science that involves the study of creating intelligent machines capable of carrying out tasks that would typically require human intelligence (Nilsson, 2009). Machines can now mimic and even surpass human intelligence, thanks to AI. AI is simply machine intelligence, rather than the intelligence displayed by humans or other animals (Holden, 2012). AI is capable of problem-solving, displaying rational behaviour, and acting like humans. It possesses the extraordinary ability to reason, effectively solve complex problems and acquire new knowledge through learning activities. Instead of pitting man against the machine, AI fosters a collaborative relationship between man and machine (Holden, 2012). AI performs actions that typically require human intelligence, such as speech recognition, visual perception, decision-making, and

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language translation (Zuraw & Aeffner, 2022). Artificial intelligence is being used to transform the management and monitoring of farm animals, including poultry, dairy cows, and pigs (Wang *et al.*, 2022). Philosophy serves as the basis for artificial intelligence, which was later modelled mathematically. Robots have been discussed throughout history by notable authors, such as Aristotle (384–322 BC), in his book "Politics", and by intellectuals like Al-Jazari and Leonardo da Vinci in their writings. Artificial intelligence is credited to Alan Mathison Turing, who posed the question, "Can machines think?" in 1943 while the world was at war. Since being a theory or problem, artificial intelligence has developed to produce different outcomes using mathematical models. It comprises subfields like machine learning, deep learning, natural language processing, pattern recognition, genetic algorithms, expert systems, speech recognition, robotics, computer vision, and optimisation, each focusing on generating solutions for different issues (Dilaver & Dilaver, 2024). The development of syllogism by Aristotle and its use of deductive reasoning represents an important turning point in humanity's quest to understand its intelligence (Awoke *et al.*, 2024). Although it has long and deep roots, the history of AI as we currently know it is less than a century old. "Computing Machinery and Intelligence", the article by the English mathematician Alan Turing, published in the year 1950, was instrumental in the invention of artificial intelligence (Nilsson, 2009; Tedeschi, 2022). The term "artificial intelligence" was first coined by John McCarthy in 1956 at his first academic conference on the subject (Smith, 2006). However, the investigation into whether machines are capable of thought began much earlier. By the mid-1960s, significant funding for artificial intelligence research was being provided by the United States Department of Defence, and AI labs had been established worldwide (McCarthy, 2007). The Lawrence Radiation Laboratory in Livermore also launched its artificial intelligence group at the same time under the direction of Sidney Fernbach (Shanahan *et al.*, 2020).

4.2 Artificial Intelligence Technologies in Animal Agriculture

Humans have always relied on agriculture and livestock production to meet their basic food needs, using harvested crops and animal products to sustain life across generations. In recent years, the livestock farming industry has increasingly incorporated artificial intelligence (AI) to reduce errors associated with human intervention and to improve operational efficiency. When applied under optimal conditions, AI has the potential to perform tasks with both effectiveness and economic value.

AI is now integrated across various facets of livestock farming, including disease detection, daily animal care, product collection, welfare monitoring, and breeding management. Core AI technologies that support these functions include machine learning, deep learning, computer vision, robotics, and natural language processing (Mijwil et al., 2023). Another rapidly growing area of application is Precision Livestock Farming (PLF), which utilises digital tools to optimise the management and care of animals.

One of the foundational AI techniques used in livestock farming is machine learning. This involves a set of methods that enable computers to perform cognitive tasks without being explicitly programmed. By training on datasets and learning through examples, machine learning algorithms can build models that predict outcomes or identify patterns—mimicking human decision-making processes (Mijwil et al., 2023). These techniques have proved useful in understanding animal health trends and optimising feed distribution.

Building upon machine learning, deep learning further enhances decision-making by using neural networks modelled after the human brain. These networks contain layers of interconnected nodes ("neurons") that allow the system to interpret and process complex data. As noted by Goodfellow et al. (2016), deep learning enables AI systems to carry out intricate tasks such as recognising animal behaviour, assessing health conditions, and even forecasting reproductive cycles—all critical to high-efficiency livestock management.

A major advancement in AI application is Precision Livestock Farming (PLF). Berckmans (2017) defines PLF as the real-time, automated, and continuous monitoring of individual animals to manage their health, welfare, productivity, and environmental impact. PLF is a revolutionary approach to animal husbandry that employs smart technologies to enhance environmental sustainability, animal comfort, and economic performance. In modern poultry farms, for instance, efforts are being made to maintain or increase bird populations while reducing labour requirements. Technologies used in PLF help monitor animal behaviours, feeding patterns, housing conditions, and overall wellbeing (Patel and Sana, 2022). Because PLF reduces the need for constant human presence, it enables remote and real-time data collection with minimal animal disruption.

