

•Digital and Precision Welfare Monitoring: A Systematic Review of Emerging Technologies for Sustainable Animal Welfare

Amin Ahmadi 1, Gazelle Jacobian 1, Ali Amini Harandi 1, Alireza Ansari Mahabadi 1

1. Department of clinical science, School of veterinary medicine, University of shahrekord, Iran

INTRODUCTION & AIM

Animal welfare has long relied on manual observation and subjective scoring systems. Although these traditional methods can be effective, they are time-consuming, prone to human bias, and limited in frequency.

The rise of digital agriculture has introduced new possibilities. Technologies such as the Internet of Things (IoT), computer vision, and wearable sensors are reshaping how welfare is monitored—offering continuous, objective, and data-rich insights. These innovations align closely with global sustainability goals, promoting animal well-being, reducing waste, and supporting more ethical and transparent farming practices.

This review systematically examines the current state of precision welfare technologies, focusing on their applications, benefits, challenges, and ethical implications.

METHOD

Following PRISMA guidelines, a systematic literature search was conducted using Scopus, Web of Science, and ScienceDirect. Search terms included “*precision livestock farming*,” “*animal welfare monitoring*,” “*wearable sensors*,” “*computer vision in livestock*,” and “*AI animal behavior detection*.”

Inclusion criteria:

- Peer-reviewed studies published between 2015 and 2025
- Focus on welfare-related parameters in livestock species
- Use of digital, automated, or sensor-based systems

Exclusion criteria:

- Studies on non-livestock species
- Studies lacking welfare outcomes
- Conference abstracts or non-English publications

Data were extracted for each study, including technology type, species, welfare indicators, and main findings.

FUTURE WORK / REFERENCES

- Standardized welfare algorithms applicable across species and environments
- Integration of explainable AI (XAI) to promote transparency and trust
- Adoption of “One Welfare” principles linking animal, human, and environmental well-being
- Digital literacy programs for farmers and caretakers
- Policy frameworks governing data ethics, privacy, and accountability in digital welfare systems

RESULTS & DISCUSSION

3.1 Computer Vision and Behavior Recognition

Computer vision powered by AI is increasingly used to analyze animal activity, posture, and social interactions. Deep learning models can detect conditions like lameness in cows, tail biting in pigs, and stress behaviors in poultry—with accuracy rates often exceeding 90%. These systems provide continuous, unobtrusive observation, allowing for early detection and more timely intervention, which directly enhances animal welfare.

3.2 Wearable and Implantable Sensors

Wearable devices—such as accelerometers, heart rate monitors, and temperature loggers—deliver real-time physiological data. They are particularly effective in identifying heat stress, disease onset, or reduced activity levels. Advances in battery technology and wireless communication have made long-term monitoring viable, both in free-range and intensive farming systems.

3.3 Acoustic and Olfactory Monitoring

Machine learning techniques applied to sound analysis can detect respiratory issues (through coughing), distress calls, or changes in feeding behavior. Emerging research into olfactory sensors shows promise for detecting volatile organic compounds associated with stress or infection, offering an entirely new, non-invasive way to assess welfare.

3.4 Integrated Platforms and Big Data Analytics

Integrating multiple data sources—visual, physiological, and environmental—enables a more holistic understanding of animal welfare. Cloud-based platforms and digital twins are being developed to simulate and predict welfare outcomes under different management scenarios, supporting evidence-based decision-making.

3.5 Ethical and Practical Considerations

Despite its benefits, digital welfare monitoring introduces new ethical and social challenges:

Concerns over animal privacy and autonomy

Questions about data ownership and potential misuse

Risks of human detachment, where overreliance on automation may reduce empathy and direct human observation

For sustainable adoption, these systems must be designed collaboratively—with input from farmers, veterinarians, engineers, and ethicists—to balance technological efficiency with compassion and responsibility.

CONCLUSION

Digital and precision welfare monitoring are redefining the future of animal agriculture—blending technology, ethics, and sustainability. These systems make it possible to monitor welfare continuously and objectively, detect problems early, and use resources more efficiently.

Yet, true progress depends on how these technologies are governed and used. To ensure welfare remains at the heart of innovation, the agricultural sector must combine ethical oversight, interdisciplinary collaboration, and human empathy. In precision agriculture, sustainability is not just about data—it’s about compassion designed into every digital system.