Information gathered from various sensors and monitoring tools can be compiled to form automated decision-making systems that regulate animal health and performance. A critical factor in the success of PLF is the compatibility of its tools with existing farm infrastructure. Properly integrated, these systems help reduce long-term losses, enable quicker management decisions, and detect animal welfare issues early—ultimately supporting a more sustainable and productive livestock industry.

Robotic systems have also made significant inroads into livestock management. The combination of AI, image processing, and automation has decreased human error, improved production speed, and enhanced the quality of

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outputs. In cattle farming, robotic technologies are used to reduce labour costs, minimise environmental impacts, and improve both animal health and farm efficiency (Dilaver and Dilaver, 2024). These innovations also promote the production of healthier animals and higher-quality products.

One of the most impactful applications of robotics is in automated milking. Robotic milking machines detect when cows are present and automatically adjust milking parameters to ensure hygienic and efficient operation. This not only reduces the physical burden on farmers but also optimises milk yield. Robotic feeding systems are another vital innovation, dispensing precisely measured feed according to each animal's dietary needs, thereby reducing waste and improving feed efficiency. Furthermore, wearable technology and smart sensors can monitor vital signs and detect symptoms of illness such as mastitis or stress, allowing automated veterinary robots to provide timely treatments. Through these technologies, farmers can maintain high standards of animal welfare while achieving greater productivity and operational sustainability.

Another vital tool in the AI toolkit is computer vision, which enables machines to interpret visual information from digital images or video footage. As Baduge et al. (2022) explain, computer vision collects and processes this data to identify patterns, distinguish between objects, and generate insights. In agriculture and livestock production, this technology is being used to detect animal movement, identify physical anomalies, monitor feeding behaviour, and support automation in areas such as breeding and health diagnostics. By replacing or enhancing human visual observation, computer vision systems can increase accuracy and allow continuous, real-time monitoring of livestock conditions.

In summary, the integration of artificial intelligence into livestock farming is transforming the industry. With technologies like machine learning, deep learning, robotics, computer vision, and precision livestock farming, farmers are better equipped to ensure animal welfare, increase productivity, and make environmentally sustainable decisions. As these technologies continue to develop, their role in shaping the future of animal agriculture will become even more critical.

4.3 The Contributions of Artificial Intelligence to Some Aspects of Animal Reproduction

Artificial intelligence (AI) is increasingly being used in animal reproduction to improve accuracy, efficiency, and animal welfare. One of its most impactful contributions is in oestrus detection, a critical factor in dairy production, where identifying the right time for insemination directly affects productivity. Traditionally, inaccurate detection has led to missed opportunities and financial loss. With the introduction of AI-enabled technologies—such as motion sensor-equipped collars—farmers can now gather comprehensive data on cow behaviour and physiology throughout the day (Vries De et al., 2023). This information is analysed by AI systems to detect signs of heat stress, changes in feeding efficiency, and indicators of oestrus. When a cow enters the oestrus phase, it releases specific hormones that influence movement and behaviour. For instance, a cow in standing heat may become still for prolonged periods, allowing other cows to mount her (Yusuf et al., 2010). By comparing this behavioural data to historical patterns, AI systems can accurately predict ovulation, which typically occurs 24 to 32 hours after the onset of oestrus (Abeygunawardena and Dematawewa, 2004). Beyond oestrus detection, AI plays a key role in monitoring fertility and predicting breeding cycles. By using predictive analytics, AI systems can track the reproductive cycles of female animals and recommend the optimal time for insemination. These systems also take environmental factors into account, helping farmers synchronise breeding schedules for improved fertilisation outcomes (Morota et al., 2018). This approach helps optimise breeding programmes while reducing resource waste.

Another innovative application is in embryonic sex determination, which offers a more ethical alternative to the controversial practice of culling male chicks. AI-powered imaging technologies, such as magnetic resonance imaging (MRI), allow the sex of embryos to be identified within the first few days of incubation. These systems use trained AI models to assess and categorise the images, enabling farmers to make informed, ethical, and economically sound decisions early in the production process (Samad et al., 2022; Zuraw and Aeffner, 2022).

Similarly, determining the viability of live embryos in eggs is essential to avoid wasting hatchery resources and to improve productivity. By combining near-infrared hyperspectral imaging with machine learning, AI systems can identify fertile eggs and monitor embryo development. Machine learning algorithms are trained with datasets containing images of both fertile and unfertile eggs, enabling them to distinguish between the two and eliminate non-viable eggs at an early stage (Rotaru et al., 2021). Computer vision enhances this process by visually tracking embryonic growth and spotting anomalies that could signal developmental issues. When integrated with environmental sensors, these AI systems provide insights into how surrounding conditions impact embryo development, helping hatchery managers maintain optimal conditions (Viejo et al., 2022).

AI also contributes to monitoring heat stress through temperature analysis, another critical factor influencing animal welfare. High stocking densities and confined environments often expose farm animals to elevated temperatures, negatively affecting their health and productivity. AI-based livestock management systems equipped with thermal cameras and temperature sensors can continuously track animal body temperatures and behaviour

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(Ezanno et al., 2021). These systems detect dangerous temperature thresholds and behavioural signs of heat stress, sending real-time alerts to farmers when animals are at risk. Over time, AI can identify patterns and offer data-driven recommendations for environmental modifications, such as improved ventilation or hydration strategies (Wang et al., 2022).

Lastly, AI is transforming vaccination and medication administration through the implementation of robotic systems. Traditional manual administration of vaccines and reproductive drugs is labour-intensive and requires significant training and oversight. Robotic injection systems integrated with dairy automation platforms are designed to address this challenge (Courtin et al., 2008). These systems read ear tags to access individual cows' health records and vaccination history. If an animal is due for an injection, the robotic arm positions itself to deliver medication accurately to the cow's neck, ensuring consistency and reducing human error (Neethirajan, 2022). This approach not only improves compliance but also supports a sustainable, economically viable model for modern dairy farming.

In summary, artificial intelligence is revolutionising reproductive management in livestock farming. Through applications such as heat detection, breeding cycle prediction, embryonic sex determination, embryo viability assessment, temperature monitoring, and robotic medication delivery, AI enhances both animal welfare and operational efficiency. These technologies empower farmers to make better decisions, reduce waste, and promote sustainable livestock practices.

4.4 PREVIOUS STUDIES RECOMMENDATIONS

Patel & Sana, 2022; Rotaru et al., (2021) Future research should focus on developing open-access, annotated datasets that span various livestock species, breeds, and farming conditions. This would improve the reproducibility and cross-applicability of AI models, especially in underrepresented areas such as reproductive efficiency beyond pigs. Bouhali et al., 2022; Awoke et al., (2024) There is also a need to design robust, multimodal AI systems that integrate vision, sound, and environmental sensors. The application of advanced technologies such as 3D LiDAR and attention-based deep learning can help address challenges like data occlusion and noise interference in real farm environments. Samad et al., (2022) stressed that researchers are encouraged to optimise lightweight AI models like TinyYOLO for edge computing. This will facilitate real-time data processing directly on farms, particularly where internet connectivity is limited. Patel & Sana, 2022; Rotaru et al., (2021), on the other hand said to ensure widespread adoption, AI technologies should be designed with a farmer-centric approach. Interfaces must be intuitive for non-technical users, and systems should integrate seamlessly with existing farm management tools.

Rotaru et al., 2021; Samad et al., (2022) recommended that further studies should investigate the ethical and economic dimensions of AI adoption in agriculture. This includes evaluating the cost-benefit balance, consumer perceptions, data privacy, and how AI impacts labour and animal welfare, especially in low-resource settings, there is a pressing need for long-term studies that validate AI technologies across full reproductive and production cycles under diverse climatic and operational conditions. Such research will offer important details about their real-world effectiveness and scalability (Bouhali et al., 2022; Patel & Sana, 2022). Samad et al., 2022; Patel & Sana, (2022) mentioned that the development of affordable, scalable AI tools for smallholder farmers should be prioritised. Examples include smartphone-compatible sensors and modular technologies tailored for resource-constrained environments. Rotaru et al., 2021; Samad et al., (2022) Bridging the digital literacy gap is essential, and future work should include farmer training and technical support programs. These will empower users to properly interpret and act upon AI-generated insights. Rotaru et al., (2021) stressed that supportive policy frameworks are crucial to encourage AI adoption. Governments and institutions should provide incentives such as subsidies and grants and promote collaborations between agricultural stakeholders and technology providers. Finally, Samad et al., (2022), interdisciplinary collaboration among AI specialists, animal scientists, veterinarians, policymakers, and farmers are essential to ensure that AI systems are not only technically robust but also practically applicable and ethically sound in improving livestock reproductive efficiency.

5 CONCLUSION

This review underscores the transformative potential of artificial intelligence (AI) in revolutionising livestock farming, particularly in reproductive efficiency. While AI technologies such as machine learning, deep learning, computer vision, and precision farming tools have already demonstrated considerable impact in sectors like dairy and poultry farming, their application remains limited across other economically important livestock species. Moreover, key areas of reproductive management, including pregnancy detection, oestrus synchronisation, prediction of parturition through endocrine profiling, and cryopreservation of genetic resources, remain underexplored in the context of AI integration.

AI offers unparalleled precision in livestock monitoring, decision-making, and predictive analytics, helping to reduce human error and improve productivity (Isabelle & Westerlund, 2022; Zuraw & Aeffner, 2022). However, these advantages can only be realised if the end-users primarily farmers are equipped to interpret and act on AI-generated insights (Ezanno et al., 2021). Without proper training and intuitive user interfaces, even the most advanced

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technologies risk becoming impractical on the ground. Additionally, challenges such as high development and maintenance costs, data privacy concerns, technical barriers, and the risk of job displacement (Kumari & Dhawal, 2021; Congdon et al., 2022) must be acknowledged and addressed.

From a research perspective, future studies should prioritise the development of farmer-centric, low-cost, and scalable AI tools that are accessible to smallholder farmers. There is also a pressing need for long-term, real-world validations of AI applications under diverse climatic and operational conditions, as well as interdisciplinary collaborations that bridge the gap between technology developers, animal scientists, veterinarians and end-users. In conclusion, while AI has already made significant strides in livestock production, its full potential in enhancing reproductive efficiency is yet to be realised. Targeted research aimed at expanding species coverage, deepening functional capabilities, and improving user accessibility will be critical in harnessing AI's power to sustainably meet the growing global demand for animal products.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this work.

AUTHORS' CONTRIBUTIONS

Yakub Adenuga was involved in the literature search and review. Yakub Adenuga and Kayode Adenuga jointly contributed to the conceptualization and design of this review. Kayode Adenuga critically revised the manuscript for intellectual content and provided final approval for submission.

REFERENCES

Abeygunawardena, H., & Dematawewa, C. M. B. (2004). Pre-pubertal and postpartum anestrus in tropical Zebu cattle. *Animal Reproduction Science*, *82*, 373-387.

Aydan, A. (2019). Impact of artificial intelligence on agricultural, healthcare and logistics industries. *Annals of Spiru Haret University. Economic Series*, *19*(2), 167-175.

Baduge, S. K., Thilakarathna, S., Perera, J. S., Arashpour, M., Sharafi, P., Teodosio, B., & Mendis, P. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction*, *141*, 104440.

Berckmans, D. (2017). General introduction to precision livestock farming. *Animal Frontiers*, *7*(1), 6-11.

Bouhali, O., Bensmail, H., Sheharyar, A., David, F., & Johnson, J. P. (2022). A review of radiomics and artificial intelligence and their application in veterinary diagnostic imaging. *Veterinary Sciences*, *9*(11), 620.

Congdon, J. V., Hosseini, M., Gading, E. F., Masousi, M., Franke, M., & MacDonald, S. E. (2022). The future of artificial intelligence in monitoring animal identification, health, and behaviour. *Animals*, *12*(13), 1711.

Courtin, D., Berthier, D., Thevenon, S., Dayo, G. K., Garcia, A., & Bucheton, B. (2008). Host genetics in African trypanosomiasis. *Infection, Genetics and Evolution*, *8*(3), 229-238.

De Vries, A., Bliznyuk, N., & Pinedo, P. (2023). Ivited Review: Examples and opportunities for artificial intelligence (AI) in dairy farms. *Applied Animal Science*, *39*(1), 14-22.

Dilaver, H., & Dilaver, K. F. (2024). Robotics Systems and Artificial Intelligence Applications in Livestock Farming. *Journal of Animal Science and Economics*, *3*(2), 63-72.

Ezanno, P., Picault, S., Beaunée, G., Bailly, X., Muñoz, F., Duboz, R., ... & Guégan, J. F. (2021). Research perspectives on animal health in the era of artificial intelligence. *Veterinary research*, *52*, 1-15.

Flint, A. P. F., & Woolliams, J. A. (2008). Precision animal breeding. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 573-590.

Fuentes, S., Viejo, C. G., Tongson, E., & Dunshea, F. R. (2022). The livestock farming digital transformation: implementation of new and emerging technologies using artificial intelligence. *Animal Health Research Reviews*, *23*(1), 59-71.

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT Press; ISBN: 9780262035613.

Henna, Hamadani., Ambreen, Hamadani., Shabia, Shabir. (2024). Artificial intelligence in animal farms for management and breeding. 167-182. doi: 10.1016/b978-0-443-24001-0.00011-7

Isabelle, D. A., & Westerlund, M. (2022). A review and categorization of artificial intelligence-based opportunities in wildlife, ocean and land conservation. *Sustainability*, *14*(4), 1979.

Khatkar, M. S., Thomson, P. C., Tammen, I., & Raadsma, H. W. (2004). Quantitative trait loci mapping in dairy cattle: review and meta-analysis. *Genetics selection evolution*, *36*(2), 163-190.

Kumari, M., & Dhawal, K. (2021). Application of artificial intelligence (AI) in animal husbandry. *Vigyan Varta*, *2*(2), 27-29.

Vol 1(2), DOI:10.82036/616zwf57, July 2025 *ISSN:2977-9332*

Laca, E. A. (2009). Precision livestock production: tools and concepts. *Revista brasileira de zootecnia*, *38*, 123-132.

McCarthy, J. (2007). What is artificial intelligence.

Melak, A., Aseged, T., & Shitaw, T. (2024). The Influence of Artificial Intelligence Technology on the Management of Livestock Farms. *International Journal of Distributed Sensor Networks*, *2024*(1), 8929748.

Mijwil, M. M., Adelaja, O., Badr, A., Ali, G., Buruga, B. A., & Pudasaini, P. (2023). Innovative livestock: A survey of artificial intelligence techniques in livestock farming management. *Wasit Journal of Computer and Mathematics Science*, *2*(4), 99-106.

Morota, G., Ventura, R. V., Silva, F. F., Koyama, M., & Fernando, S. C. (2018). Big data analytics and precision animal agriculture symposium: Machine learning and data mining advance predictive big data analysis in precision animal agriculture. *Journal of animal science*, *96*(4), 1540-1550.

Neethirajan, S. (2022). Affective state recognition in livestock—artificial intelligence approaches. *Animals*, *12*(6), 759.

Nilsson, N. J. (2009). *The quest for artificial intelligence*. Cambridge University Press.

Patel, H., & Sana, A. (2022). Role of Computer Science (Artificial Intelligence) In Poultry Management. *Devotion: Journal of Research and Community Service*, *3*(12), 2068-2088.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate risk management*, *16*, 145-163.

Rotaru, A., Vâtcă, A., Pop, I., & Andronie, L. (2021). Artificial intelligence, a possible solution for agriculture and animal husbandry sector. *Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Animal Science & Biotechnologies*, *78*(2).

Samad. A, Hamza. M, Muazzam. A, and Khoiruddin. M, "Role of artificial intelligence in livestock and poultry farming," *Sinkron: Jurnal Dan Penelitian Teknik Informatika*, vol. 7, no. 4, pp. 2425–2429, 2022

Shanahan, M., Crosby, M., Beyret, B., & Cheke, L. (2020). Artificial intelligence and the common sense of animals. *Trends in Cognitive Sciences*, *24*(11), 862-872.

Smith, C., McGuire, B., Huang, T., & Yang, G. (2006). The history of artificial intelligence. University of Washington. *Retrieved June*, *8*, 2017.

Tedeschi, L. O. (2022). ASAS-NANP Symposium: Mathematical Modelling in Animal Nutrition: The progression of data analytics and artificial intelligence in support of sustainable development in animal science. *Journal of Animal Science*, *100*(6), skac111.

Wang, S., Jiang, H., Qiao, Y., Jiang, S., Lin, H., & Sun, Q. (2022). The research progress of vision-based artificial intelligence in smart pig farming. *Sensors*, *22*(17), 6541.

Yusuf, M., Nakao, T., Ranasinghe, R. B. K., Gautam, G., Long, S. T., Yoshida, C., ... & Hayashi, A. (2010). Reproductive performance of repeat breeders in dairy herds. *Theriogenology*, *73*(9), 1220-1229.

Zuraw, A., & Aeffner, F. (2022). Whole-slide imaging, tissue image analysis, and artificial intelligence in veterinary pathology: An updated introduction and review. *Veterinary Pathology*, *59*(1), 6-25.